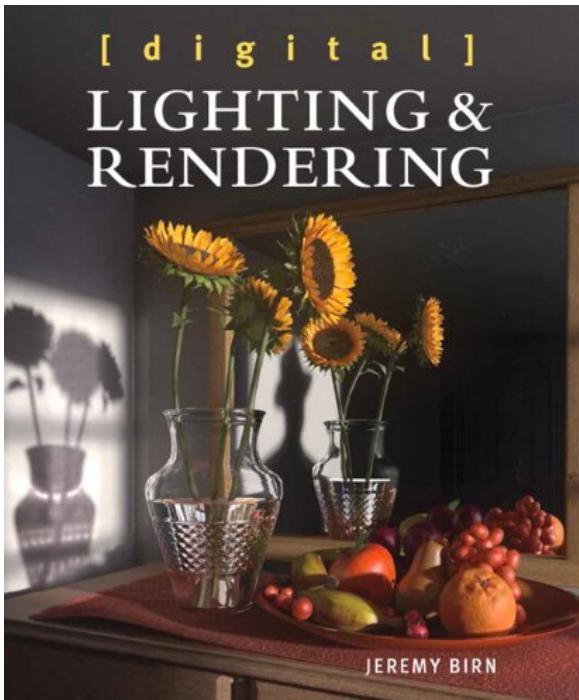


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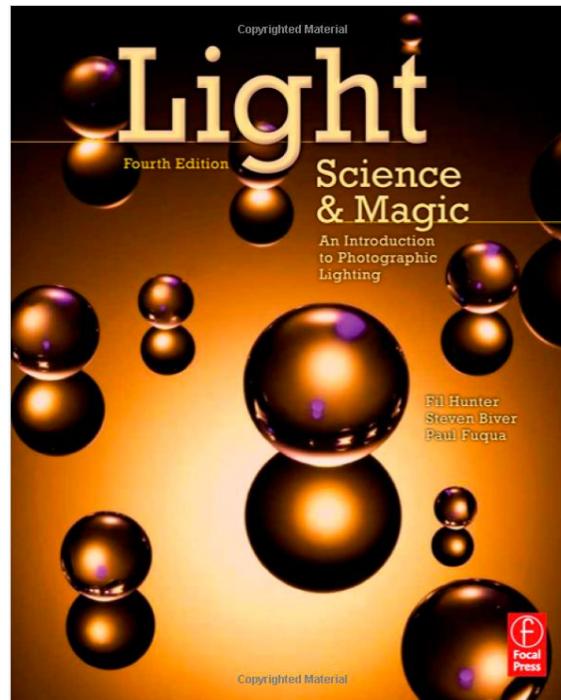
RECOMMENDED READING:

DIGITAL LIGHTING AND RENDERING –
JEREMY BIRN



3RD EDITION (NOV 2013)

LIGHT, SCIENCE & MAGIC – FIL HUNTER,
STEVEN BIVER, PAUL FUQUA



4TH EDITION (SEPT 2011)

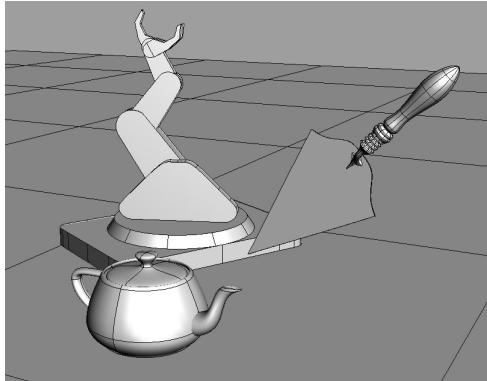
LIGHT FOR VISUAL ARTISTS –
RICHARD YOT



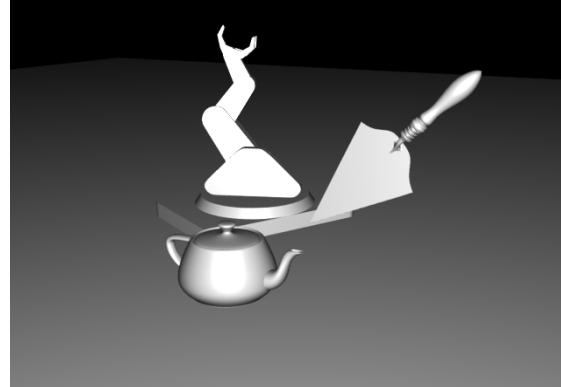
REPRINT EDITION (APR 2011)

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Scenes will render with no lights

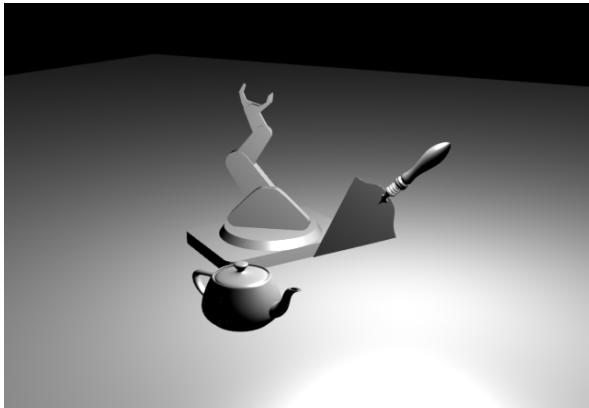


Simple Scene – no lights

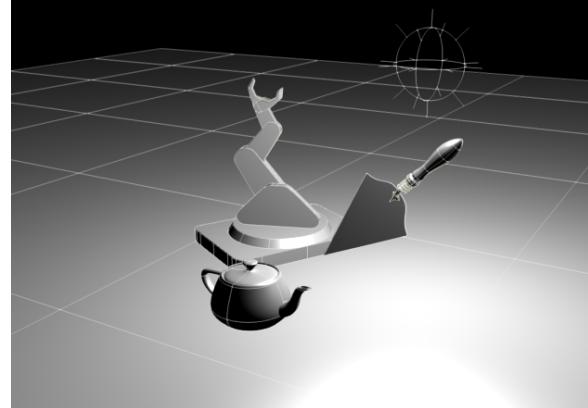


Simple Scene Rendered – light added at render time by the renderer using the camera as the light source

A Light Source is never rendered by default

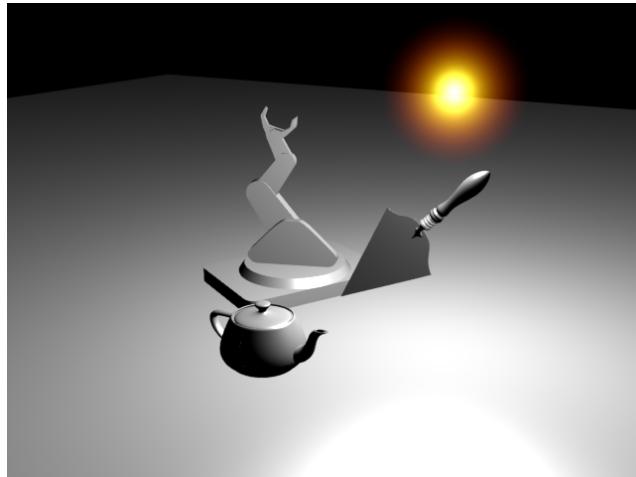


Point Light Added to Scene



Wireframe overlay reveals only the effect of the light is rendered, not the light source.

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Artificial Light Source added



Colour of Light is then adjusted to match Light Source

LIGHTS CAN ALSO BE SWITCHED ON OR OFF

Lighting is manually configured on a per scene basis using a suite of lighting tools. The more lights in a scene, the longer the image takes to render.



Lighting Tools are accessed using a Shelf of buttons, through menu options, or by interactive creation.

Lighting tools can be distinguished into two types: **DIRECT & INDIRECT LIGHTING TOOLS**.

IT IS THE COMBINATION OF DIRECT AND INDIRECT LIGHTING TOOLS WHICH MAKE A SCENE ‘WELL LIT’

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Direct Lighting Tools – Each Direct Lighting Tool has its own visual character...

Tool Name: **Distant Light**

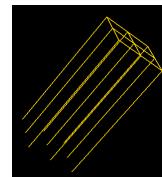
Description: Emits parallel rays of light, similar to the rays of the sun.

