3D Animation

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Welcome to 3D Lighting & Rendering

Lighting is a very important topic in Rendering, standing equal to modelling, materials and textures. The most accurately modelled and textured scene will yield poor results without a proper lighting scheme, while a simple model can become very realistic if skilfully lit.

Light would not even exist without its counterpart: Shadows. Shadows are a darkening of a portion of an object, because light is being partially or totally blocked from illuminating the object.

In this course, you will learn about Lighting using Lamps in Blender. A Shading model is used to describe how surfaces respond to light. Lighting refers to the simulation of light in computer graphics using Blender.

A rig is a standard setup and combination of objects; there can be lighting rigs, or armature rigs, etc. A rig provides a basic setup and allows you to start from a known point and go from there. Different rigs are used for different purposes and emulate different conditions; the rig you start with depends on what you want to convey in your scene.

In Block 1, Block 2 and Block 3, you have learnt about 3D Modelling, 3D Shading and 3D Animation and Rigging respectively. Now In this Block 4, you will learn about 3D Lighting and Rendering.

Introduction to Lighting

Lighting is a very important topic in Rendering, standing equal to modelling, materials and textures. The most accurately modelled and textured scene will yield poor results without a proper lighting scheme, while a simple model can become very realistic if skilfully lit. Lighting plays key role in 3D Animation, because it convinces the audience that the story is believable psychological and physical of lighting emphasizes the role of lighting on the audience “light dictates activities, influences our frame of mind and affects the way we perceive all manner of things”. In this Unit
1, you will learn to create your **3D Scene for Lighting**; Identify the restrictions between the color of an object and the lighting of your scene; Design global influences affecting the lighting in the scene; Practice setting up the lights and how to Apply **texture maps** to lamp color channels.

---

### Understanding Shadows

Light would not even exist without its counterpart: **Shadows**. Shadows are a darkening of a portion of an object, because light is being partially or totally blocked from illuminating the object. They add contrast and volume to a scene; there is nearly no place in the real world without shadows, so to get realistic renders, you will need them. Blender supports the various kinds of shadows: Lamps: Ray-traced Shadows; Lamps: Buffered Shadows; Ambient Occlusion and Indirect Lighting. In this course, you will learn about **Shadows**; the various **kinds of Shadows**; and how to work on Direct and Indirect Lighting.

---

### Using lamps in Blender

In this Unit, you will learn about **Lighting** using Lamps in Blender. A Shading model is used to describe how surfaces respond to **light**. Lighting refers to the simulation of light in computer graphics using Blender. In this Unit, you will learn how to Design lighting with relevant **Lamp type**; Differentiate the Lamp types with its Options; Apply **Lamp options** for the available light setup and shadow parameters in Blender software; Create **illumination** using Lamps in Blender; Work on different setups created for diverse needs of your 3D Scene and to Work on **Dome type of lighting** called **Hemi** and Area Lighting to create the desired effects on the objects using Lamps in Blender.

---

### Using Light Rigs

A **rig** is a standard setup and combination of objects; there can be **lighting rigs**, or **armature rigs**, etc. A rig provides a **basic setup** and allows you to start from a known point and go from there. Different rigs are used for different purposes and emulate different conditions; the rig you start with depends on what you want to convey in your scene. Lighting can be very confusing, and
the defaults do not give good results. Further, very small changes can have a dramatic effect on the mood and colors. In this Unit, you will learn how to Design One-point, Two-point and Three-point light rigs; Utilize Camera Setup for Final rendering; Recall all the lighting parameters to create one final Light Rig; Practice Lighting for different light setups Home, Factory, Office, Indoor, outdoor etc.; Use Lighting Rig to produce photorealistic results with its physically plausible shading and lighting system; Work with lights realistically, with shape and falloff; and to Produce final quality results, resulting in faster setup and more accurate results.

This video will provide a brief overview of this course.

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**Course outcomes**

Upon completion of 3D Lighting and Rendering you will be able to:

- Plan your 3D Scene for Lighting
- Apply texture maps to lamp color channels
- Compose lighting with relevant shadow type
- Differentiate the types of shadows
- Design lighting with relevant Lamp type
- Differentiate the Lamp types with its Options
- Design One-point, Two-point and Three-point light rigs
- Utilize Camera Setup for Final rendering
Course overview

Timeframe

This course will be completed within “2” classes.
This course is of “1” credits.
1 Hour of study time is required for this unit.

Study skills

This is a totally practical oriented course.
Hence, you should have access to personal computer or personal laptop for better understanding of this unit.
Each and every options are explained step by step in the course material.
Apart from this course material, the learner has to adopt the tendency of learning from multiple sources i.e.,

- Internet tutorials
- Video tutorials on YouTube
- Collaboration with people working in the industry etc.

Only classroom study will not make you a professional. You have to be active to grab the opportunity of learning wherever you get a chance.

Need help?

In case of any help needed you can browse the internet sites like youtube.com for video tutorials about the subject.

Apart from that, you can contact the writer of this course material at balaji.ac@manipal.edu
Assignments

There will be some assignments at the end of each unit.

These assignments are mostly practical based and should be submitted in CD or DVD. Theoretical assignments are to be submitted neatly written on A4 size sheet.

All assignments will be submitted to Regional centre of Odisha State Open University or as directed by Co-ordinator.

All assignment should be unit wise on separate CD/DVDs clearly mentioning course title and unit on Top. Theoretical Assignment will be neatly filed or spiral bind with cover clearly mentioning necessary information of course, student detain on top.

Assessments

There will be few assessment questions for each unit.

All practical assessment will be submitted to OSOU.

Assessment will take place once at the end of each unit.

Learner will be allowed to complete the assessment within stipulated time frame given by the university.

Video Resources

This study material comes with additional online resources in the form of videos. As videos puts in human element to e-learning at the same time demonstrating the concepts visually also improves the overall learning experience.

You can download any QR code reader from Google Play to view the videos embedded in the course or type the URL on a web browser.
Getting around this Course material

Margin icons

While working through this Course material you will notice the frequent use of margin icons. These icons serve to “signpost” a particular piece of text, a new task or change in activity; they have been included to help you to find your way around this Course material.

A complete icon set is shown below. We suggest that you familiarize yourself with the icons and their meaning before starting your study.

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Unit-1

Introduction to 3D Lighting

Introduction

Lighting is a very important topic in Rendering, standing equal to modelling, materials and textures. The most accurately modelled and textured scene will yield poor results without a proper lighting scheme, while a simple model can become very realistic if skilfully lit.

Lighting plays key role in 3D Animation, because it convinces the audience that the story is believable psychological and physical of lighting emphasizes the role of lighting on the audience “light dictates activities, influences our frame of mind and affects the way we perceive all manner of things”.

Outcomes

Upon completion of this unit you will be able to:

- Plan your 3D Scene for Lighting
- Identify the restrictions between the color of an object and the lighting of your scene
- Design global influences affecting the lighting in the scene
- Practice setting up the lights
- Apply texture maps to lamp color channels

Terminology

Ambient Light: Ambient light means the light that is already present in a scene, before any additional lighting is added. It usually refers to natural light, either outdoors or coming through windows etc. It can also mean artificial lights such as normal room lights.

Ambient occlusion is a method to approximate how bright light should be shining on any
### Occlusion:

Specific part of a surface, based on the light and its environment. This is used to add realism.

### Indirect Lighting:

Lighting provided by reflection usually from wall or ceiling surfaces. In day lighting, this means that the light coming from the sky or the sun is reflected on a surface of high reflectivity like a wall, a window sill or a special redirecting device. In electrical lighting, the luminaries are suspended from the ceiling or wall mounted and distribute light mainly upwards so it gets reflected off the ceiling or the walls.

### Direct Lighting:

Direct sunlight is when you (or the plant) get the rays directly on it. It is like sitting outside, without a hat, and nothing is between you and the sun.

### Viewing Restrictions

The color of an object and the lighting of your scene are affected by:

- Your **ability** to see different colors (partial color blindness is common).
- The **medium** in which you are viewing the image (e.g. an LCD panel versus printed glossy paper).
- The **quality** of the image (e.g. a jpeg at 0.4 compression versus 1.0).
- The **environment** in which you are viewing the image (e.g. a CRT monitor with glare versus in a dark room, or in a sunshiny blue room).

Your brain's perception of the color and intensity relative to those objects around it and the world background color, which can be changed using color manipulation techniques using Blender Composite Nodes.
Global Influences

In Blender, the elements under your control which affect lighting are:

- The color of the world ambient light.
- The use of Ambient Occlusion to cast that ambient light onto the object.
- The degree to which the ambient light colors the material of the object.
- The use of Indirect lighting, where the color of one object radiates onto another.
- The lamps in your scene.
- The physics of light bouncing around in the real world is simulated by Ambient Occlusion (a world setting), buffer shadows (which approximate shadows being cast by objects), ray tracing (which traces the path of photons from a light source).

Also, within Blender you can use **Indirect lighting**. Ray tracing, Ambient Occlusion, and Indirect Lighting are **computer-intensive processes**. Blender can perform much faster rendering with its internal scan line renderer, which is a very good scan line renderer indeed. This kind of rendering engine is much faster since it does not try to simulate the real behavior of light, assuming many simplifying hypotheses.

Lighting Settings

Only after the above global influences have been considered, do you start adding light from lamps in your scene. The main things under your control are the:

- **Type of light used** (*Sun, Spot, Lamp, Hemi*, etc.).
- **Color of the light**.
- **Position of the light and its direction**.
- **Settings for the light**, including energy and falloff.

Then you are back to how that material’s Shader reacts to the light.
This Unit attempts to address the above, including how lights can work together in rigs to light your scene. In this Unit, we will analyze the **different type of lights** in Blender and their behavior; we will discuss their **strong and weak points**. We will also describe many lighting rigs, including the ever-popular **three-point light method**.

**Lighting in the Workflow**

In this Unit, you should set up your lighting before assigning materials to your meshes. Since the material Shaders react to light, without proper lighting, the material Shaders will not look right, and you will end up fighting the Shaders, when it is really the bad lighting that is causing you grief. All the example images in this Unit do not use any material setting at all on the ball, cube or background.

**Overriding Materialsto Reset Lighting**


**Title-Img 1.** Material field in the Render Layers panel.

**Attribution-**

**Source-**

**Link-**

If you have started down the road of assigning materials, and are now fiddling with the lighting, we suggest that you

**Step 1:** create a default, generic gray material – no

*Vertex Color, no Face Texture, no Shadeless,* just plain old middle gray with RGB (0.8, 0.8, 0.8).

**Step 2:** Name this “Gray”.

**Step 3:** Next go to the *Render Layer* tab.

**Step 4:** In the *Layer* panel, select your new “Gray” material in the *Material* field. This will override any materials you may have set, and render everything with this color. Using this material, you can now go about adjusting the lighting.

**Step 5:** Just empty this field to get back to your original materials.

**Lamp Panel**

![Lamp Panel Image]

*Title*-Img 1. 2Lamp tab.
Link-

Lamp
A Data-Block Menu. Its list shows all light settings used in the current scene.

- **Texture Count**
  Shows the count of textures in the lamp texture stack.

- **Preview**
  A quick preview of the light settings.

Lamp Type
Types of lamps available in Blender Internal. They share all or some of the options listed here:

- **Color**
  The color of the light source’s illumination.

- **Energy**
  The intensity of the light source’s illumination from (0.0 to 10.0).

- **Distance**
  The *Distance* number button indicates the number of Blender Units (BU) at which the intensity of the current light source will be half of its intensity. Objects less than the number of BU away from the lamp will get more light, while objects further away will receive less light. Certain settings and lamp falloff types affect how the *Distance* is interpreted, meaning that it will not always react the same.

  The *Sun and Hemi Lamps* are another class of Lamps which uses a constant falloff. Those lamps do not have a *Distance* parameter, and are often called “*Base Lighting Lamps*”.

- **Influence**
  Every lamp has a set of switches that control which objects receive its light, and how it interacts with materials.
• **Negative**
  Let the lamp cast negative light. The light produced by the lamp is *subtracted* from the irradiance on the surfaces it hits, which darkens these surfaces instead of brightening them.

• **This Layer Only**
  The Lamp only illuminates objects on the same layer the lamp is on. Causes the lamp to only light objects on the same layer.

• **Specular**
  The Lamp creates specular highlights.

• **Diffuse**
  The Lamp affects diffuse shading.