Usage: Sunlight / Moon Light

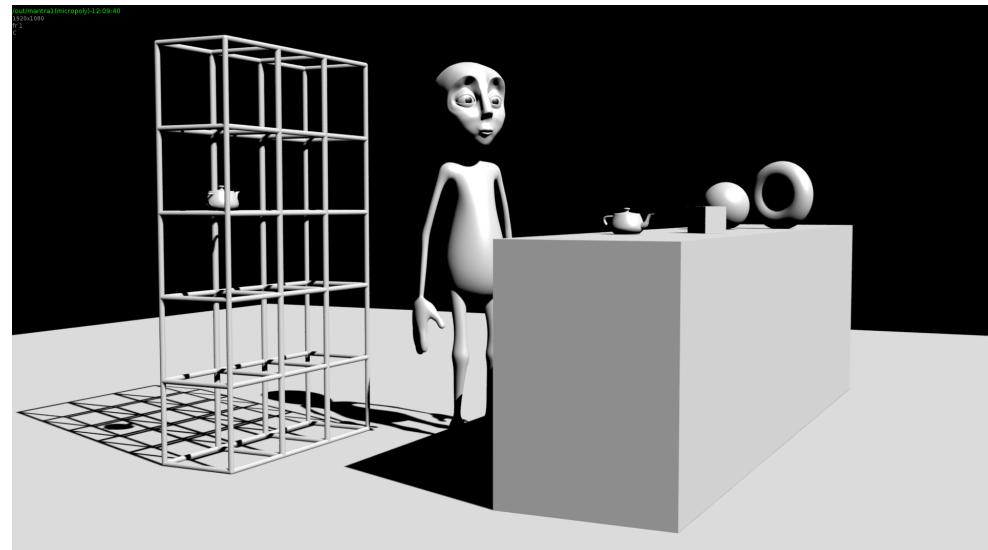
Real World Examples:



Tool Icon:



CG Example:



Distant Light (with Ray Trace Shadows activated)

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Tool Name: Point Light

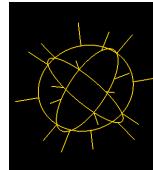
Description: Emits light from a point in all directions, similar to a light bulb

Usage: Candle Light, Light bulbs

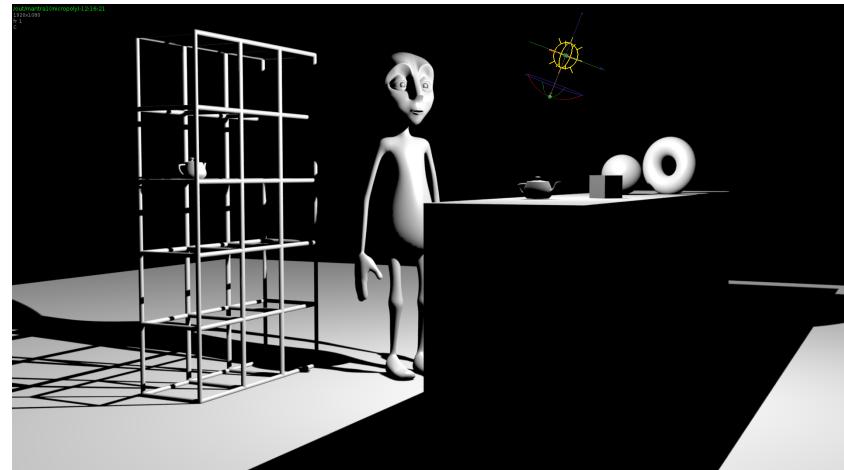
Real World Examples:



Tool Icon:



CG Example:



Point Light (with Ray Traced Shadows activated)

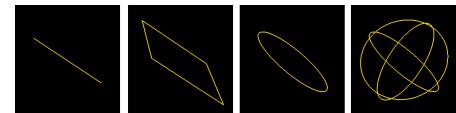
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Tool Name: **Area Light**

Description: Automatically distributes a number of light sources over a specified area (Tube, Grid, Circle, Sphere)

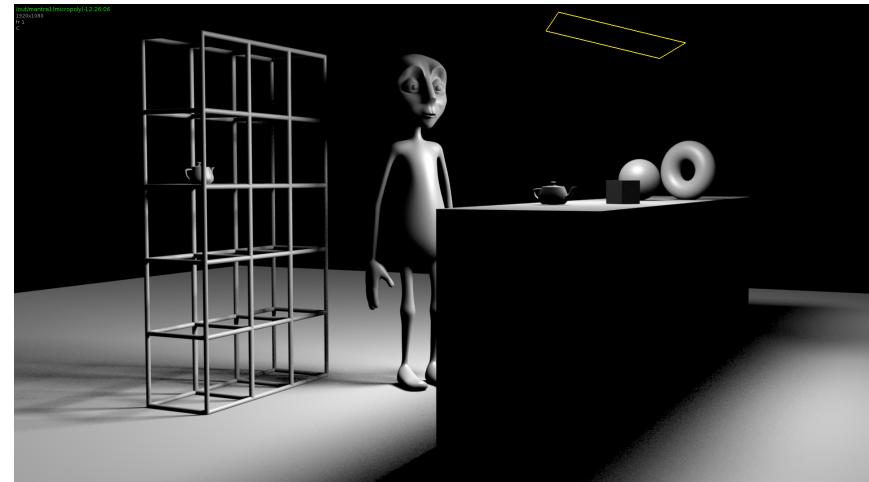
Usage: Strip Lighting, Panel Lighting, Light from Windows

Real World Example:



Tool Icon (varies upon area shape):

CG Example:



Grid Area Light (with Ray Traced Shadows activated)

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Tool Name: Spot Light

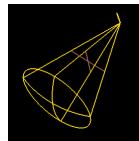
Description: A cone shaped beam of light from a certain direction

Usage: Lamps, Spotlights

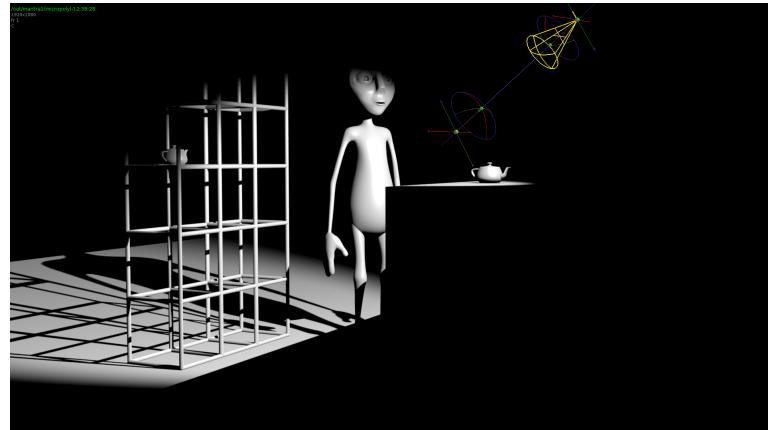
Real World Examples:



Tool Icon:

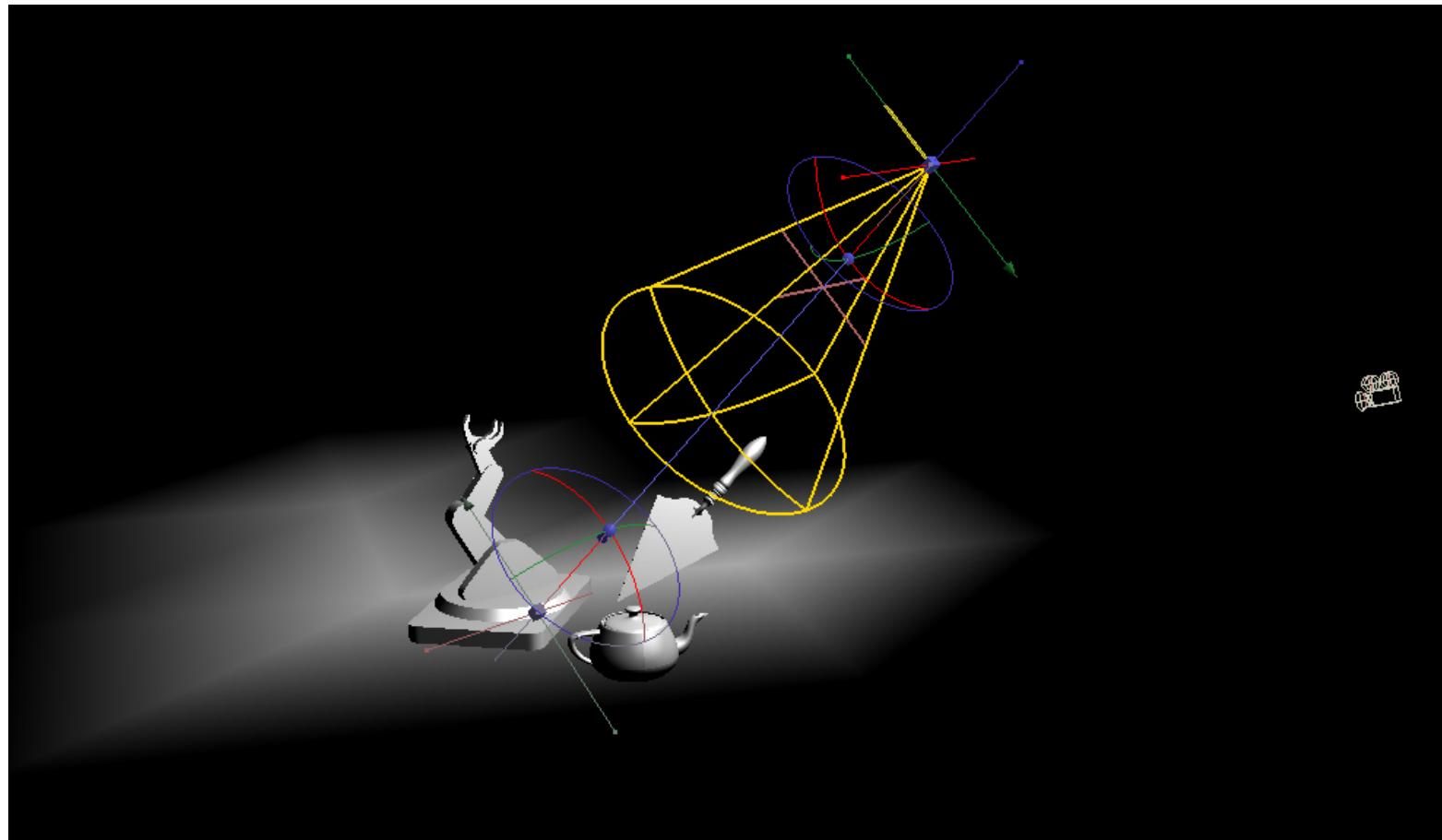


CG Example:



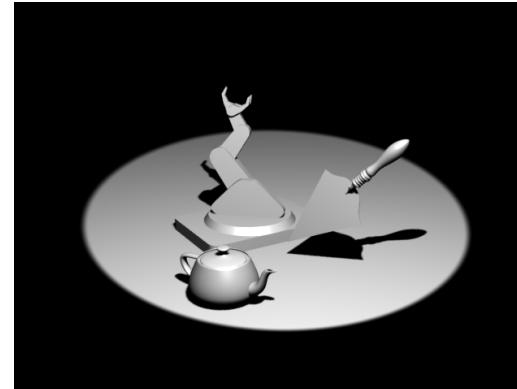
Spot Light (with Ray Traced Shadows activated)

ALL DIRECT LIGHTING TOOLS CAN BE INTERACTIVELY POSITIONED IN THE VIEWER OF THE 3D SOFTWARE PACKAGE. THE VIEWER OPENGL PREVIEW ACTS AS AN APPROXIMATE GUIDE FOR HOW THE LIGHTING WILL APPEAR IN THE FINAL RENDER.

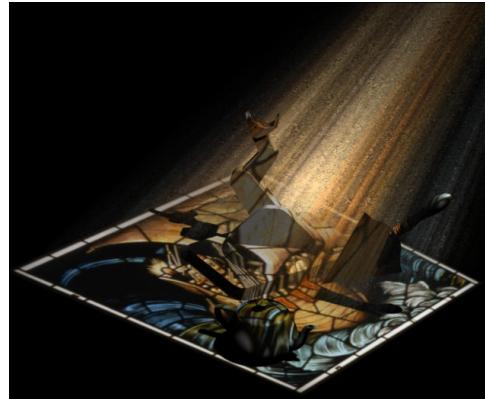
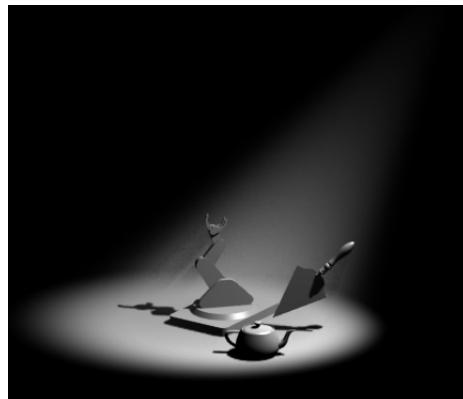


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Spot Lights can also specify Cone Angle and Cone Sharpness



Direct Lighting can also have volumetrics associated with them and or project images



Volumetrics assigned to lights can take a long time to render.

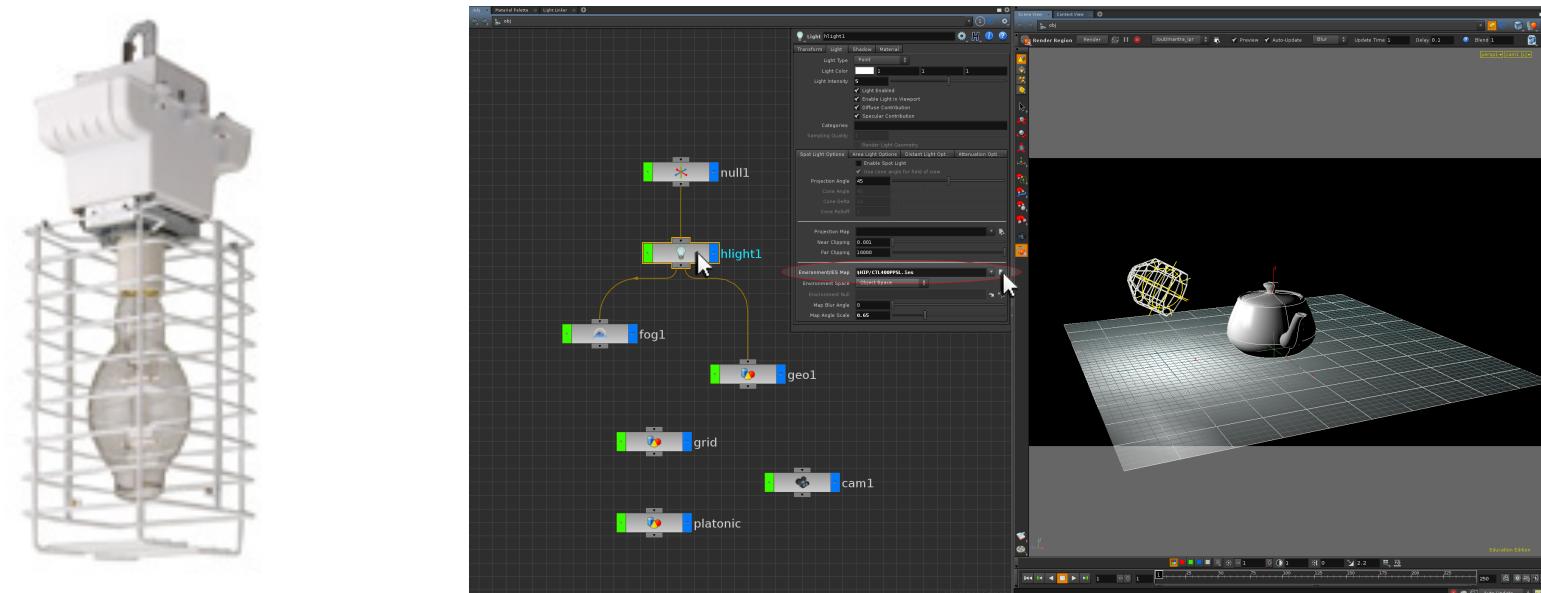
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IES Lighting

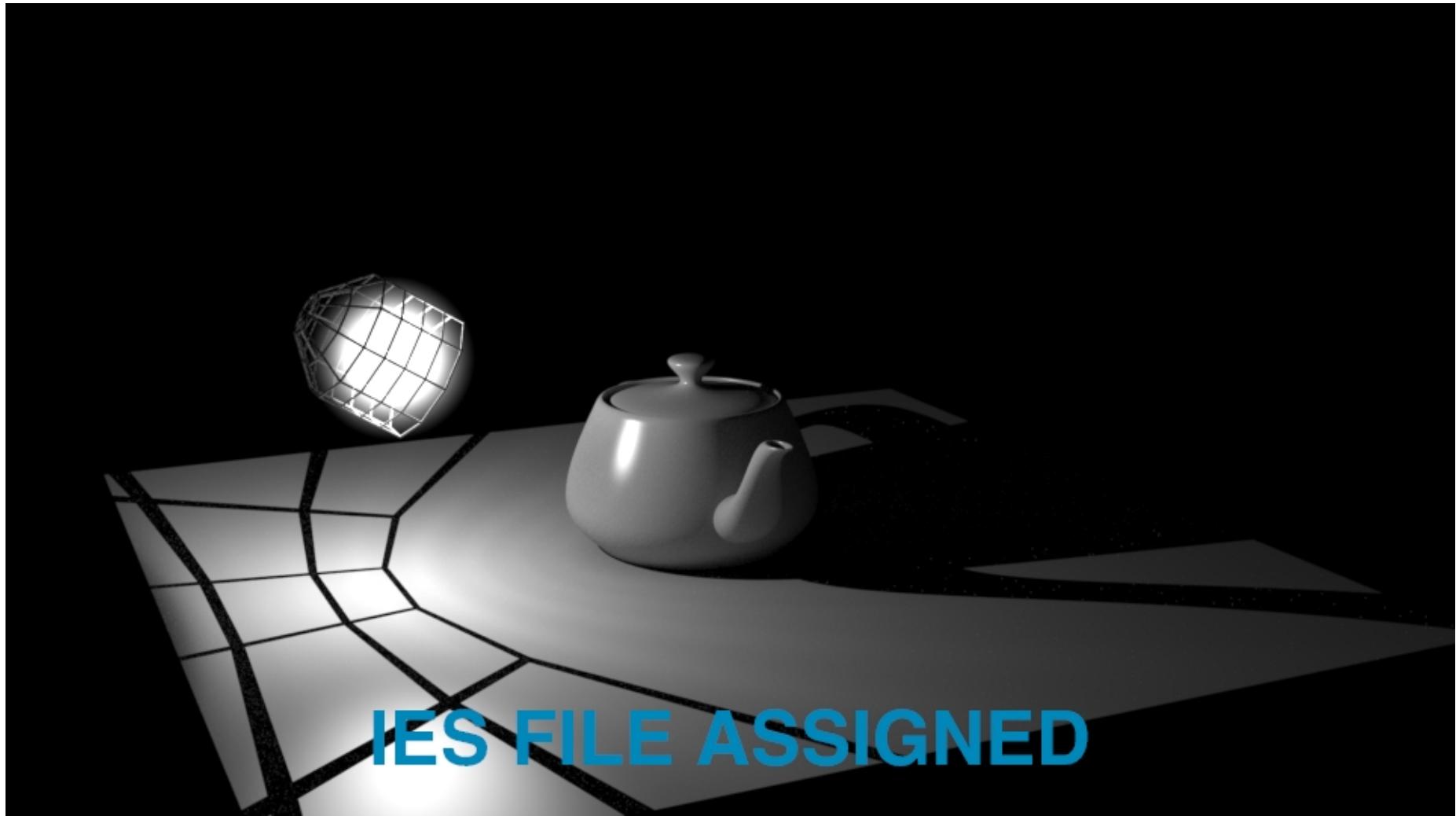
<http://www.cgarena.com/freestuff/tutorials/max/ieslights/>

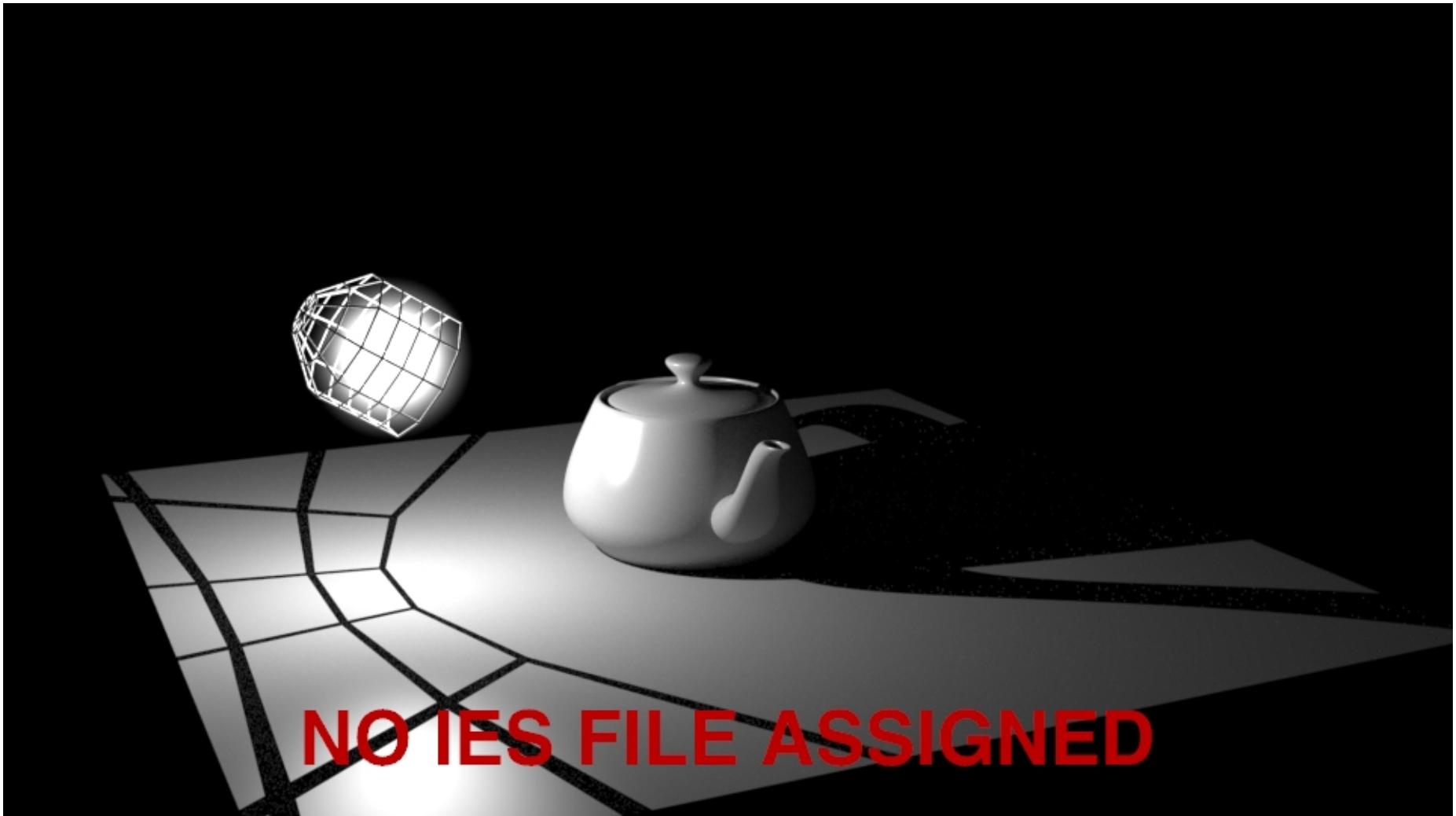
<http://www.lithonia.com/photometrics.aspx>

CG Lights can accept IES files (Illuminating Engineering Society) that tint the light with the real world lighting artifice created by the bulb. This can help aid realism to the render.



The IES file for a Temporary Worklight assigned to a test scene.





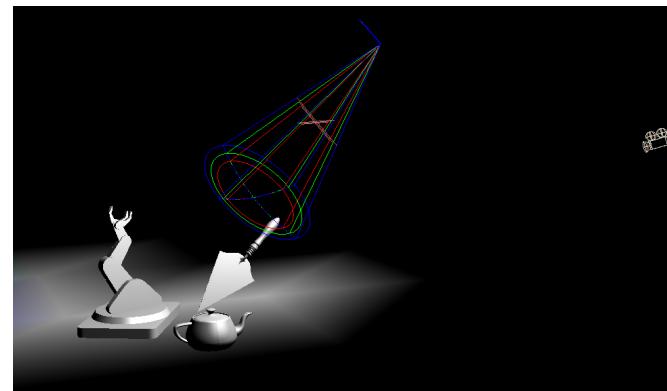
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DIRECT LIGHTING PROPERTIES - All Direct Lighting Tools share a number of characteristics. All are able to specify:

Colour



A yellow spotlight



In this example three spotlights are created with slightly lessening cone angles. Each spot light has its own colour (red, green & blue). The render returns white light; however the falloff between the light and dark areas is white-blue-black rather than white- black.