**Light Attenuation**

![Lamp panel, falloff options highlighted.](Image)

**Title**-Img 1. 3Lamp panel, falloff options highlighted.

**Link**-

There are **two main controls** for light falloff for *Point* and *Spot* lamps:

1. The lamp *Falloff* type selector
2. The *Sphere* checkbox
Falloff Types

Lin/Quad Weighted

When this setting is chosen, two sliders are shown, Linear and Quadratic, which control respectively the “linearness” and “quadraticness” of the falloff curve.

This lamp falloff type is in effect allowing the mixing of the two light attenuation profiles (linear and quadratic attenuation types).

Quadratic Attenuation
This slider input field can have a value between (0.0 to 1.0). A value of 1.0 in the Quadratic field and 0.0 in the Linear field means that the light from this source is completely quadratic.

**Quadratic Attenuation** type lighting is considered a more accurate representation of how light attenuates (in the real world). In fact, fully quadratic attenuation is selected by default. For Lin/Quad Weighted lamp fallout. Here again, the light intensity is half when it reaches the Distance value from the lamp. Comparing the quadratic falloff to the linear falloff, the intensity decays much slower at distances lower than the set Distance, however, it attenuates much quicker after Distance is reached.

**Zeroing both “Linear” and “Quad”**

If both the Linear and Quadratic sliders have 0.0 as their values, the light intensity will not attenuate with distance. This does not mean that the light will not get darker, rather it will, however, only because the energy the light has is spread out over a wider and wider distance. The total amount of energy in the spread-out light will remain the same, though. The light angle also affects the amount of light you see. It is in fact the behavior of light in the deep space vacuum.

If you want a light source that does not attenuate and gives the same amount of light intensity to each area it hits, you need a light with properties like the Constant lamp Falloff type.

Also, when the Linear and Quad sliders are both 0.0 values the Distance field ceases to have any influence on the light attenuation, as shown by the equation above.

**Graphical Summary**

Below is a Graph Summarizing the lin/quad attenuation type, showing attenuation with or without the Sphere option (described later).
Title-Img 1. 6 Lin/quad attenuation type

Source-blender.org

Link-

**Light Attenuation:**

- Linear (Linear=1.0, Quad=0.0);
- Quadratic (Linear=0.0, Quad=1.0);
- Linear and quadratic (Linear=Quad=0.5);
- Null (Linear=Quad=0.0);

Also, shown in the graph the “same” curves, in the same colors, however, with the Sphere button turned on.

**Custom Curve**

The *Custom Curve Lamp Falloff* type is very flexible.

Most other lamp falloff types work by having their light intensity start at its maximum (when nearest to the light source) and then with some predetermined pattern decrease their light intensity when the distance from the light source increases.

When using the *Custom Curve* Lamp Falloff type, a new panel is created called *Falloff Curve*. This *Falloff Curve* profile graph allows the user to alter how intense light is at a particular point along a light’s attenuation profile (i.e. at a specific distance from the light source).

The *Falloff Curve* profile graph has two axes, the **Distance-axis and the Intensity-axis**.
1. Distance axis

It represents the **position** at a particular point along a light source’s attenuation path. The far left is at the position of the light source and the far right is the place where the light source’s influence would normally be completely attenuated.

2. Intensity axis

It represents the **intensity** at a particular point along a light source’s attenuation path. Higher intensity is represented by being higher up the intensity axis, while lower intensity light is represented by being lower down on the intensity axis.

Altering the *Falloff Curve* profile graph is easy. Just **LMB click** on a part of the graph you want to alter and drag it where you want it to be. If you click over or near one of the tiny black square handles, it will turn white, indicating that this handle is now selected, and you will be able to drag it to a new position. If when you click on the graph you are not near a handle, one will be created at the point that you clicked, which you can then drag where you wish. You can also create handles at specific parts of the graph, clicking with **LMB** while holding **Ctrl**; it will create a **new handle** at the point you have clicked.

In the example below (the default for the *Falloff Curve* Profile Graph), the graph shows that the intensity of the light starts off at its maximum (when near the light), and linearly attenuates as it moves to the right (further away from the light source).

![Default Falloff Curve panel graph.](Image)

![Render showing the Custom Curve lamp falloff type effect with default settings.](Image)

*Title*-Img 1. 7 Falloff Curve Profile Graph
If you want to have a light attenuation profile that gets more intense as it moves away from the light source, you could alter the graph as below:

You are obviously not just limited to simple changes such as reversing the attenuation profile, you can have almost any profile you desire.

Here is another example of a different **Falloff Curve** profile graph, along with its resultant render output:
3D Animation

Oscillating attenuation profile.

Render showing the effects of a “wavelet” profile graph on the light attenuation.

Title-Img 1. 9 Falloff Curve Profile Graph

Source-blender.org

Link-

Inverse Square

Title-Img 1. 10 Render showing the Inverse Square lamp falloff type effect with default settings.

Source-blender.org

Link-
This lamp falloff type attenuates its intensity according to inverse square law, scaled by the Distance value. Inverse square is a sharper, realistic decay, useful for lighting such as desk lamps and street lights. This is similar to the old Quad option (and consequently, to the new Lin/Quad Weighted option with Linear to 0.0 and Quad to 1.0), with slight changes.

**Inverse Linear**

This lamp falloff type attenuates its intensity linearly, scaled by the Distance value. This is the default setting, behaving the same as the default in previous Blender versions without Quad switched on, and consequently, like the new Lin/Quad Weighted option with Linear to 1.0 and Quad to 0.0. This is not physically accurate, however, can be easier to light with.

**Constant**

This lamp falloff type attenuates its intensity linearly, scaled by the Distance value. This is the default setting, behaving the same as the default in previous Blender versions without Quad switched on, and consequently, like the new Lin/Quad Weighted option with Linear to 1.0 and Quad to 0.0. This is not physically accurate, however, can be easier to light with.
Source-blender.org
Link-

This lamp falloff type does not attenuate its intensity with distance. This is useful for distant light sources like the sun or sky, which are so far away that their falloff is not noticeable. **Sun and Hemi lamps always have constant falloff.**

Such a falloff model is commonly used in real-time rendering applications via a shading language like GLSL.

**Sphere**

![Sphere](https://docs.blender.org/manual/en/dev/render/blender_render/lighting/lights/attenuation.html)

Title-Img 1. 6Screenshot of the 3D View editor, showing the Sphere light clipping circle.

Source-blender.org
Link-

The **Sphere** option restricts the light illumination range of a Lamp or Spot lamp, so that it will completely stop illuminating an area once it reaches the number of Blender Units away from the Lamp, as specified in the **Distance** field.

When the **Sphere** option is **active**, a dotted sphere will appear around the light source, indicating the demarcation point at which this light intensity will be null.
# Unit 1 Introduction to 3D Lighting

## Render showing the light attenuation of a Constant falloff light type with the Sphere option active.

### Title
Img 1. 7Lin/Quad Weighted attenuation option.

### Source
blender.org

### Link

## Examples

### Distance Example

In this example, the *Lamp* has been set **pretty close** to the group of planes. This causes the light to affect the front, middle and rear planes more dramatically. Looking at Img 1.15 below, you can see that as the Distance is increased, more and more objects become progressively brighter.

| Distance: 10. | Distance: 100. | Distance: 1000. |

### Title
Img 1. 8 Various Distance settings (shadows disabled).

### Source
blender.org

### Link
The *Distance* parameter is controlling where the light is falling – at a linear rate by default – to half its original value from the light’s origin. As you increase or decrease this value, you are changing where this half falloff occurs. You could think of *Distance* as the surface of a sphere and the surface is where the light’s intensity has fallen to half its strength in all directions. Note that the light’s intensity continues to fall even after *Distance*. *Distance* just specifies the distance where half of the light’s energy has weakened.

Notice in [Img 1.15](#) *Distance*: 1000., that the farthest objects are very bright. This is because the falloff has been extended far into the distance, which means the light is very strong when it hits the last few objects. It is not until 1000 Units that the light’s intensity has fallen to half of its original intensity.

Contrast this with [Img 1.15](#) *Distance*: 100., where the falloff occurs so soon that the farther objects are barely lit. The light’s intensity has fallen by a half by time it even reaches the tenth object.

You may be wondering why the first few planes appear to be dimmer? This is because the surface angle between the light and the object’s surface normal is getting close to *oblique*. That is the nature of a *Lamp* light object. By moving the light infinitely far away you would begin to approach the characteristics of the *Sun lamp type*.

**Inverse Square Example**

*Inverse Square* makes the light’s intensity falloff with a non-linear rate, or specifically, a quadratic rate. The characteristic feature of using *Inverse Square* is that the light’s intensity begins to fall off very slowly however, then starts falling off very rapidly. We can see this in [Img. 1.16](#) *Inverse Square* selected. (with the specified distances). images.
With *Inverse Square* selected, the *Distance* field specifies where the light begins to fall off faster, roughly speaking; see the light attenuation description in Falloff types for more info.

In *Img. 1.16* Inverse Square with 10., the light’s intensity has fallen so quickly that the last few objects are not even lit.

Both *Img. 1.16* Inverse Square with 100. and *Img. 1.16* Inverse Square with 1000. appear to be almost identical and that is because the *Distance* is set beyond the farthest object’s distance which is at about 40 BU out. Hence, all the objects get almost the full intensity of the light.

As above, the first few objects are dimmer than farther objects because they are very close to the light. Remember, the brightness of an object’s surface is also based on the angle between the surface normal of an object and the ray of light coming from the lamp.

This means there are at least two things that are controlling the surface’s brightness: intensity and the angle between the light source and the surface’s normal.

**Sphere Example**

![Sphere Example](https://docs.blender.org/manual/en/dev/render/blender_render/lighting/lights/attenuation.html)

**Title**-Img 1. 10Clipping Sphere.

**Source-blender.org**

**Link**-

**Sphere** indicates that the light’s intensity is null at the *Distance* and beyond, regardless of the chosen light’s falloff. In **Img 1.17** Clipping Sphere, you can see a side view example of the setup with **Sphere** enabled and a distance of 10.

Any object beyond the sphere receive **no light** from the lamp.

The *Distance* field is now specifying both where the light’s rays become null, and the intensity’s ratio falloff setting. Note that there is no abrupt transition at the sphere: the light attenuation is progressive (for more details, see the descriptions of the Sphere and Falloff types above).

![Sphere with 10.](image1) ![Sphere with 20.](image2) ![Sphere with 40.](image3)

**Title** - Img 1.11 Sphere enabled with the specified distances, Inverse Linear light falloff.

**Source** - blender.org


In **Img 1.18** Sphere with 10., the clipping sphere’s radius is 10 Units, which means the light’s intensity is also being controlled by 10 Units of distance. With a linear attenuation, the light’s intensity has fallen very low even before it gets to the first object.

In **Img 1.18** Sphere with 20., the clipping sphere’s radius is now 20 BU and some light is reaching the middle objects.

In **Img 1.18** Sphere with 40., the clipping sphere’s radius is now 40 Units, which is beyond the last object. However, the light does not make it to the last few objects because the intensity has fallen to nearly 0.
Lamps Textures

When a new lamp is added, it produces light in a uniform, flat color. While this might be sufficient in simple renderings, more sophisticated effects can be accomplished through the use of textures. Subtle textures can add visual nuance to a lamp, while hard textures can be used to simulate more pronounced effects, such as a disco ball, dappled sunlight breaking through treetops, or even a projector. These textures are assigned to one of ten channels, and behave exactly like material textures, except that they affect a lamp’s color and intensity, rather than a material’s surface characteristics.

Options
The lamp textures settings are grouped into two panels. Here we will only talk about the few things that differ from object material textures.
Refer “DMA-04, Block 02 3D Shading, Unit 01 - Materials and Shader” for details about the standard options.

The Texture-specific and the Mapping panels remain the same. However, you will note there are much fewer Mapping options. You can only choose between Global, View or another Object’s texture coordinates (since a lamp has no texture coordinates by itself), and you can scale or offset the texture.

The Mapping panel is also a subset of its regular material’s counterpart. You can only map a lamp texture to its regular, basic Color and/or to its Shadow color. As you can only affect colors, and a lamp has no texture coordinates on its own, the Diffuse, Specular, Shading, and Geometry options have disappeared.

Lamps Related Settings

Here are some options closely related to light sources, without being lamps settings.

Lighting Groups:

Materials

Title-Img 1. 13Light Group options for Materials.

Source-blender.org

Link-

By default, materials are lit by all lamps in all visible layers, however, a material (and thus all objects using that material) can be limited to a single group of lamps. This sort of control can be
incredibly useful, especially in scenes with complex lighting setups. To enable this, navigate to the **Material menu's Options** panel and select a **group of lamps** in the **Light Group** field. Note that a light group must be created first.

If the **Exclusive** button is enabled, lights in the specified group will **only** affect objects with this material.

**Render Layers**

There is a similar control located in the **Layer panel** of the Render Layers tab. If a light group name is selected in this **Light** field, the scene will be lit exclusively by lamps in the specified group.
Unit summary

In this Unit, you have learnt what is 3D Lighting and how to

- Plan your 3D scene for lighting
- View limitations and global influences to setup a perfect lighting angle for your 3D Assets
- Set up the lights using Lamp Panel controlling light intensity with the help of curve, attenuation.
- Produce subtle visual nuance using texture connecting with channels

After learning this Unit, you can download the Open Source Software available on the internet for free of cost to practice the possibilities of creating 3D Interface.

Assignment

Students are expected to experiment the lighting setups and parameters available in the panel.
Assessment

1. Define Indirect Lighting
2. Write a note on Lamp Panel
3. Describe Light Attenuation
4. Describe Sphere Option in Lighting

Write down the steps to create Lamp Texturing

Fill in the Blanks

1. ____________ means the light that is already present in a scene.
2. Direct lighting is equal to _________ Light.
3. Lamp only illuminates objects on the _________ when the lamp is on.
4. There are two main controls for light falloff - Point and___________.
5. The ______________ option restricts the light illumination range of a Lamp or Spot lamp
Resources

While studying this Unit, you can browse the internet links for online video tutorials and several books and training DVDs available in the Blender Store and on the Blender Cloud.

- wiki.blender.org
- ia600207.us.archive.org
- archive.org
- www.blender.org
- docs.blender.org
Unit 2

Introduction to Understanding Shadows

Introduction

Light would not even exist without its counterpart: Shadows. Shadows are a darkening of a portion of an object, because light is being partially or totally blocked from illuminating the object. They add contrast and volume to a scene; there is nearly no place in the real world without shadows, so to get realistic renders, you will need them. Blender supports the following kinds of shadows:

1. Lamps: Ray-traced Shadows
2. Lamps: Buffered Shadows
3. Ambient Occlusion
4. Indirect Lighting

In this Unit, you will learn about Shadows and the various kinds of Shadows.

Outcomes

Upon completion of this unit you will be able to:

- Compose lighting with relevant shadow type
- Differentiate the types of shadows
- Apply shadow options for the available light setup in Blender software
Terminology

Raytrace: In computer graphics, ray tracing is a technique for generating an image by tracing the path of light through pixels in an image plane and simulating the effects of its encounters with virtual objects, such as reflection and refraction, scattering, and dispersion phenomena.

Ambient Occlusion: Ambient occlusion is a method to approximate how bright light should be shining on any specific part of a surface, based on the light and its environment. This is used to add realism.

Attenuation: Length of rays defines how far away other faces may be and still have an occlusion effect. The longer this distance, the greater impact that far-away geometry will have on the occlusion effect.

Chains of Bones: Bone can be the parent of several children, and hence be part of several chains at the same time.

Lamps: Ray-traced Shadows

Ambient Occlusion really is not a shadow based on light per se, however, based on geometry. However, it does mimic an effect where light is prevented from fully and uniformly illuminating an object, so it is mentioned here. Also, it is important to mention Ambient Lighting, since increasing Ambient decreases the effect of a shadow.

You can use a combination of ray-traced and Buffer Shadows to achieve different results. Even within ray-traced shadows, different lamps cast different patterns and intensities of shadow. Depending on how you arrange your lamps, one lamp may wipe out or override the shadow cast by another lamp.

Shadows are one of those trifectas in Blender, where multiple things must be set up in different areas to get results:

- The Lamp must cast shadows (ability and direction).
• An Opaque object must block light on its way (position and layer).

• Another object’s material must receive shadows (Shadow and Receive Transparent enabled).

• The render engine must calculate shadows (Shadow for buffered shadows, Shadow and Ray for ray-traced shadows).

For example, the simple Lamp, Area, and Sun light have the ability to cast ray shadows, however, not Buffer Shadows. The Spot light can cast both, whereas the Hemi light does not cast any. If a Sun lamp is pointing sideways, it will not cast a shadow from a sphere above a plane onto the plane, since the light is not traveling that way. All lamps able to cast shadows share some common options, described in the Shadow Panel.

Just to give you more shadow options (and further confuse the issue), lamps and materials can be set to respectively only cast and receive shadows, and not light the diffuse/specular aspects of the object. Also, render layers can turn on/off the shadow pass, and their output may or may not contain shadow information.

Title-Img 2. Ray Shadow enabled for a lamp.

Source-blender.org

Link-

Ray-traced shadows produce very precise shadows with very low memory use, however, at the cost of processing time. This type of shadowing is available to all lamp types except Hemi.
As opposed to buffered shadows (Lamps: Buffered Shadows), ray-traced shadows are obtained by **casting rays from a regular light source**, uniformly and in all directions. The ray-tracer then records which pixel of the final image is hit by a ray light, and which is not. Those that are not are obviously obscured by a shadow.

Each light casts rays in a different way. For example, a **Spot light** casts rays uniformly in all directions within a cone. The **Sun light** casts rays from an infinitely distant point, with all ray’s parallel to the direction of the Sun light.

For each additional light added to the scene, with ray-tracing enabled, the rendering time **increases**. Ray-traced shadows require **more computation** than buffered shadows however, produce **sharp shadow borders** with very less memory resource usage.

**To enable Ray-traced shadows, three actions are required:**

- **Step 1:** Enable *Shadows* globally in the *Render Menu’s Shading* panel.

- **Step 2:** Enable *Ray tracing* globally from the same panel.

- **Step 3:** Enable ray-traced shadows for the light using the *Ray Shadow* button in the *Light menu’s Shadow* panel. This panel varies depending on the type of light.

All lamps able to cast ray-traced shadows share some common options, described in Ray-traced Properties.

Ray-traced shadows can be cast by the following types of lamp:

1. **Point lamp**
2. **Spot lamp**
3. **Area lamp**
4. **Sun lamp**

**Lamps: Buffered Shadows**
Buffered shadows provide fast-rendered shadows at the expense of precision and/or quality. Buffered shadows also require more memory resources as compared to ray tracing. You must use buffered shadows depending on your requirements. If you are rendering animations or cannot wait hours to render a complex scene with soft shadows, Buffer Shadows are a good choice.

For a scanline renderer – and Blender’s built-in engine is, among other things, a scanline renderer – shadows can be computed using a shadow buffer. This implies that an “image”, as seen from
the spot lamp’s point of view, is “rendered” and that the distance – in the image – for each point from the spot light is saved. Any point in the “rendered” image that is farther away than any of those points in the spot light’s image is then considered to be in shadow. The shadow buffer stores this image data.

**To enable buffered shadows these actions are required:**

- **Step 1:** Enable shadows globally from the *Scene* Menu’s *Gather* panel by selecting *Approximate*.

- **Step 2:** Enable shadows for the light using the *Buffer Shadow* button in the *Lamp* menu’s *Shadow* panel.

- **Step 3:** Make sure the *Cast Buffer Shadows* options is enabled in each *Material*’s *Shadow* panel.

The **Spot lamp** is the only lamp able to cast buffered shadows.

**Indirect Lighting**

*Indirect Lighting* adds indirect light bouncing of surrounding objects. It models the light that is reflected from other surfaces to the current surface. It is more comprehensive, more physically correct, and produces more realistic images. It is also more computationally expensive.

![Indirect Lighting parameters](Title-Img 2. 4Indirect Lighting parameters)

*Source:* blender.org
Link-

Options

**Indirect Lighting Panel** contains two options:

1. Factor

   Defines how much surrounding objects contribute to light.

2. Bounces

   Number of indirect diffuse light bounces.

**Gather Panel** contains settings for the indirect lighting quality. Note that these settings also apply to *Environment Lighting and Ambient Occlusion*.

Approximate

![Image 2.5 The Indirect Lighting panel, Approximate method.](https://docs.blender.org/manual/en/dev/render/blender_render/world/indirect_lighting.html)

**Title**-Img 2. 5 The Indirect Lighting panel, Approximate method.

**Source**- blender.org

**Link**-

The **Approximate method** gives a much smoother result for the same amount of render time, however, as its name states, it is only an approximation of the **Raytrace method**, which implies it might produce some artifacts and it cannot use the sky’s texture as the base color.

This method seems to tend to “over-occlude” the results. You have two complementary options to reduce this problem:

- **Passes**
Set the number of pre-processing passes, between (0 to 10) passes. Keeping the pre-processing passes high will increase render time, however, will also clear some artifacts and over-occlusions.

- **Error**
  This is the tolerance factor for approximation error (i.e. the max allowed difference between approximated result and fully computed result). The lower, the slower the render, however, the more accurate the results... Ranges between (0.0 to 10.0), defaults to 0.250.

- **Pixel Cache**
  When enabled, it will keep values of computed pixels to interpolate it with its neighbors. These further speeds up the render, generally without visible loss in quality...

- **Correction**
  A correction factor is to reduce over-occlusion. Ranges between (0.0 to 1.0) correction.

**Ambient Occlusion (AO)**

Ambient Occlusion is a sophisticated ray-tracing calculation which simulates soft global illumination shadows by *faking darkness* perceived in corners and at mesh intersections, creases, and cracks, where ambient light is occluded, or blocked.

There is no such thing as AO in real life; **AO is a specific not-physically-accurate (but generally nice-looking) rendering trick.** It basically samples a hemisphere around each point on the face, sees what proportion of that hemisphere is occluded by other geometry, and shades the pixel accordingly.

It has got nothing to do with light at all; it is purely a rendering trick that tends to look nice because generally in real life surfaces that are close together (like small cracks) will be darker than surfaces that do not have anything in front of them, because of shadows, dirt, etc.

The AO process, though, approximates this result; it is not simulating light bouncing around or going through things. That is why AO still works when you do not have any lights in the scene, and it is why just switching on AO alone is a very bad way of “lighting” a scene.
You must have **ray tracing enabled** as a **Render panel option** in the **Shading** section for this to work.

You must have an ambient light color set as you desire. By default, the ambient light color (world) is black, simulating midnight in the basement during a power outage. Applying that color as ambient will actually darken all colors. A good outdoor mid-day color is RGB (0.9, 0.9, 0.8) which is a whitish yellow sunny kind of color on a bright-but-not-harsly-bright day.

**Options**

![Image 2.6 The World panel with ambient color sliders highlighted.](Image)

**Source:** blender.org


- **Factor**

  The strength of the AO effect, a multiplier for addition.

**Ambient Occlusion** is composited during the render. **Two blending modes** are available:

I. **Add**

   The pixel receives light according to the number of non-obstructed rays. The scene is lighter. This simulates global illumination.

II. **Multiply**

   Ambient occlusion is multiplied over the shading, making things darker.
If Multiply is chosen, there must be other light sources; otherwise the scene will be pitch black. In the other two cases, the scene is lit even if no explicit light is present, just from the AO effect. Although many people like to use AO alone as a quick shortcut to light a scene, the results it gives will be muted and flat, like an overcast day. In most cases, it is best to light a scene properly with Blender’s standard lamps, then use AO on top of that, set to Multiply, for the additional details and contact shadows.

The Gather panel contains settings for the ambient occlusion quality. Note that these settings also apply to Environment Lighting and Indirect Lighting.

Ambient occlusion has two main methods of calculation:

I. Raytrace and

II. Approximate

Gather

Gather Panel contains settings for the Ambient occlusion quality. Note that these settings also apply to Environment Lighting and Ambient Occlusion.

Raytrace

Title-Img 2. 7 The Amb Occ panel, Raytrace method.

Source- blender.org

The *Raytrace* method gives the more accurate, however, also the more noisy results. You can get a nearly noiseless image, however, at the cost of render time... It is the only option if you want to use the colors of your sky’s texture.

**Attenuation**

Length of rays defines how far away other faces may be and still have an occlusion effect. The longer this distance, the greater impact that far-away geometry will have on the occlusion effect. A high *Distance* value also means that the renderer must search a greater area for geometry that occludes, so render time can be optimized by making this distance as short as possible for the visual effect that you want.

**Sampling Method**

- **Constant QMC**
  The base Quasi-Monte Carlo, gives evenly and randomly distributed rays.

- **Adaptive QMC**
  An improved method of QMC, that tries to determine when the sample rate can be lowered or the sample skipped, based on its two settings:

  - **Threshold**
    The limit below which the sample is considered fully occluded (“black”) or un-occluded (“white”), and skipped.