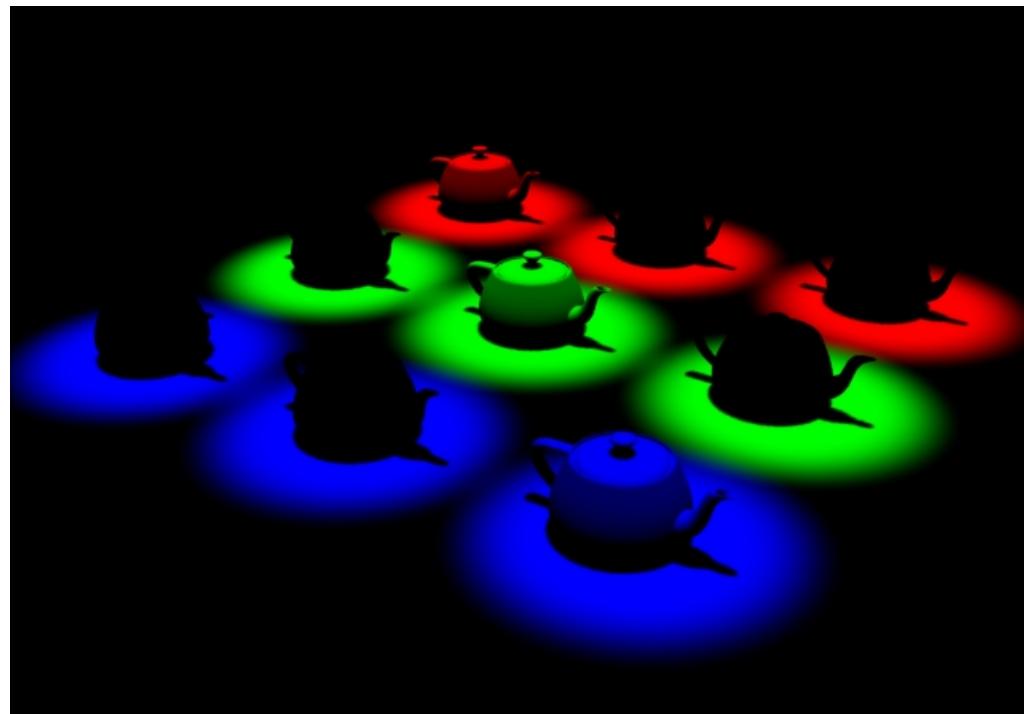
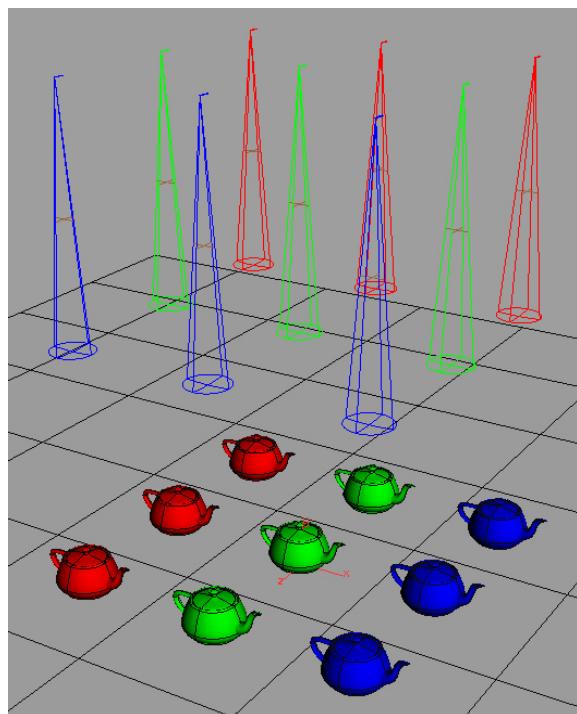
COLOUR TEMPERATURE

The colour of a light can also be used to set the temperature of a light. This is where a near white light has a slight colour hue assigned to simulate a certain type of light bulb, or exterior light colour. <http://planetpixelemporium.com/tutorialpages/light.html>

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LIGHT COLOURS ALSO RESPOND TO SURFACE COLOURS ASSIGNED TO OBJECTS.

In this example red, green and blue teapots are each lit by red, green and blue lights.



If you have a blue light $[0,0,1]$ and a red surface $[1,0,0]$, multiplying these values results in $[0,0,0]$

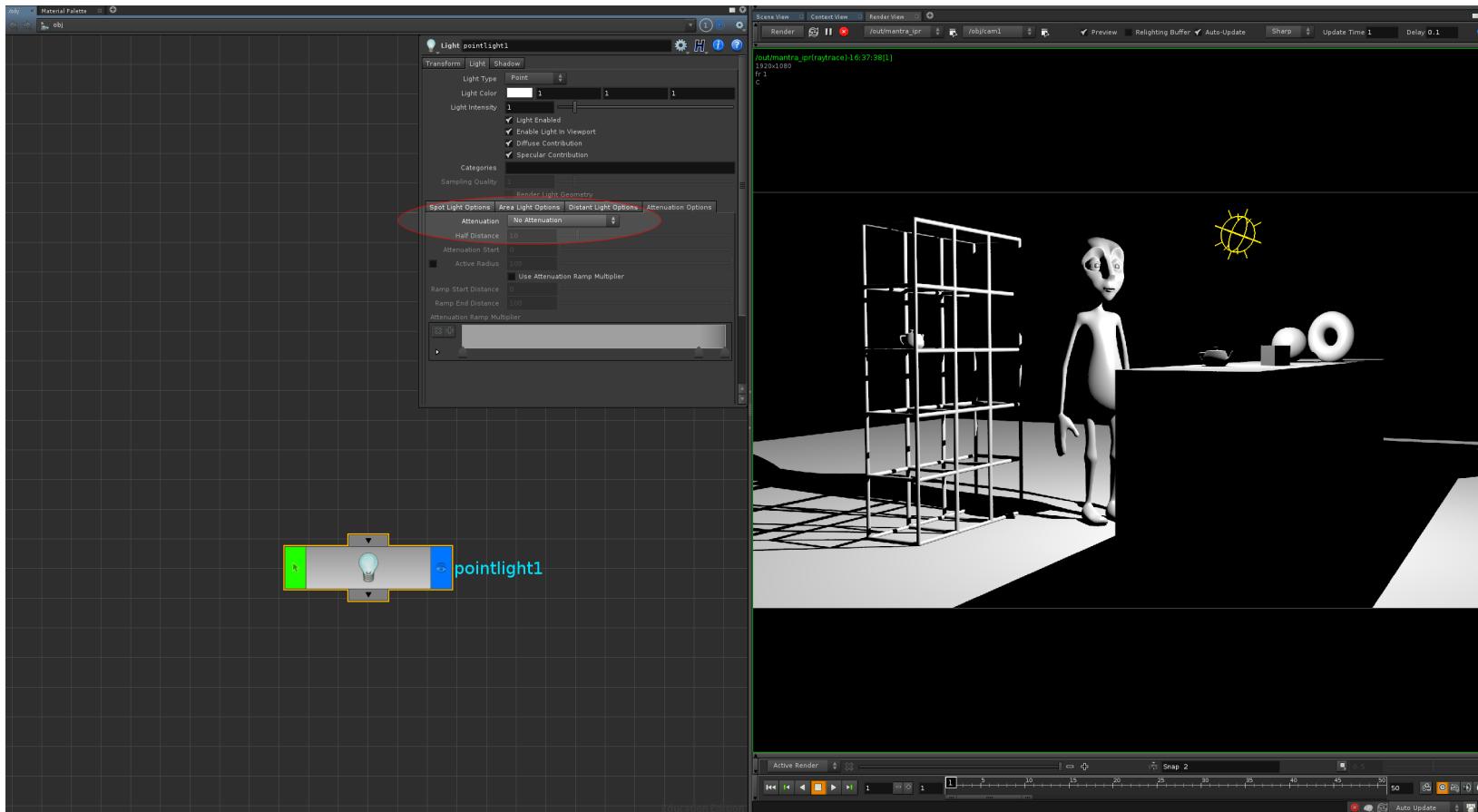
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Coloured light in the real world also interacts with surface colour in this way

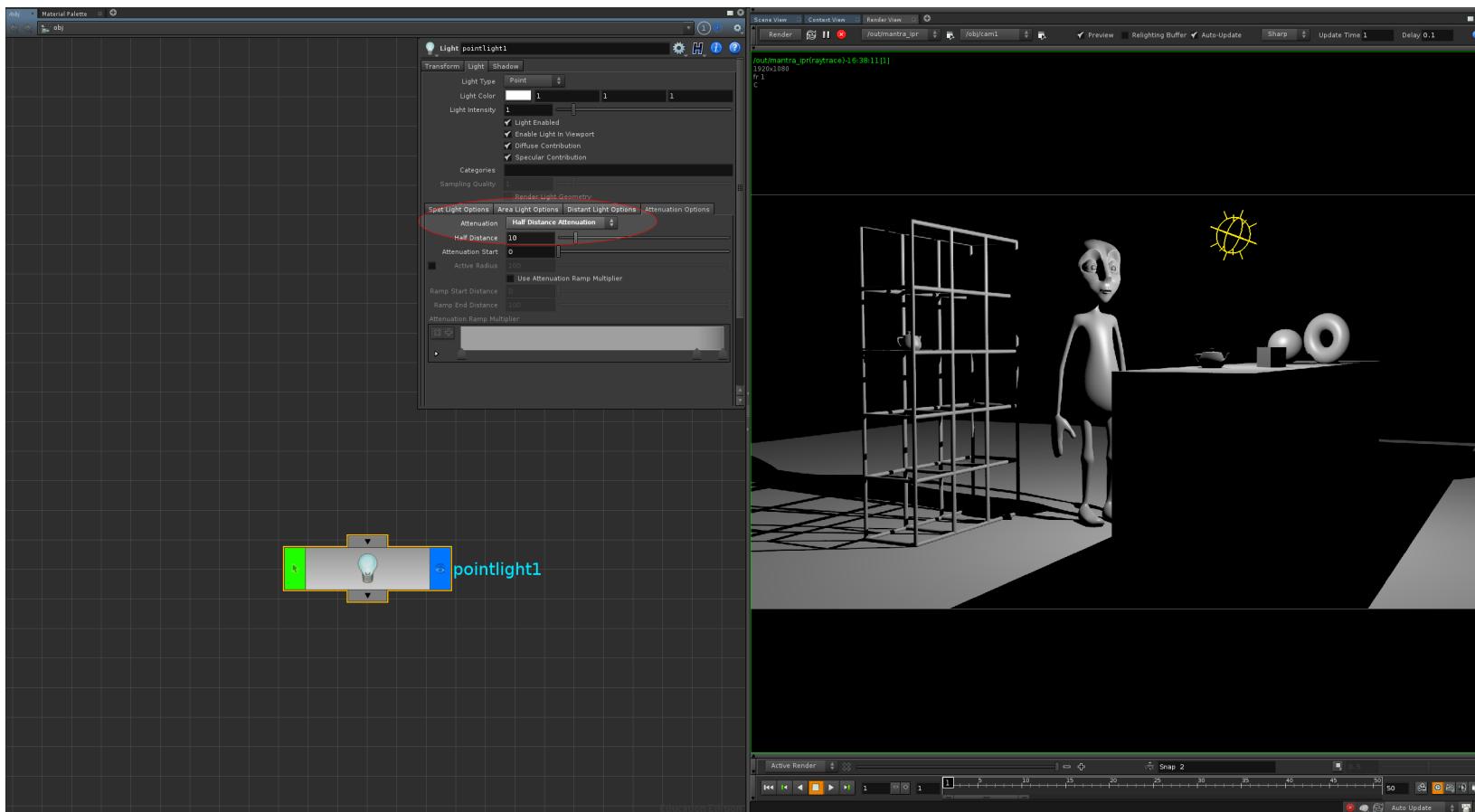
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Attenuation (Light Fall Off) Attenuation describes the intensity of the light relative to its distance from the light source.