  - **Adapt to Speed**
    A factor to reduce AO sampling on fast-moving pixels. As it uses the *Vector* render pass, that must also be enabled.

- **Constant Jittered**
  The historical sample method, more prone to “bias” artifacts...

- **Bias**
  The angle (in radians) the hemisphere will be made narrower (i.e. the hemisphere will no longer be a real hemisphere: its section will no longer be a semicircle, however, an arc of a circle of: $\pi - bias$ radians).
The bias setting allows you to control how smooth “smooth” faces will appear in AO rendering. Since AO occurs on the original faceted mesh, it is possible that the AO light makes faces visible even on objects with “smooth” on. This is due to the way AO rays are shot, and can be controlled with the Bias slider. Note that while it might even happen with QMC sampling methods, it is much more visible with the Constant Jittered one and anyway, you have no Bias option for QMC.

![24×24 UV Sphere with Bias: 0.05 (default). Note the facets on the sphere’s surface even though it is set to smooth.](image)

Raising the Bias to 0.15 removes the faceted artifacts.

**Title:** Img 2.8 Bias

**Source:** blender.org

**Link:**

**Samples**

The number of rays used to detect if an object is occluded. Higher numbers of samples give smoother and more accurate results, at the expense of slower render times. The default value of 5 is usually good for previews. The actual number of rays shot out is the square of this number (i.e. Samples at 5 means 25 rays). Rays are shot at the hemisphere according to a random pattern (determined by the sample methods described above); this causes differences in the occlusion pattern of neighboring pixels unless the number of shot rays is big enough to produce good statistical data.
Title-Img 2.9 Ambient Occlusion samples

Source- blender.org

Link- 

Approximate

Title-Img 2.10 Ambient Occlusion panels, approximate method

Source- blender.org

Link- 

The Approximate method gives a much smoother result for the same amount of render time, however, as its name states, it is only an approximation of the Raytrace method, which implies it might produce some artifacts and it cannot use the sky’s texture as the base color.

This method seems to tend to “over-occlude” the results. You have two complementary options to reduce this problem:

- **Passes**

  Set the number of pre-processing passes, between (0 to 10) passes. Keeping the pre-processing passes high will
increase render time however, will also clear some artifacts and over-occlusions.

- **Error**
  This is the tolerance factor for approximation error (i.e. the max allowed difference between approximated result and fully computed result). The lower, the slower the render, however, the more accurate the results... Ranges between (0.0 to 10.0), defaults to 0.250.

- **Pixel Cache**
  When enabled, it will keep values of computed pixels to interpolate it with its neighbours. This further speed up the render, generally without visible loss in quality...

- **Correction**
  A correction factor to reduce over-occlusion. Ranges between (0.0 to 1.0) correction.

**Common Settings**

- **Falloff**
  When activated, the distance to the occluding objects will influence the “depth” of the shadow. This means that the further away the occluding geometry is, the lighter its “shadow” will be. This effect only occurs when the **Strength** factor is higher than 0.0. It mimics light dispersion in the atmosphere...

- **Strength**
  Controls the attenuation of the shadows enabled with **Use Falloff**. Higher values give a shorter shadow, as it falls off more quickly (corresponding to a more foggy/dusty atmosphere). Ranges from (0.0 to 10.0), default is 0.0, which means no falloff.

- **Technical Details**
  Ambient occlusion is calculated by casting rays from each visible point, and by counting how many of them actually reach the sky, and how many, on the other hand, are obstructed by objects.
The amount of light on the point is then proportional to the number of rays which have “escaped” and have reached the sky. This is done by firing a hemisphere of shadow rays around. If a ray hits another face (it is occluded) then that ray is considered “shadow”, otherwise it is considered “light”. The ratio between “shadow” and “light” rays defines how bright a given pixel is.

**Tip**

Ambient Occlusion is a ray-tracing technique (at least with the Raytrace method), so it tends to be slow. Furthermore, performance severely depends on octree size.

### Shadow Panel


All lamps able to cast shadows. Share some options, described below:

**Shadow Method**

- **No Shadow**
  The lamp casts no shadow.

- **Buffered Shadow**
  The Spot lamp is the only lamp able to cast buffered shadows.
• **Raytraced Shadows**
  Ray-traced Properties.

• **This Layer Only**
  When this option is enabled, only the objects on the same layer as the light source will cast shadows.

• **Only Shadow**
  The light source will not illuminate an object however, will generate the shadows that would normally appear. This feature is often used to control how and where shadows fall by having a light which illuminates however, has no shadow, combined with a second light which does not illuminate however, has *Only Shadow* enabled, allowing the user to control shadow placement by moving the “Shadow Only” light around.

• **Shadow color**
  This color picker control allows you to choose the color of your cast shadows (black by default). The images below were all rendered with a white light and the shadow color was selected independently.

![Red colored shadow example.](image)
![Green colored shadow example.](image)
![Blue colored shadow example.](image)

**Title:** Img 2.12 Shadow color

**Source:** blender.org

**Link:**

Although you can select a pure white color for a shadow color, it appears to make a shadow disappear.
Raytraced Shadows

Raytraced Shadows

<table>
<thead>
<tr>
<th>No Shadow</th>
<th>Buffer Shadow</th>
<th>Ray Shadow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sampling:

- Samples: 1
- Soft Size: 1.000
- Adaptive QMC
- Constant QMC
- Threshold: 0.001

Title: Image 2.13 Ray shadowing options for lamps.

Source: blender.org

Link: https://docs.blender.org/manual/en/dev/render/blender_render/lighting/shadows/raytraced_properties.html

Most lamp types (Lamp, Spot and Sun) share the same options for the ray-traced shadows generation, which are described below. Note that the Area lamp, even though using most of these options, have some specifics described in its own ray-traced shadows page.

Ray Shadow

The Ray Shadow button enables the light source to generate ray-traced shadows. When the Ray Shadow button is selected, another set of options is made available, those options being:

Shadow sample generator type

Method for generating shadow samples:

- **Adaptive QMC** is fastest,

- **Constant QMC** is less noisy however, slower. This allows you to choose which algorithm is to be used to generate the samples that will serve to compute the ray-traced shadows

- **Constant QMC**

  The Constant QMC method is used to calculate shadow values in a very uniform, evenly distributed way. This method results in very good calculation of shadow value
however, it is not as fast as using the Adaptive QMC method; however, Constant QMC is more accurate.

- **Adaptive QMC**
  The Adaptive QMC method is used to calculate shadow values in a slightly less uniform and distributed way. This method results in good calculation of shadow value however, not as good as Constant QMC. The advantage of using Adaptive QMC is that it is in general much quicker while being not much worse than Constant QMC in terms of overall results.

- **Samples**
  Number of extra samples taken (samples x samples). This slider sets the maximum number of samples that both Constant QMC and Adaptive QMC will use to do their shadow calculations. The maximum value is 16: the real number of samples is actually the square of it, so setting a sample value of 3 really means $3^2 = 9$ samples will be taken.

- **Soft Size**
  Light size for ray shadow sampling. This slider determines the size of the fuzzy/diffuse/penumbra area around the edge of a shadow. Soft Size only determines the width of the soft shadow size, not how graded and smooth the shadow is. If you want a wide shadow which is also soft and finely graded, you must also set the number of samples in the Samples field higher than 1; otherwise this field has no visible effect and the shadows generated will not have a soft edge. The maximum value for Soft Size is 100.0.

Below is a table of renders with different Soft Size and Samples settings showing the effect of various values on the softness of shadow edges:
Title-Img 2.14 Different soft size and samples

Source-blender.org

Link-

Below is an animated version of the above table of images showing the effects.
Title-img 2.15 Animated version renders with different Soft Size and Samples settings showing the effect of various values on the softness of shadow edges.

Source-blender.org

Link-

Threshold

Threshold is for Adaptive Sampling. This field is used with the Adaptive QMC shadow calculation method. The value is used to determine if the Adaptive QMC shadow sample calculation can be skipped based on a threshold of how shadowed an area is already. The maximum Threshold value is 1.0.

Quasi-Monte Carlo method

The Monte Carlo method is a method of taking a series of samples/readings of values (any kind of values, such as light values, color values, reflective states) in or around an area at random, so as to determine the correct actions to take in certain calculations which usually require multiple sample values to determine overall accuracy of those calculations. The Monte Carlo method tries to be as random as possible; this can often cause areas that are being sampled to have large irregular gaps in them (places that are not sampled/read). This in turn can cause problems for certain calculations (such as shadow calculation).

The solution to this was the Quasi-Monte Carlo method.

The Quasi-Monte Carlo method is also random, however, tries to make sure that the samples/readings it takes are also better
distributed (leaving less irregular gaps in its sample areas) and more evenly spread across an area. This has the advantage of sometimes leading to more accurate calculations based on samples/reading.

**Volumetric Lighting**

Volumetric lighting is a technique used in 3D computer graphics to add lighting effects to a rendered scene. It allows the viewer to see beams of light shining through the environment; seeing sunbeams streaming through an open window is an example of volumetric lighting, also known as **God rays**. The term seems to have been introduced from cinematography and is now widely applied to 3D modeling and rendering especially in the field of 3D gaming. In volumetric lighting, the light cone emitted by a light source is modeled as a transparent object and considered as a container of a “volume”: as a result, light has the capability to give the effect of passing through an actual three dimensional medium (such as fog, dust, smoke, or steam) that is inside its volume, just like in the real world.”

—According to Wikipedia, Volumetric Lighting.

A classic example is the search light with a visible halo/shaft of light being emitted from it as the search light sweeps around.

By default, Blender does not model this aspect of light. For example, when Blender lights something with a Spot light, you see the objects and area on the floor lit however, not the shaft/halo of light coming from the spotlight as it progresses to its target and would get scattered on the way.

The halo/shaft of light is caused in the real world by light being scattered by particles in the air, some of which get diverted into your eye and that you perceive as a halo/shaft of light. The scattering of light from a source can be simulated in Blender using various options, however, by default is not activated.

The only lamp able to create volumetric effects is the **Spot lamp** (even thought you might consider some of the “Sky & Atmosphere” effects of the Sun lamp as volumetric as well).
Unit summary

In this Unit, you have learnt

- Create depth using Shadows and lights
- Work on different types of shadows based on needs of your 3D Scene
- Work on Direct and Indirect Lighting
- Work on Shadows using ambient occlusion and shadow passes.

After learning this Unit, you can download the Open Source Software available on the internet for free of cost to practice the possibilities of creating 3D Objects.

Assignment

- Use the same Living Room scene created for Block 02, Unit – 01 Assignment to light with Blender.
- Use this key word “photo frame on wall” on www.google.com to collect the reference image to build your lighting reference.

Assessment

1. Describe Ambient Occlusion
2. Write a note on Indirect Lighting
3. Define Volumetric Lighting
4. Write few lines about Raytracing
5. List the types of Shadow Settings available in Blender
Fill in the Blanks

1. Ray-traced shadows produce very precise ______________ with very low memory.

2. __________ shadows provide fast-rendered shadows.

3. Indirect Lighting adds light ______ of surrounding objects.

4. __________ simulates soft global illumination shadows.

5. __________ is also known as God rays.

Resources

While studying this Unit, you can browse the internet links for online video tutorials and several books and training DVDs available in the Blender Store and on the Blender Cloud.

Links to download 3D Files for practice - Copyright Notice  Attribution-Non Commercial – Share Alike CC BY-NC-SA

2. https://cloud.blender.org/p/hdri
3. wiki.blender.org
4. ia600207.us.archive.org
5. archive.org
6. www.blender.org
7. docs.blender.org

Books to refer

8. Blender 2.5 Lighting and Rendering

Unit 3

Using Lamps in Blender

Introduction

In this Unit, you will learn about Lighting using Lamps in Blender. A Shading model is used to describe how surfaces respond to light. Lighting refers to the simulation of light in computer graphics using Blender. This simulation can either be extremely accurate, as is the case in an application like Radiance which attempts to track the energy flow of light interacting with materials using Radiosity computational techniques. Alternatively, the simulation can simply be inspired by light physics, as is the case with non-photorealistic rendering. Between these two extremes, there are many different lighting approaches which can be employed to achieve almost any desired visual result.

Outcomes

Upon completion of this unit you will be able to:

- Design lighting with relevant Lamp type
- Differentiate the Lamp types with its Options
- Apply Lamp options for the available light setup and shadow parameters in Blender software
Terminology

**Turbidity:** Turbidity is the cloudiness or haziness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality.

**Light Falloff:** A candle across the room illuminates your book less well than a candle at your shoulder. The decline in illumination with distance is called *falloff* or *attenuation* and in a physics.

**Volumetric Lighting:** Volumetric lighting is a technique used in 3D computer graphics to add lighting effects to a rendered scene.

Lamp: Point

Title- Img 3. 1Point lamp

Source- docs.blender.org
The *Point* lamp is an **omni-directional point of light**, that is, a point radiating the same amount of light in all directions. It’s visualized by a **plain, circled dot**. Being a point light source, the direction of the light hitting an object’s surface is determined by the line joining the lamp and the point on the surface of the object itself.

Light intensity/energy decays based on (among other variables) distance from the *Point* lamp to the object. In other words, surfaces that are further away are rendered darker.

**Shadows**

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Title-Img 3. 2 Without ray shadows.

Source- docs.blender.org


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Title-Img 3. 3 Point lamp with ray shadows and Adaptive QMC sample generator enabled.

Source- docs.blender.org


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The *Point* light source can only cast ray-traced shadows. It shares with other lamp types the common shadow options described in Shadow Panel.

The ray-traced shadows settings of this lamp are shared with other lamps, and are described Raytraced Properties.
Lamp: Sun

A **Sun lamp** provides light of constant intensity emitted in a single direction. A Sun lamp can be very handy for a **uniform clear daylight** open-space illumination. In the 3D View, the Sun light is represented by an encircled **black dot with rays** emitting from it, plus a dashed line indicating the direction of the light.

This direction can be changed by rotating the Sun lamp, like any other object, but because the light is emitted in a constant direction, the location of a Sun lamp does not affect the rendered result (unless you use the “sky & atmosphere” option).

![Sun lamp panel](https://docs.blender.org/manual/en/dev/render/blender_render/lighting/lamps/sun/introduction.html)

**Lamp options**

- **Energy and Color**
  These settings are common to most types of lamps, and are described in Light Properties.

- **Negative, This Layer Only, Specular, and Diffuse**
  These settings control what the lamp affects, as described in What Light Affects.

The Sun lamp has **no light falloff** settings: it always uses a **constant attenuation** (i.e. no attenuation!).

**Sky & Atmosphere**
Various settings for the appearance of the sun in the sky, and the atmosphere through which it shines, are available.

**Shadow**

Title - Img 3. 6Shadow panel.

Link -
The **Sun light** source can only cast **ray-traced shadows**. It shares with other lamp types the same common shadowing options, described in Shadow Panel.

The ray-traced shadows settings of this lamp are shared with other lamps, and are described in Raytraced Properties.

**Lamp: Sky & Atmosphere**


**Title-Img 3. 7Sky & Atmosphere panel.**

**Attribution-**

**Source-**

**Link-**


This panel allows you to enable an effect that **simulates various properties** of real sky and atmosphere: the scattering of sunlight as it crosses the kilometers of air overhead. For example, when the **Sun is high**, the **sky is blue** (and the horizon, somewhat whitish). When the **Sun is near the horizon**, the **sky is dark blue/purple**, and the horizon turns orange. The dispersion of the atmosphere is also more visible when it is a bit foggy: the farther away an object is, the more “faded” in light gray it is... Go out into the countryside on a nice hot day, and you will see it.
To enable this effect, you have to use a **Sun light source**. If, as usual, the *position* of the lamp has no importance, its *rotation* is crucial: it determines which hour it is. As a starting point, you should reset rotation of your Sun (with Alt-R, or typing 0 in each of the three Rotation Fields X, Y, Z in the Transform panel). This way, you will have a nice mid-day sun (in the tropics).

Now, there are two important angles for the **Sky/Atmosphere** effect: the “*incidence*” angle (between the light direction and the X-Y plane), which determines the “hour” of the day (as you might expect, the default rotation – straight down – is “mid-day”, a light pointing straight up is “midnight”, and so on...). And the rotation around the Z axis determines the position of the sun around the camera.

![Img 3.8 The dashed “light line” of the Sun lamp crossing the camera focal point.](https://docs.blender.org/manual/en/dev/render/blender_render/lighting/lamps/sun/sky_atmosphere.html)

**Source:** docs.blender.org

**Link:**

In fact, to have a good idea of where the sun is in your world, relative to the camera in your 3D View, you should always try to have the dashed “light line” of the lamp crossing the center of the camera (its “focal” point), as shown in [Img 3.8](https://docs.blender.org/manual/en/dev/render/blender_render/lighting/lamps/sun/sky_atmosphere.html) (The dashed “light line” of the Sun lamp crossing the camera focal point). This way, in camera view (NumPad0, center area in the example picture), you will see where the “virtual” sun created by this effect will be.

It is important to understand that **the position of the sun** has no importance for the effect: only its *orientation* is relevant. The position just might help you in your scene design.
Hints and limitations

To always have the Sun pointing at the camera center, you can use a Track To constraint on the sun object, with the camera as target, and -Z as the “To” axis (use either X or Y as “Up” axis). This way, to modify height/position of the sun in the rendered picture, you just have to move it; orientation is automatically handled by the constraint. Of course, if your camera itself is moving, you should also add e.g. a Copy Location constraint to your Sun lamp, with the camera as target and the Offset option activated... This way, the sun light will not change as the camera moves around.

If you use the default Add mixing type, you should use a very dark-blue world color, to get correct “nights”...

This effect works quite well with a Hemi lamp, or some ambient occlusion, to fill in the Sun shadows.

Atmosphere shading currently works incorrectly in reflections and refractions and is only supported for solid shaded surfaces. This will be addressed in a later release.

Lamps: Spot

A Spot lamp emits a cone-shaped beam of light from the tip of the cone, in a given direction.

The Spot light is the most complex of the light objects and indeed, for a long time, among the most used thanks to the fact that it was the only one able to cast shadows. Nowadays, with a ray tracer
integrated into Blender’s internal render engine, all lamps can cast shadows (except *Hemi*). Even so, *Spot* lamps’ shadow buffers are much faster to render than ray-traced shadows, especially when blurred/softened, and spot lamps also provide other functionality such as “volumetric” halos.

**Lamp options**

![Lamp Options](image.png)

**Title** - Img 3. Common Lamp options of a Spot.

**Source** - docs.blender.org


- **Distance, Energy and Color**
  These settings are common to most types of lamps, and are described in Light Properties.

- **This Layer Only, Negative, Diffuse and Specular**
  These settings control what the lamp affects, as described in What Light Affects.

- **Light Falloff and Sphere**
  These settings control how the light of the *Spot* decays with distance.
Title-Img 3. 10 Changing the Spot options also changes the appearance of the spotlight as displayed in the 3D View.

Source- docs.blender.org

Shadows

Title-Img 3. 11 Shadow panel set to Ray Shadow.

Source- docs.blender.org

Spotlights can use either ray-traced shadows or buffered shadows. Either of the two can provide various extra options. Ray-traced shadows are generally more accurate, with extra
capabilities such as transparent shadows, although they are quite slower to render.

- **No Shadow**
  Choose this to turn shadows off for this spot lamp. This can be useful to add some discreet directed light to a scene.

- **Buffer Shadow**
  *Buffered Shadows* are also known as depth map shadows. Shadows are created by calculating differences in the distance from the light to scene objects. Buffered shadows are more complex to set up and involve more faking, but the speed of rendering is a definite advantage. Nevertheless, it shares with other lamp types common shadow options described in Shadow Panel.

- **Ray Shadow**
  The ray-traced shadows settings of this lamp are shared with other lamps, and are described in Raytraced Properties.

**Spot Shape**

**Size**

The size of the outer cone of a *Spot*, which largely controls the circular area a *Spot* light covers. This slider in fact controls the angle at the top of the lighting cone, and can be between (1.0 to 180.0).

![Spot Shape Diagram](image)

*Title*-Img 3. 12 Changing the spot size option

*Source-* docs.blender.org
Blend

The *Blend* slider controls the inner cone of the *Spot*. The *Blend* value can be between (0.0 to 1.0). The value is proportional and represents that amount of space that the inner cone should occupy inside the outer cone *Size*.

The inner cone boundary line indicates the point at which light from the *Spot* will start to blur/soften; before this point its light will mostly be full strength. The larger the value of *Blend* the more blurred/soft the edges of the spotlight will be, and the smaller the inner cone’s circular area will be (as it starts to blur/soften earlier).

To make the *Spot* have a sharper falloff rate and therefore less blurred/soft edges, decrease the value of *Blend*. **Setting Blend to 0.0** results in very sharp spotlight edges, without any transition between light and shadow.

The falloff rate of the *Spot* lamp light is a ratio between the *Blend* and *Size* values; the larger the circular gap between the two, the more gradual the light fades between *Blend* and *Size*.

*Blend* and *Size* only control the *Spot* light cone’s aperture and softness (“radial” falloff); they do not control the shadow’s softness as shown below (Img 3.14)

**Title**-Img 3.13 Render showing the soft edge spotlighted area and the sharp/hard object shadow.

**Link**
Notice in the picture above [Img 3. 14] that the object’s shadow is sharp as a result of the ray tracing, whereas the spotlight edges are soft. If you want other items to cast soft shadows within the **Spot area**, you will need to alter other shadow settings.

- **Square**
  The *Square* button makes a *Spot* light cast a square light area, rather than the default circular one.

- **Show Cone**
  Draw a transparent cone in 3D View to visualize which objects are contained in it.

- **Halo**
  Adds a volumetric effect to the spot lamp.

### Spot Buffered Shadows

When the *Buffer Shadow* button is activated, the currently selected *Spot light* generates shadows, using a “shadow buffer” rather than using raytracing, and various extra options and buttons appear in the *Shadow* panel.

#### Buffer Type

There more than one way to generate buffered shadows. The shadow buffer generation type controls which generator to use.

**There are four shadow generation types, those being:**

1. Classical
2. Classic-Halfway
3. Irregular
4. Deep
Title-Img 3. 14Buffer Shadow set to Classic-Halfway.

Link-

Classical

A Classical shadow generation method, which is used to be the Blender default and unique method for generation of buffered shadows. It used an older way of generating buffered shadows, but it could have some problems with accuracy of the generated shadows and can be very sensitive to the resolution of the shadow buffer Shadow Buffer • Size, different Bias values, and all the self-shadowing issues that brings up.

The Classical method of generating shadows is obsolete and is really only still present to allow for backward compatibility with older versions of Blender. In most other cases, you will want to use Classic-Halfway instead.

Classic-Halfway

This shadow buffer type is an improved shadow buffering method and is the default option selected in Blender. It works by taking an averaged reading of the first and second nearest Z depth values allowing the Bias value to be lowered and yet not suffer as much from self-shadowing issues.
Not having to increase Bias values helps with shadow accuracy, because large Bias values can mean small faces can lose their shadows, as well as preventing shadows being overly offset from the larger Bias value.

Classic-Halfway does not work very well when faces overlap, and biasing problems can happen.

Options

Here are now the options specific to these generation methods:

- Size

The Size number button can have a value from *(512 to 10240).* Size represents the resolution used to create a shadow map. This shadow map is then used to determine where shadows lay within a scene.

As an example, if you have a Size with a value of 1024, you are indicating that the shadow data will be written to a buffer which will have a *square* resolution of **1024×1024 pixels/samples** from the selected spotlight.

The higher the value of Size, the **higher resolution** and accuracy of the resultant shadows, assuming all other properties of the light and scene are the same, although more memory and processing time would be used. The reverse is also true — if the Size value is lowered, the resultant shadows can be of lower quality, but would use less memory and take less processing time to calculate.

As well as the Size value affecting the quality of generated shadows, another property of Spot lamps that affects the quality of their buffered shadows is the angle of the spotlights lighted area (given in the Spot Shape Panel’s Size field).

As the spot shape Size value is increased, the quality of the cast shadows degrades. This happens because when the Spot lighted area is made larger (by increasing spot shape Size), the shadow buffer area must be stretched and scaled to fit the size of the new lighted area.

The Size resolution is not altered to compensate for the change in size of the spotlight, so the quality of the shadows degrades. If you want to keep the generated shadows the same quality, as you increase the spot shape Size value, you also need to increase the buffer Size value.
The above basically boils down to

**Tip**

If you have a spotlight that is large you will need to have a larger buffer Size to keep the shadows good quality. The reverse is true also – the quality of the generated shadows will usually improve (up to a point) as the Spot lamp covers a smaller area.

---

**Filter Type**

The *Box, Tent, and Gauss filter types* control what filtering algorithm to use to anti-alias the buffered shadows.

They are closely related to the *Samples* number button, as when this setting is set to 1, shadow filtering is disabled, so none of these buttons will have any effect whatsoever.