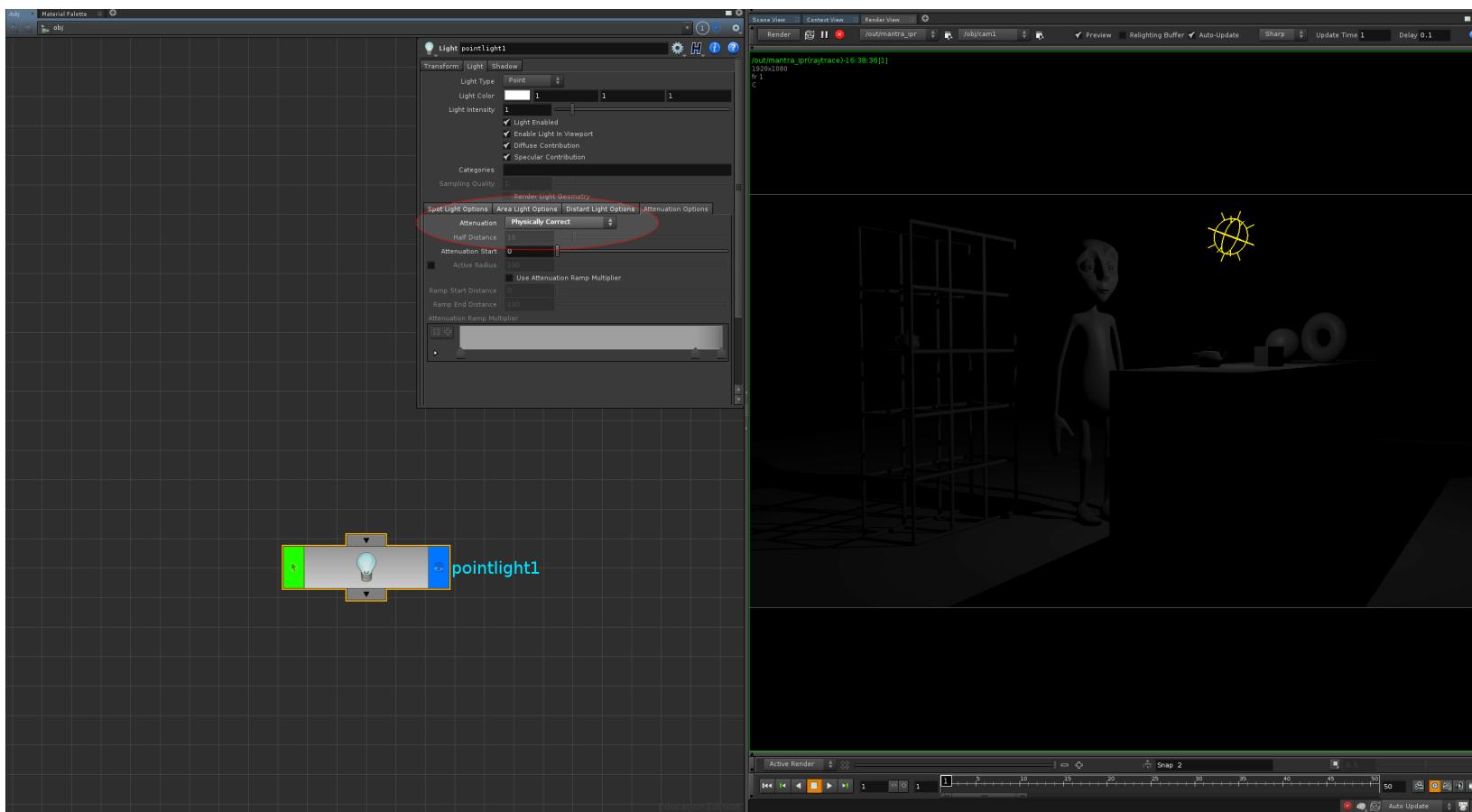
No Attenuation means that there will be no light intensity fall off over the distance of the scene.

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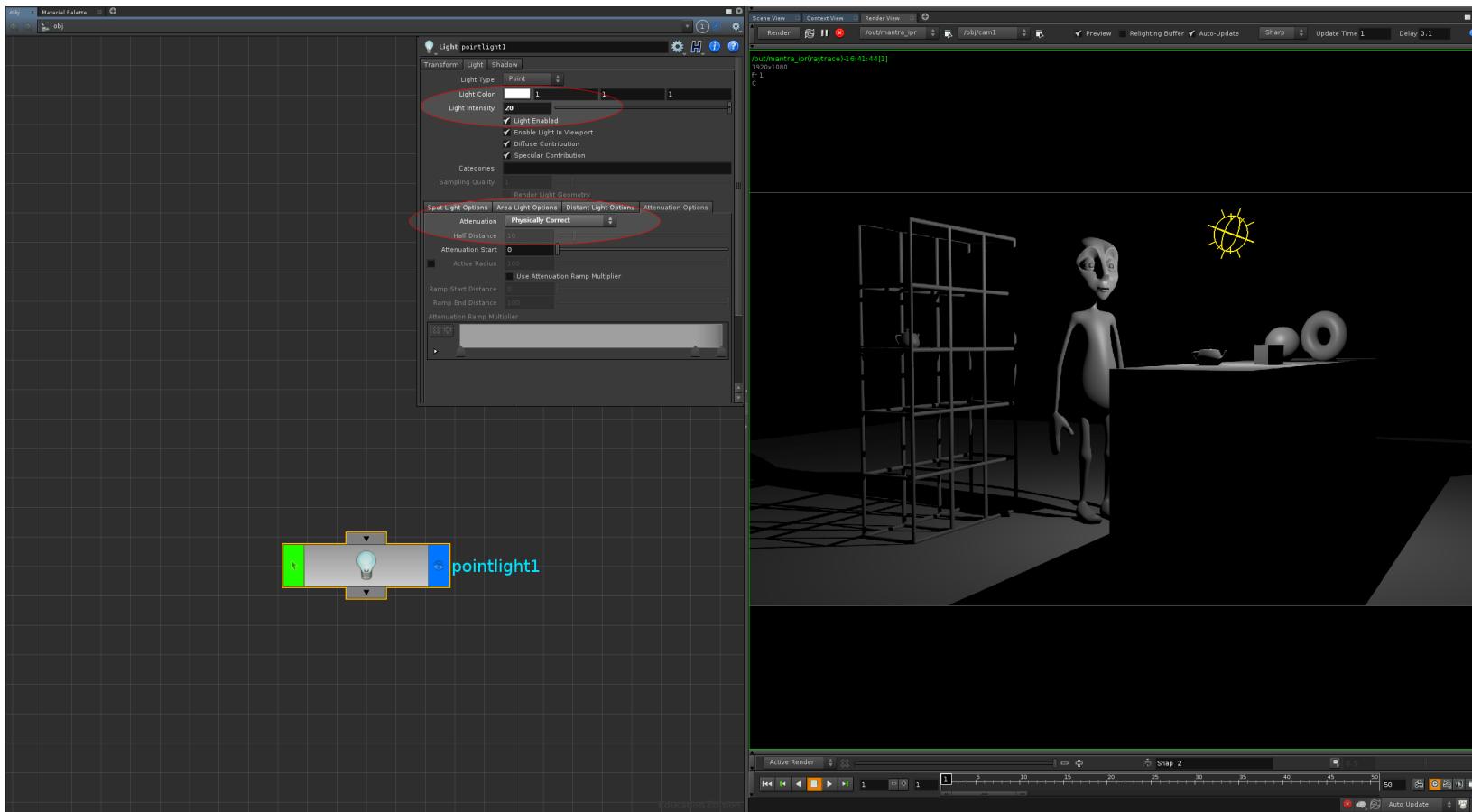
Half Distance Attenuation allows the user to specify the distance from the light source where the light intensity becomes half its original value.