- **Box**
  
The buffered shadows will be anti-aliased using the “box” filtering method. This is the original filter used in Blender. It is relatively low quality and is used for low resolution renders, as it produces very sharp anti-aliasing. When this filter is used, it only takes into account oversampling data which falls within a single pixel, and does not take into account surrounding pixel samples. It is often useful for images which have sharply angled elements and horizontal/vertical lines.

- **Tent**
  
The buffered shadows will be anti-aliased using the “tent” filtering method. It is a simple filter that gives sharp results, an excellent general-purpose filtering method. This filter also takes into account the sample values of neighboring pixels when calculating its final filtering value.

- **Gauss**
  
The buffered shadows will be anti-aliased using the “Gaussian” filtering method. It produces a very soft/blurry anti-aliasing. As result, this filter is excellent with high resolution renders.

**Samples**

The *Samples* number button can have a value between (1 and 16). It controls the number of samples taken per pixel when calculating shadow maps.

The higher this value, the more filtered, smoothed and anti-aliased the shadows cast by the current lamp will be, but the longer they will take to calculate and the more memory they will use. The **anti-**
aliasing method used is determined by having one of the Box, Tent or Gauss buttons activated.

Having a Samples value of 1 is similar to turning off anti-aliasing for buffered shadows.

**Soft**

The Soft number button can have a value between (1.0 to 100.0). It indicates how wide an area is sampled when doing anti-aliasing on buffered shadows. The larger the Soft value, the more graduated/soft the area that is anti-aliased/softened on the edge of generated shadows.

**Sample Buffers**

The Sample Buffers setting can be set to values (1, 4 or 9), and represents the number of shadow buffers that will be used when doing anti-aliasing on buffered shadows.

This option is used in special cases, like very small objects which move and need to generate really small shadows (such as strands). It appears that normally, pixel width shadows do not anti-alias properly, and that increasing Buffer Size does not help much.

So, this option allows you to have a sort of extra sample pass, done above the regular one (the one controlled by the Box / Tent / Gauss, Samples and Soft settings).

The default 1 value will disable this option.

Higher values will produce a smoother anti-aliasing – but be careful: using a Sample Buffers of 4 will require four times as much memory and process time, and so on, as Blender will have to compute that number of sample buffers.

**Irregular**

Title-Img 3. 15Buffer Shadow set to Irregular.
Irregular shadow method is used to generate sharp/hard shadows that are placed as accurately as raytraced shadows. This method offers very good performance because it can be done as a multi-threaded process.

This method supports transparent shadows. To do so, you will first need to setup the shadow setting for the object which will receive the transparent shadow Material > Shadow > Cat Buffer Shadows and Buffer Bias.

**Deep Generation Method**

Deep Shadow buffer supports transparency and better filtering, at the cost of more memory usage and processing time.

- **Compress**
  
  Deep shadow map compression threshold.
Common options

The following settings are common to all buffered shadow generation method.

- **Bias**
  
The *Bias* number button can have a value between *(0.001 to 5.0).* *Bias* is used to add a slight offset distance between an object and the shadows cast by it. This is sometimes required because of inaccuracies in the calculation which determines whether an area of an object is in shadow or not.

  Making the *Bias* value smaller results in the distance between the object and its shadow being smaller. If the *Bias* value is too small, an object can get *artifacts*, which can appear as lines and interference patterns on objects. This problem is usually called “**self-shadowing**”, and can usually be fixed by increasing the *Bias* value, which exists for that purpose!

  Other methods for correcting self-shadowing include increasing the size of the *Shadow Buffer Size* or using a different buffer shadow calculation method such as *Classic-Halfway* or *Irregular*.

  Self-shadowing interference tends to affect curved surfaces more than flat ones, meaning that if your scene has a lot of curved surfaces it may be necessary to increase the *Bias* value or *Shadow Buffer Size* value.

  Having overly large *Bias* values not only places shadows further away from their casting objects, but can also cause objects that are very small to not cast any shadow at all. At that point altering *Bias*, *Shadow Buffer Size* or *Spot Size* values, among other things, may be required to fix the problem.

---

**Tip**

You can now refine the *Bias* value independently for each Material, using the *Bias* slider (Material menu, Shadow panel). This value is a factor by which the *Bias* value of each *Spot* buffered shadows lamp is multiplied, each time its light hits an object using this
material. The (0.0 and 1.0) values are equivalent. They do not alter the lamp’s Bias original value.

- **Clip Start & Clip End**

  When a *Spot* light with buffered shadows is added to a scene, an extra line appears on the *Spot* 3D View representation.

  The start point of the line represents *Clip Start* ‘s value and the end of the line represents *Clip End* ‘s value. *Clip Start* can have a value between *(0.1 to 1000.0)*, and *Clip End*, between *(1.0 to 5000.0)*. Both values are represented in Blender Units.

  *Clip Start* indicates the point after which buffered shadows can be present within the *Spot* light area. Any shadow which could be present before this point is ignored and no shadow will be generated.

  *Clip End* indicates the point after which buffered shadows will not be generated within the *Spotlight* area. Any shadow which could be present after this point is ignored and no shadow will be generated.

  The area between *Clip Start* and *Clip End* will be capable of having buffered shadows generated.

  Altering the *Clip Start* and *Clip End* values helps in controlling where shadows can be generated. Altering the range between *Clip Start* and *Clip End* can help speed up rendering, save memory and make the resultant shadows more accurate.

  When using a *Spot* lamp with buffered shadows, to maintain or increase quality of generated shadows, it is helpful to adjust the *Clip Start* and *Clip End* such that their values closely bound around the areas which they want to have shadows generated at. Minimizing the range between *Clip Start* and *Clip End*, minimizes the area shadows are computed in and therefore helps increase shadow quality in the more restricted area.
• **Autoclip Start & Autoclip End**

As well as manually setting *Clip Start* and *Clip End* fields to control when buffered shadows start and end, it is also possible to have Blender pick the best value independently for each *Clip Start* and *Clip End* field.

Blender does this by looking at where the visible vertices are when viewed from the *Spot* lamp position.

**Hints**

Any object in Blender can act as a camera in the 3D View. Hence you can select the *Spot* light and switch to a view from its perspective by pressing **Ctrl-Numpad0**.

**Spot Volumetric Effects**

*Spot lamps also can produce “volumetric” effects.*

- **Halo**

  The *Halo* button allows a *Spot lamp* to have a volumetric effect applied to it. This button must be active if the volumetric effect is to be visible. Note that if you are using buffered shadows.

- **Intensity**

  The *Intensity* slider controls how *intense/dense* the volumetric effect is that is generated from the light source. The lower the value of the *Intensity* slider, the less visible
the volumetric effect is, while higher *Intensity* values give a much more noticeable and dense volumetric effect.

- **Step**
  
  This field can have a value between *(0 to 12)*. It is used to determine whether this Spot will cast volumetric shadows, and what quality those volumetric shadows will have. If Step is set to a value of 0, then no volumetric shadow will be generated. Unlike most other controls, as the Step value increases, the quality of volumetric shadows decreases (but take less time to render), and vice versa.

- **Tip**
  
  **Step values**

  A value of **8 for Halo Step** is usually a good compromise between speed and accuracy.

Blender only simulates volumetric lighting in *Spot* lamps when using its internal renderer. This can lead to some strange results for certain combinations of settings for the light’s *Energy* and the halo’s *Intensity*. For example, having a *Spot* light with null or very low light *Energy* settings but a very high halo *Intensity* setting can result in a dark/black halo, which would not happen in the real world. Just be aware of this possibility when using halos with the internal renderer.

**Tip**

*The halo effect can be greatly enhanced when using buffered shadows: when the halo’s Step is not null, they can create “volumetric shadows”.*

**Lamp: Hemi**

![Image: Hemi light conceptual scheme.](Img 3.18_hemi_light_conceptual_scheme.png)
The *Hemi* lamp provides light from the direction of a **180-hemisphere**, designed to simulate the light coming from a heavily clouded or otherwise uniform sky. In other words, it is a light which is shed, uniformly, by a glowing dome surrounding the scene.

Similar to the *Sun* lamp, the *Hemi*’s location is unimportant, while its **orientation is key**.

The *Hemi* lamp is represented with **four arcs**, visualizing the orientation of the hemispherical dome, and a dashed line representing the direction in which the maximum energy is radiated, the inside of the hemisphere.

**Options**

- **Energy and Color**
  These settings are common to most types of lamps.

- **Layer, Negative, Specular, and Diffuse**
  These settings control what the lamp affects, as described in What Light Affects.

The *Hemi* lamp has **no light falloff** settings: it always uses a constant attenuation (i.e. no attenuation).
Since this lamp is the only lamp which cannot cast any shadow, the Shadow panel is absent.

**Lamp: Area**

The *Area* lamp simulates light originating from a **surface (or surface-like) emitter**. For example, a TV screen, your supermarket’s neon lamps, a window, or a cloudy sky are just a few types of area lamp. The area lamp produces **shadows with soft borders** by sampling a lamp along a grid the size of which is defined by the user. This is in direct contrast to point-like artificial lights which produce sharp borders.

Tip

Note that the *Distance* setting is much more sensitive and important for *Area* lamps than for others; usually any objects within the range of *Distance* will be blown out and overexposed. For best results, set the *Distance* to just below the distance to the object that you want to illuminate.

**Lamp Options**

- **Distance, Energy and Color**
  
  These settings are common to most types of lamps, and are described in *Light Properties*.

- **Gamma**
  
  Amount to gamma correct the brightness of illumination. Higher values give more contrast and shorter falloff.

The *Area* lamp does not have light falloff settings. It uses an “inverse quadratic” attenuation law. The only way to control its falloff is to use the *Distance* and/or *Gamma* settings.

- **This Layer Only, Negative, Specular and Diffuse**
  These settings control what the lamp affects.

**Shadows**

When an *Area* light source is selected, the *Shadow* panel has the following default layout:


**Area Shape**

The shape of the area light can be set to *Square or Rectangle*.


**Square / Rectangular**

Emit light from either a square or a rectangular area
• **Size / Size X / Size Y**
  Dimensions for the *Square* or *Rectangle*

Choosing the appropriate shape for your *Area light* will enhance the believability of your scene. For example, you may have an indoor scene and would like to simulate light entering through a window. You could place a *Rectangular* area lamp in a window (vertical) or from neons (horizontal) with proper ratios for *Size X* and *Size Y*. For the simulation of the light emitted by a TV screen a vertical *Square* area lamp would be better in most cases.

**Area Raytraced Shadows**

![Image](http://blender-manual-i18n.readthedocs.io/ja/latest/render/blender_render/lighting/lamps/area.html)

The *Area* light source can only cast ray-traced shadows. The ray-traced shadows settings of this lamp are mostly shared with other lamps. However, there are some specifics with this lamp, which are detailed below:

**Shadow Samples**

**Samples**

This has the same role as with other lamps, but when using a *Rectangle Area lamp*, you have two samples settings: *Samples X* and *Samples Y*, for the two axes of the area plane. Note also that when using the *Constant Jittered sample generator method*, this is more or less equivalent to the number of virtual lamps in the

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**Tip**

Choosing the appropriate shape for your *Area light* will enhance the believability of your scene. For example, you may have an indoor scene and would like to simulate light entering through a window. You could place a *Rectangular* area lamp in a window (vertical) or from neons (horizontal) with proper ratios for *Size X* and *Size Y*. For the simulation of the light emitted by a TV screen a vertical *Square* area lamp would be better in most cases.
area. With QMC sample generator methods, it behaves similarly to with Lamp or Spot lamps.

Sample Generator Types

- Adaptive QMC / Constant QMC
  
  These common setting are described in Shadow Panel.

- Constant Jittered
  
  The Area lamp has a third sample generator method, Constant Jittered, which is more like simulating an array of lights. It has the same options as the old one: Umbra, Dither and Jitter.

The following three parameters are only available when using the Constant Jittered sample generator method, and are intended to artificially boost the “soft” shadow effect, with possible loss in quality:

- Umbra
  
  Umbra, emphasizes the intensity of shadows in the area fully within the shadow rays. The light transition between fully shadowed areas and fully lit areas changes more quickly (i.e. a sharp shadow gradient). You need Samples values equal to or greater than 2 to see any influence of this button.

- Dither
Applies a sampling over the borders of the shadows, similar to the way anti-aliasing is applied by the OSA button on the borders of an object. It artificially softens the borders of shadows; when Samples is set very low, you can expect poor results, so Dither is better used with medium Samples values. It is not useful at all with high Samples values, as the borders will already appear soft.

- **Jitter**

Jitter adds noise to break up the edges of solid shadow samples, offsetting them from each other in a pseudo-random way. Once again, this option is not very useful when you use high Samples values where the drawback is that noise generates quite visible graininess.

**Hints**

You will note that changing the Size parameter of your area lamp does not affect the lighting intensity of your scene. On the other hand, rescaling the lamp using the S in the 3D View could dramatically increase or decrease the lighting intensity of the scene. This behavior has been coded this way so that you can fine tune all your light settings and then decide to scale up (or down) the whole scene without suffering from a drastic change in the lighting intensity. If you only want to change the dimensions of your Area lamp, without messing with its lighting intensity, you are strongly encouraged to use the Size button(s) instead.

If your computer is not very fast, when using the Constant Jittered sample generator method, you could find it useful to set a low Samples value (like 2) and activate Umbra, Dither, and/or Jitter in order to simulate slightly softer shadows. However, these results will never be better than the same lighting with high Samples values.
Unit summary

In this Unit, you have learnt how to

- Create illumination using Lamps in Blender.
- Use lights allowing various shadow option types.
- Work on different setups created for diverse needs of your 3D Scene.
- Work on Dome type of lighting called Hemi and Area Lighting to create the desired effects on the objects using Lamps in Blender.

After learning this Unit, you can download the Open Source Software available on the internet for free of cost to practice the possibilities of creating 3D Objects.

Assignment

- Use the same Living Room scene created for Block 02, Unit – 01 Assignment to light with Blender, improvise the same using Lamps as required.

- Use these key words “photo frame on wall” on www.google.com to collect the reference image to build your lighting references.
Assessment

1. Explain Light Falloff

2. Write a note on Point Lamp

3. Write short note on the following
   a. Sun
   b. Sky & Atmosphere

4. Explain Buffer Shadow with Illustrations

5. Draw Soft Shadow Edge and Hard Shadow edge using “Sphere” as a reference point

Fill in the Blanks

1. ___________ is an omni-directional source of light

2. Spot is a __________ source of light.

3. __________ is a source simulating light, as windows, neon, TV screens.

4. Hemi simulates a very wide and far away light source, like the________.

5. __________ simulates a very far away and punctual light source, like the sun.

Resources

While studying this Unit, you can browse the following internet links for online video tutorials and several books and training DVDs available in the Blender Store and on the Blender Cloud.

Links to download 3D Files for practice - Copyright Notice
Attribution-Non Commercial-Share Alike CC BY-NC-SA


2. https://cloud.blender.org/p/hdri/

3. wiki.blender.org

4. ia600207.us.archive.org

5. archive.org
6. www.blender.org
7. docs.blender.org

Books to refer

8. Blender 2.5 Lighting and Rendering by Aaron W. Powell


Unit 4

Using Light Rigs

Introduction

In this Unit, you will learn about Light Rigs and how it is used. A rig is a standard setup and combination of objects; there can be lighting rigs, or armature rigs, etc. A rig provides a basic setup and allows you to start from a known point and go from there.

Different rigs are used for different purposes and emulate different conditions; the rig you start with depends on what you want to convey in your scene. Lighting can be very confusing, and the defaults do not give good results. Further, very small changes can have a dramatic effect on the mood and colors.

Outcomes

Upon completion of this unit you will be able to:

- Design One-point, Two-point and Three-point light rigs
- Utilize Camera Setup for Final rendering
- Recall all the lighting parameters to create one final Light Rig
- Practice Lighting for different light setups Home, Factory, Office, Indoor, outdoor etc.,

Terminology

**Light Rigs:** It is a collection of lights used to set up a simple light to effectively highlight and show off your modeled assets. This series of lessons will walk through the absolute basics of lighting for presentation. Showcasing your work is an essential part of being a Computer Graphic artist, and lighting is essential to showing off.

**Lens:** A lens is a transmissive optical device that focuses or disperses a light beam by means of refraction. A simple lens consists of a single
piece of transparent material, while a compound lens consists of several simple lenses (elements), usually arranged along a common axis

**Depth of Field:** In optics, particularly as it relates to film and photography, depth of field (DOF), also called focus range or effective focus range.

**Lighting Rigs**

In all the lighting rigs, the default camera is always positioned nearly **15 degrees** off dead-on, about **25 BU (Blender Units)** back and **9 BU to the side** of the subject, at eye level, and uses a long lens of 80 mm. Up close, a **35 mm lens** will distort the image. A long lens takes in more of the scene. A dead-on camera angle is too dramatic and frames too wide a scene to take in. So now you know; next time you go to a play, sit off-center and you will not miss the action happening on the sidelines and will have a greater appreciation for the depth of the set. Anyway, enough about camera angles; this is about lighting.

**Environment or Ambient Light Only**

Title-Img. 4. 1Environment (Ambient) lighting only.
In the World tab, there is a panel **Environment Lighting**, where you enable environment or ambient lighting of your scene. **Ambient light** is the scattered light that comes from sunlight being reflected off every surface it hits, hitting your object, and traveling to camera.

![Ambient Occlusion](https://docs.blender.org/manual/en/dev/render/blender_render/lighting/lighting_rigs.html)

**Title**-Img. 4. 2Ambient occlusion.

**Link**-

**Ambient light** illuminates, in a perfectly balanced, Shadeless way, without casting shadows. You can vary the intensity of the ambient light across your scene via ambient occlusion. The ambient color is a **sunny white**.

**Single Rig**
The **sole, or key, spot light rig** provides a dramatic, showy, yet effective illumination of one object or a few objects close together. It is a **single Spot light**, usually with a hard edge. **Halos** are enabled in this render to remind you of a smoky nightclub scene. It is placed above and directly in front of the subject; in this case **10 BU in front and 10 BU high**, just like a stage, it shines down at about a **40 degrees angle**. We use quadratic attenuation.

You can make the spot wider by increasing **Size Spot Shape** and softening the edge by increasing **Blend Spot Shape**, and parent it to the main actor, so that the spot follows him as he moves around. Objects close to the main actor will naturally be more lit and your viewer will pay attention to them.

Moving this spot directly overhead and pointing down gives the interrogation effect. At the opposite end of the show-off emotional spectrum is one soft candlelight (**Point lamp**, short falloff **Distance**, yellow light) placed really up close to the subject, dramatizing the fearful “lost in the darkness” effect.

Somewhere in the macabre spectrum is a hard spot on the floor shining upward. For fun, grab a flashlight, head into the bathroom and close the door. Turn out the light and hold the flashlight under your chin, pointing up. Look in the mirror and turn it on. From this
you can see that lighting, *even* with a single light, varying the intensity, location and direction, changes *everything* in a scene.

- Use this rig, with *Environment Lighting* (and props receiving and being lit by ambient light in their material settings) for scenes that feature one main actor or a product being spotlighted.

- Do not use this rig for big open spaces or to show all aspects of a model.

**Two-Point Rig**

![Two-Point Rig](https://docs.blender.org/manual/en/dev/render/blender_render/lighting/lighting_rigs.html)

**Title** - Img. 4. Standard two-point light rig.

**Link** -

The two-point lighting rig provides a *balanced illumination* of an object. Shown to the right are the views of the standard two-point lighting rig. It is called the **two-point** because there are **two points of light**. The standard two-point lighting rig provides a balanced illumination of untextured objects hanging out there in 3D space. This rig is used in real studios for lighting a product, especially a glossy one.

Both lights are almost the same but do **different things**. Both emulate very wide, soft light by being *Hemi*. In real life, these lights bounce light off the inside of a *silver umbrella*.

Notice how we use low *Energy* to bring out the dimensionality of the sphere; I cannot stress that enough. Hard, bright lights actually flatten it and make you squint. Soft lights allow your eye to focus.
We disable specular for right *Hemi*, so we do not get that shiny forehead or nose.

The lamp on the left however, lets it be known that it is there by enabling specular; specular flare is that bright spot that is off center above midline on the sphere.

- Use this rig to give even illumination of a scene, where there is no main focus.

The *Hemi*s will light up background objects and props, so *Environment Lighting* is not that important. At the opposite end of the lighting spectrum, two narrow *Spot* lights at higher power with a hard edge give a “This is the Police, come out with your hands up” kind of look, as if the subject is caught in the crossfire.

**Three-Point Rig**

The standard three-point lighting rig is the most common illumination of objects and scenes bar none. If you want to show off your model, use this rig. As you can see, the untextured unmaterialized sphere seems to come out at you. There are multiple thesis on this rig, and you will use one of two:

1. **Studio**: Used in a real studio to film in front of a green screen or backdrop. Use this rig when you are rendering your CG objects to alpha into the scene so that the lighting on the actors and your CG objects is the same.

2. **Standard**: Used in real life to light actors on a set, and gives some backlighting to highlight the sides of actors, making them stand out more and giving them depth.

**Studio Rig**

![Image of Studio Rig](Title-Img. 4. 5Studio three-point light rig.)
Shown to the right are the “Studio” top, front, and side views of the standard three-point lighting rig. It changes the dynamics of the scene, by making a brighter “key” light give some highlights to the object, while two side “fill” lights soften the shadows created by the key light.

In the studio, use this rig to film a talking head (actor) in front of a green screen, or with multiple people, keeping the key light on the main actor. This rig is also used to light products from all angles, and the side fill lights light up the props.

The key light is the Area light placed slightly above and to the left of the camera. It allows the specular to come out. It is about 30 BU back from the subject, and travels with the camera. A little specular shine lets you know there is a light there, and that you are not looking at a ghost. In real life, it is a spot with baffles, or blinders, that limit the area of the light.

The two sidelights are reduced to only fill; each of them are Hemi lights placed 20 BU to the side and 5 BU in front of the subject, at ground level. They do not cause a spot shine on the surface by disabling specular, and at ground level, light under the chin or any horizontal surfaces, countering the shadows caused by the key light.

- Use this rig to give balanced soft lighting that also highlights your main actor or object.

It combines the best of both the single rig and the two-point rig, providing balanced illumination and frontal highlights. For a wide scene, you may have to pull the sidelights back to be more positioned like the two-point rig.
Without a curtain in back of your main subject, you have depth to work with. The left fill light has been moved behind the subject (so it is now called a *backlight*) and is just off-camera, while the right-side fill light remains the same. The *key light* gives you specular reflection so you can play with specularity and hardness in your object’s material settings. The key light gives that “in-the-spotlight” feel, highlighting the subject, while the backlight gives a crisp edge to the subject against the background. This helps them stand out.

In this rig, the key light is a *fairly bright spot light*. Use a slighter tinge of yellow because the light is so bright; it is the only light for that side. The other sidelight has been moved in back and raised to eye (camera) level. You need to cut the energy of the backlight in half, or when it is added to the remaining sidelight, it will light up the side too much and call too much attention to itself. You can vary the angle and height of the backlight to *mimic sun lighting* up the objects.

- Use this rig in normal 3D animations *to light the main actor*.
- Use this rig especially if you have transparent objects (like glass) so that there is plenty of light to shine through them to the camera.

The tricky part here is balancing the intensities of the lights so that no one light competes with or overpowers the others, while making sure all three works together as a team.
The **four-point lighting rig** provides a better simulation of outside lighting, by adding a **Sun lamp 30 BU** (Blender Unit) above, **10 to the side**, and **15 BU behind** the subject. This sunlight provides backlighting and fills the top of the subject; even producing an intentional glare on the top of their head, telling you there is a sun up there. Notice it is **colored yellow**, which balances out the **blue sidelights**.

Changing the key light to a **Spot**, select **Inverse Square**, disable **Specular** and pure white light combines with and softens the top sun flare while illuminating the face, resulting in a bright sunshine effect. Two lights above mean sharper shadows as well, so you might want to adjust the side fill lights. In this picture, they are still **Hemi, disable Specular**.

- Use this rig when the camera will be filming from behind the characters, looking over their shoulder or whatnot, because the sun provides the backlight there.
- Also use this rig when you have transparent objects, so there is light to come through the objects to the camera.

Another spot for the fill light is shining up onto the main actor’s face, illuminating the underside of his chin and neck. This gets rid
of a sometimes-ugly shadow under the chin, which if not corrected, can make the actor look fat or like they have a double chin; otherwise distracting. It evens out the lighting of the face.

Troubleshooting

If you run into a problem with your render, where there are really bright areas, or really dark ones, or strange shadows, or lines on your objects, here are some good steps to debugging what is wrong:

- First, try **deactivating all materials** (create a default, gray one, and enter its name in the **Mat field, Layer panel, the Render Layer tab** to get back all your normal materials, just erase this text field!). See if you get those problems with just grayness objects. If you do not have the problem anymore, that should tell you that you have got a materials-interacting-with-light problem. Check the material settings, especially ambient, reflection and all those little buttons and sliders in the **Material tab**. You can set some lights to affect only certain materials, so if there is an issue with only a few objects being really bright, start with those.