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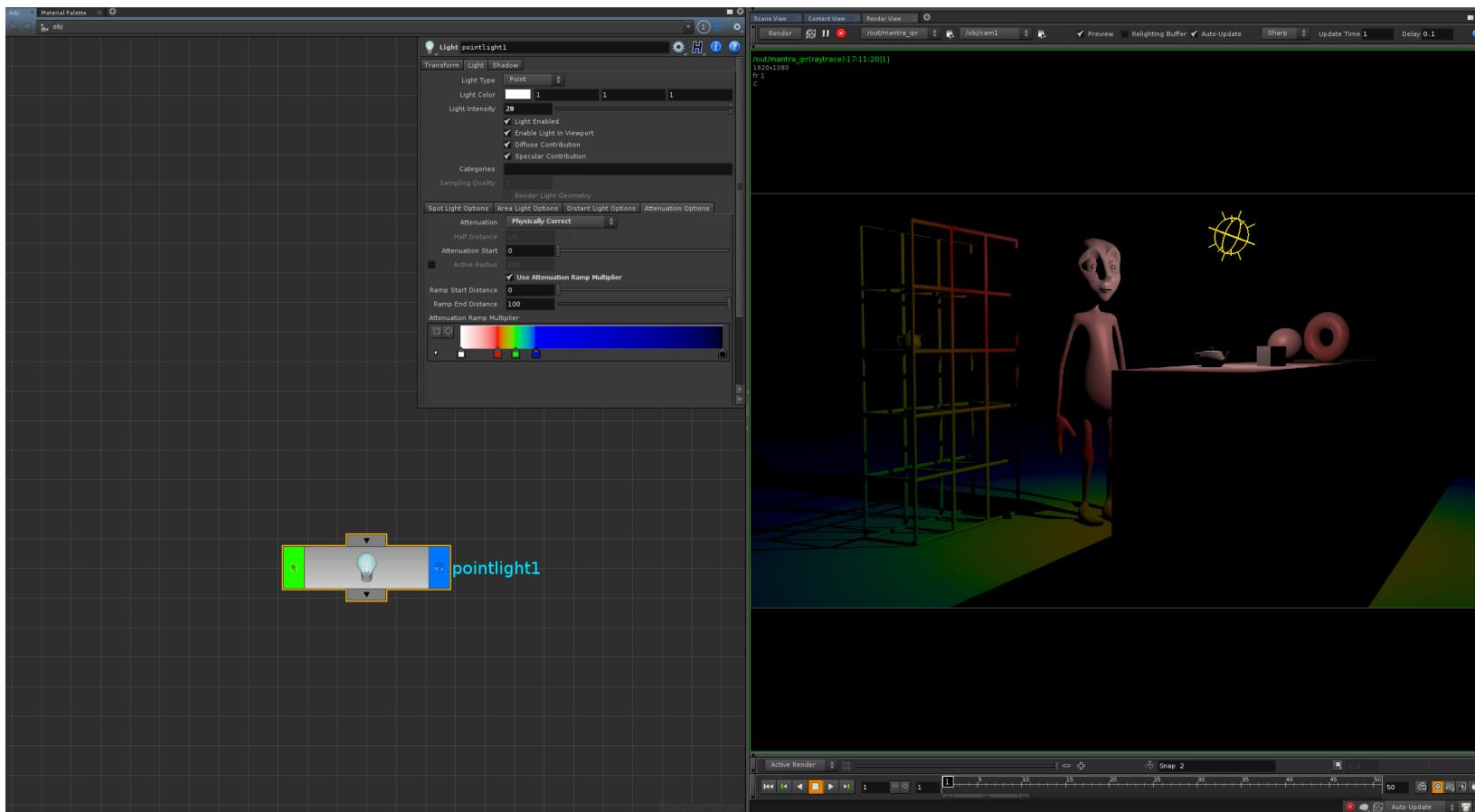
Physically Correct Attenuation uses an algorithm based on real world principles to control light intensity falloff over distance.

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Increasing the **Light Intensity** parameter can artistically modify physically correct attenuation relative to the scene being developed.

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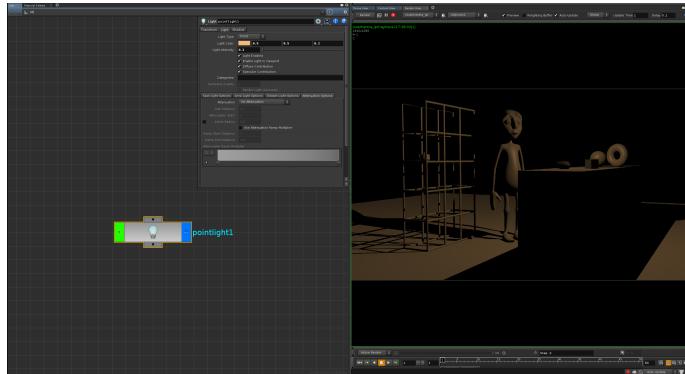


Attenuation falloff can also be controlled using colour ramps...

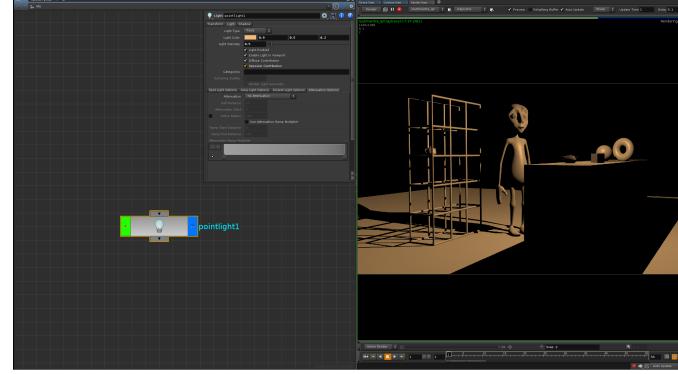
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Intensity (Brightness)

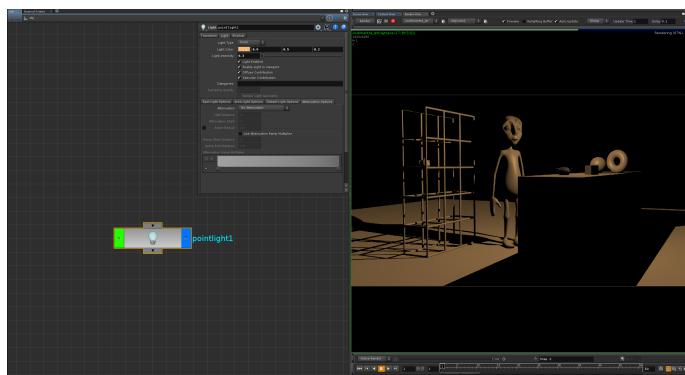
Intensity acts as a multiplier for the light colour.