- Then **start “killing” lights** (e.g. moving them to an unused layer); regress all the way back to one light, make sure it is smooth, then add them in one by one. As they add together, reduce power in the tested ones so they merge cleanly, or consider not adding it at all, or, especially, reduce the energy of the lamp you just introduced.

- You can also **set lights to only light** objects on a layer, so again, if some of the gray spheres have weirdness, check for that as well. Again, you may have done some of this accidentally, so sometimes deleting the light and re-adding it with defaults helps you reset to a known-good situation.

- **Negative lights can be very tricky**, and make your model blotchy, so pay special attention to your use of those special lights. Shadow-only lights can throw off the look of the scene as well. Overly textured lights can make your scene have random weird colors. Do not go too far off a slight tinge of blue or yellow or shades of
white, or your material may show blue in the Material tab but render green, and you will be very confused.

Look at your Environment Settings World tab: Horizon, Zenith, and Environment Lighting.

**Camera**

A *Camera* is an object that provides a means of rendering images from Blender. It defines which portion of a scene is visible in the rendered image. By default, a scene contains one camera. However, a scene can contain more than one camera, but only one of them will be used at a time.

**Add a New Camera**

In Object mode simply press Shift-A and in the pop-up menu, choose Add ‣ Camera.

The default scene in Blender includes a camera, so you’ll probably only need to add a new one if you have deleted the default one, or need to animate a cut between two cameras.

**Changing the Active Camera**

**Reference**

- Mode: Object Mode
- Hotkey: Ctrl-Numpad0

---

8Active camera (left one).
The Active Camera is the camera that is currently being used for rendering and camera view Numpad0.

- **Step 1:** Select the camera you would like to make active
- **Step 2:** Press Ctrl-Numpad0
- **Step 3:** Switch the view to camera view.

In order to render, each scene must have an active camera.

The active camera can also be set in the Scene tab of the Properties Editor.

The camera with the solid triangle on top is the active camera.

**Warning**

The active camera, as well as the layers, can be specific to a given view, or global (locked) to the whole scene.

**Render Border**

**Reference**

- Mode: All modes
- Menu: View ➤ Render Border
- Hotkey: Ctrl-B

![Render Border toggle](image)

**Title**- Img. 4. 9Render Border toggle.
While in camera view, you can define a sub region to render by drawing out a rectangle within the camera’s frame. Your renders will now be limited to the part of scene visible within the render border. This can be very useful for reducing render times for quick previews on an area of interest.

The border can be disabled by disabling the Border option in the Dimensions panel in the Render tab or by activating the option again.

**Note**

When Render Border is activated, Sampled Motion Blur will become available to view in the 3D View.

---

**Object Data**

Cameras are invisible in renders, so they do not have any material or texture settings. However, they do have Object and Editing setting panels available which are displayed when a camera is the selected (active!) object.
Camera Lens

Title-Img. 4. 10Camera Lens panel.

Link-

The camera lens options control the way 3D objects are represented in a 2D image.

Lens Type

There are three different lens types:

1. Perspective
2. Orthographic
3. Panoramic

Perspective

This matches how you view things in the real-world. Objects in the distance will appear smaller than objects in the foreground, and parallel lines (such as the rails on a railroad) will appear to converge as they get farther away.
Title-Img. 4. 11 Render of a train track scene with a Perspective camera.

Link-

Settings which adjust this projection include:

- Focal length
- Shift
- Sensor size

Focal length

The focal length setting controls the amount of zoom, i.e. the amount of the scene which is visible all at once. Longer focal lengths result in a smaller FOV (more zoom), while short focal lengths allow you to see more of the scene at once (larger FOV, less zoom).
Title-Img. 4. 12 Render of the same scene as above, but with a focal length of 210mm instead of 35mm.

Link-  

Lens Unit
The focal length can be set either in terms of millimeters or the actual Field of View as an angle.

Orthographic
With Orthographic perspective objects always appear at their actual size, regardless of distance. This means that parallel lines appear parallel, and do not converge like they do with Perspective.
Orthographic Scale

This controls the apparent size of objects in the camera.

Note that this is effectively the only setting which applies to orthographic perspective. Since parallel lines do not converge in orthographic mode (no vanishing points), the lens shift settings are equivalent to translating the camera in the 3D View.

Panoramic

Panoramic cameras are only supported in the Cycles render engine.

Shift

The Shift setting allows for the adjustment of vanishing points. Vanishing points refer to the positions to which parallel lines converge. In this example, the most obvious vanishing point is at the end of the railroad.

To see how this works, take the following examples:
Notice how the horizontal lines remain perfectly horizontal when using the lens shift, but do get skewed when rotating the camera object.

Using lens shift is equivalent to rendering an image with a larger FOV and cropping it off-center.

- **Clipping**

  Set the clipping limits with the *Start* and *End* values.

Only objects within the limits are rendered.

For **OpenGL display**, setting clipping distances to limited values is important to ensure sufficient rasterization precision. Ray tracing renders do not suffer from this issue so much, and as such more extreme values can safely be set.

When **Limits in the Display panel** is enabled, the clip bounds will be visible as **two yellow connected dots** on the camera line of sight.
Camera Preset

Options

Camera Presets

![Camera Presets panel.](https://docs.blender.org/manual/en/dev/render/blender_render/camera/object_data.html)

- **Sensor size**
  
  This setting is an alternative way to control the focal length, it is useful to match the camera in Blender to a physical camera & lens combination, e.g. for motion tracking.

Depth of Field

![Depth of Field panel.](https://docs.blender.org/manual/en/dev/render/blender_render/camera/object_data.html)

- **Sensor size**
  
  This setting is an alternative way to control the focal length, it is useful to match the camera in Blender to a physical camera & lens combination, e.g. for motion tracking.

Real world cameras transmit light through a lens that bends and focuses it onto the sensor. Because of this, objects that are a
certain distance away are in focus, but objects in front and behind that are blurred.

The area in focus is called the *focal point* and can be set using either an exact value, or by using the distance between the camera and a chosen object:

- **Focus Object**
  Choose an object which will determine the focal point. Linking an object will deactivate the distance parameter. Typically, this is used to give precise control over the position of the focal point, and also allows it to be animated or constrained to another object.

- **Distance**
  Sets the distance to the focal point, when no *Focus Object* is specified. If *Limits* are enabled, a yellow cross is shown on the camera line of sight at this distance.

- **Hint**
  Hover the mouse over the *Distance* property and press E to use a special *Depth Picker*. Then click on a point in the 3D View to sample the distance from that point to the camera.

- **High Quality**
  In order for the viewport to offer an accurate representation of depth of field, like a render, you must enable High Quality. Without it, you may notice a difference in shading.

- **Viewport F-stop**
  Controls the real-time focal blur effect used during sequencer or OpenGL rendering and, when enabled, camera views in the 3D View. The amount of blur depends on this setting, along with Focal Length and Sensor Size. Smaller Viewport F-stop values result in more blur.

- **Blades**
  Add a number of polygonal *blades* to the blur effect, in order to achieve a *bokeh effect* in the viewport. To enable this feature, the blades must be set to at least 3 (3 sides, triangle)
Title - Img. 4. 18 The viewport bokeh effect with the blades set to 3.

Link -

Display

Title - Img. 4. 19 Camera Display Panel.

Link -

- **Limits**
  Shows a line which indicates *Start* and *End Clipping* values.
• **Mist**
  Toggles viewing of the mist limits on and off. The limits are shown as two connected white dots on the camera line of sight. The mist limits and other options are set in the *World* panel, in the Mist section.

Title-Img. 4. 20Camera view displaying safe areas, sensor and name.

Link-

• **Sensor**
  Displays a dotted frame in camera view.

• **Name**
  Toggle name display on and off in camera view.

• **Size**
  Refers to the size of the camera icon in the 3D View. This setting has no effect on the render output of a camera, and is only a cosmetic setting. The camera icon can also be scaled using the standard Scale S transform key.

• **Passé partout, Alpha**
  This mode darkens the area outside of the camera's field of view, based on the *Alpha* setting.
• **Composition Guides**

*Composition Guides* are available from the menu, which can help when framing a shot. There are eight types of guides available:

• **Center**

  Adds lines dividing the frame in half vertically and horizontally.

• **Center Diagonal**

  Adds lines connecting opposite corners.

• **Thirds**

  Adds lines dividing the frame in thirds vertically and horizontally.

• **Golden**

  Divides the width and height into Golden proportions (About 0.618 of the size from all sides of the frame).

• **Golden Triangle A**

  Draws a diagonal line from the lower-left to upper-right corners, then adds perpendicular lines that pass through the top left and bottom right corners.

• **Golden Triangle B**

  Same as A, but with the opposite corners.

• **Harmonious Triangle A**

  Draws a diagonal line from the lower-left to upper-right corners, then lines from the top left and bottom right corners to 0.618 the lengths of the opposite side.

• **Harmonious Triangle B**

  Same as A, but with the opposite corners.

**Safe Areas**

Safe areas are guides used to **position elements** to ensure that the most important parts of the content can be seen across all screens.
Different screens have varying amounts of over scan (specially older TV sets). That means that not all content will be visible to all viewers, since parts of the image surrounding the edges are not shown. To work around this problem TV producers defined, two areas where content is guaranteed to be shown: action safe and title safe.

Modern LCD/plasma screens with purely digital signals have no over scan, yet safe areas are still considered best practice and may be legally required for broadcast.

In Blender, safe areas can be set from the Camera and Sequencer views.

**Main Safe Areas**

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Title- Img. 4. 21The Safe areas panel found in the camera properties, and the view mode of the sequencer.


Title-Img. 4. 22Red line: Action safe. Green line: Title safe.

Title Safe

Title safe is also known as *Graphics Safe*. Place all important information (graphics or text) inside this area to ensure it can be seen by the majority of viewers.

Action Safe

Make sure any significant action or characters in the shot are inside this area. This zone also doubles as a sort of “margin” for the screen which can be used to keep elements from piling up against the edges.

Tip

Legal Standards

Each country sets a legal standard for broadcasting. These include, among other things, specific values for safe areas. Blender defaults for safe areas follow the EBU (European Union) standard. Make sure you are using the correct values when working for broadcast to avoid any trouble.

Center-Cuts

Title- Img. 4. 23Cyan line: action center safe. Blue line: title center safe.

Link-
Center-cuts are a **second set of safe areas** to ensure content is seen correctly on screens with a different aspect ratio. Old TV sets receiving **16:9 or 21:9** video will cut off the sides. Position content inside the center-cut areas to make sure the most important elements of your composition can still be visible in these screens.

Blender defaults show a **4:3 (square) ratio inside 16:9 (widescreen)**.
Unit summary

In this Unit, you have learnt how to

- Use Lighting Rig to produce photorealistic results with its physically plausible shading and lighting system.
- Work with lights realistically, with shape and falloff.
- Produce final quality results, resulting in faster setup and more accurate results.

After learning this Unit, you can download the Open Source Software available on the internet for free of cost to practice the possibilities of creating 3D Objects.

Assignment

- Use the same Living Room scene created for Block 02, Unit – 01 Assignment to light with Blender, improvise the same using Lamps as rigs and render using camera with required DOF – Depth of Field
- Use this key word “photo frame on wall” on www.google.com to collect the reference image to build your lighting reference.
Assessment

1. Describe the use of Light Rigs
2. Explain One-point light rig with appropriate example
3. Explain Two-point light rig with appropriate example
4. Explain Studio light rig with appropriate example
5. Describe Depth of Filed

Objective type Questions

1. You can make the spot wider by increasing spot ___________
2. Studio Light rig is similar to ___________ Light Rig
3. You cannot set lights to only light objects on a layer (True / False)
4. Hard, bright lights actually flatten it and make you squint. Soft lights allow your eye to focus (True / False)
5. Ambient light illuminates, in a perfectly balanced, Shadeless way, without casting shadows (True / False)

Resources

While studying this Unit, you can browse the following internet links for online video tutorials and several books and training DVDs available in the Blender Store and on the Blender Cloud.

Links to download 3D Files for practice - Copyright Notice
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2. https://cloud.blender.org/p/hdri
3. wiki.blender.org
4. ia600207.us.archive.org
5. archive.org
6. www.blender.org
7. docs.blender.org

Books to refer
8. Blender 2.5 Lighting and Rendering by Aaron W. Powell