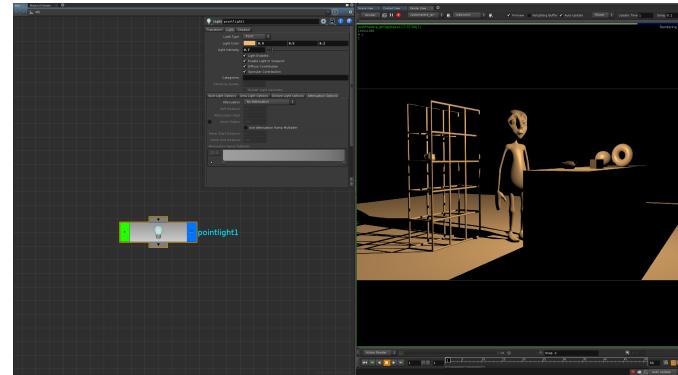
Intensity 0.1



Intensity 0.5

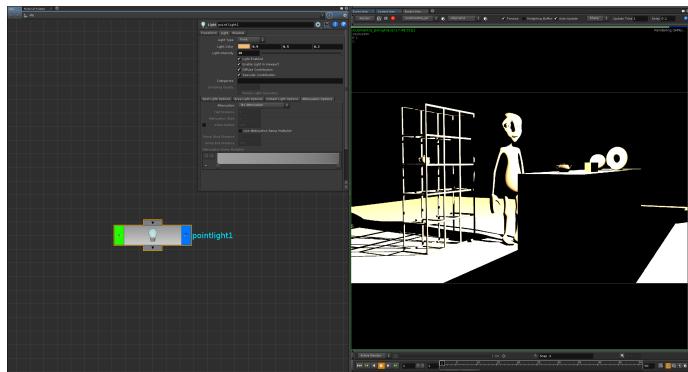


Intensity 0.3

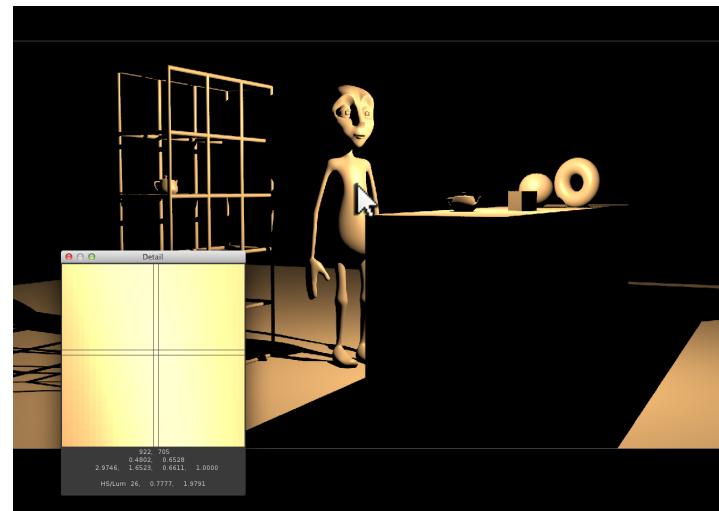


Intensity 0.7

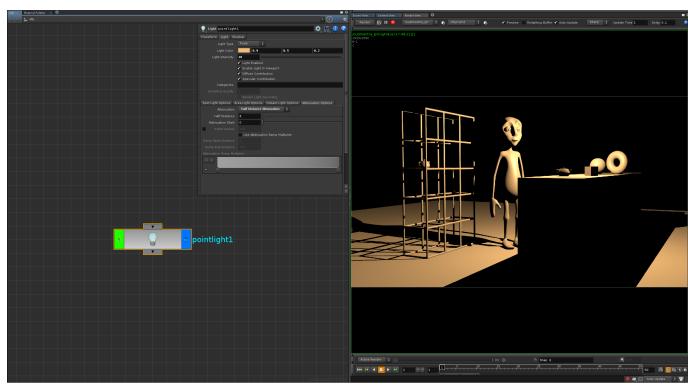
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Intensity 10.0



Lights with high intensity values above 1 can result in over exposure of the render. Attenuation can however be activated to compensate for this; with the higher light intensity acting as a hot spot for the light source.



Intensity 10.0 (but with Half Distance Attenuation activated and modified).

Lights with high intensities will result in high contrast looking renders.

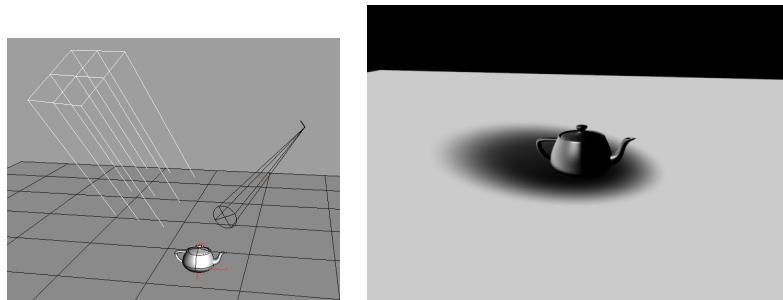
Care should always be taken to measure pixel values in the rendered image to ensure that appropriate values are being created. When working at 16 bit output, creative latitude can be used with pixel values over 1.0, as the 16 bit image can be further massaged in the composite.

When working for a 8 bit output, the final maximum pixel brightness in the render should be 1.0 (white). This will help prevent clipping (where blocks of differing colours are rendered out as white, as their RGB values are all above 1.0).

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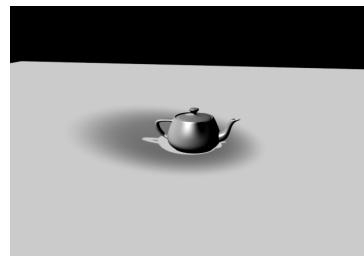
Negative Lights

Lights can also be set to negative values (as either Colour or Intensity). Negative lights will remove light information from the scene. Negative Lights are useful for creating subtle shadow areas, including the underside of characters feet.

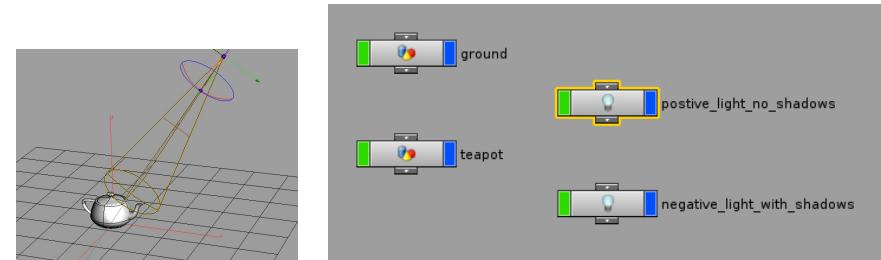


In this example, a Distant Light with a colour setting of [1,1,1] is being countered by a spotlight set with the colour [-1,-1,-1].

Note: Negative Lights will cast positive shadows.



This can be utilised to create a render pass containing only the shadow information.



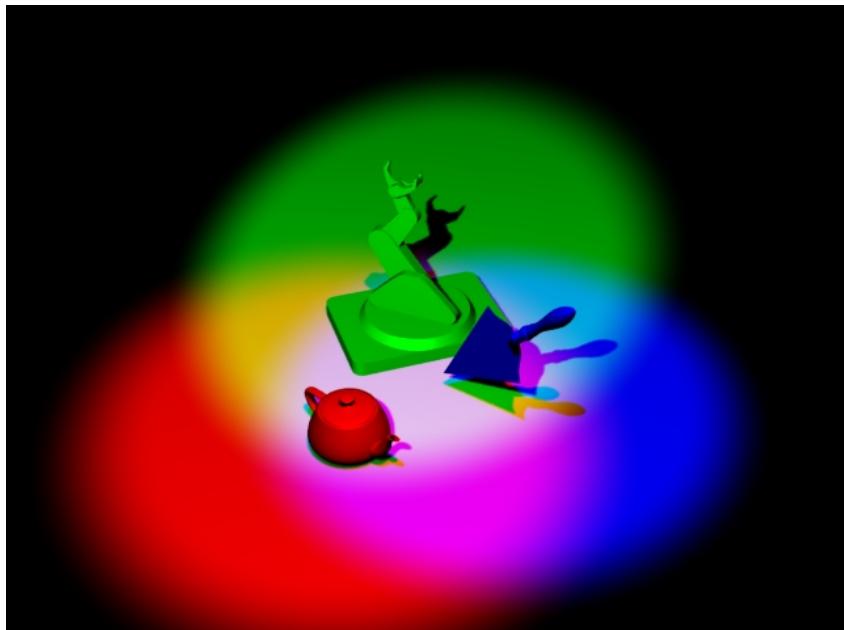
In this example, a positive and negative light are created at the same position and orientation. The negative light is assigned shadows while the positive light remains shadow-less. The resulting render returns only the shadow information.



This effect can also be achieved by assigning a Shadow Matte Material to all objects in the scene. Shadows passes can then be reintegrated into the final image in the composite.

Light Linking

Lights can be set to only influence specific objects



In this example, all three lights are illuminating the ground, whilst only lighting a single scene object.

Shadow Linking

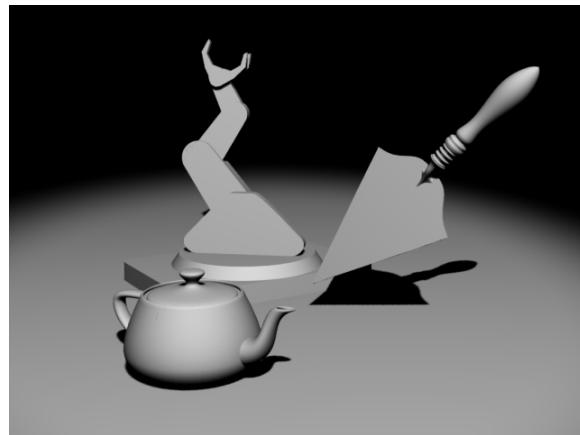
Lights can also be set to only cast shadows from certain objects.



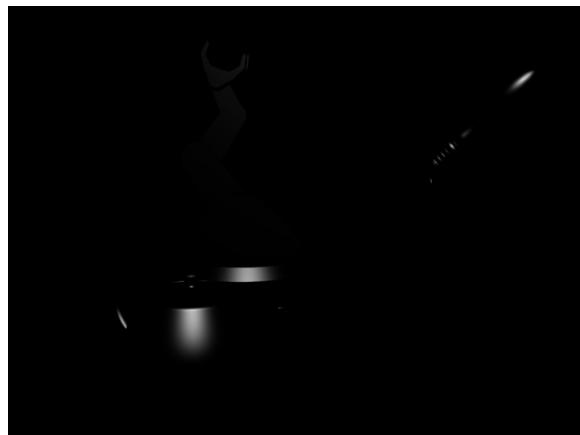
In this example, a single Distant Light is set to not cast shadows from the teapot.

Diffuse and Specular Contributions

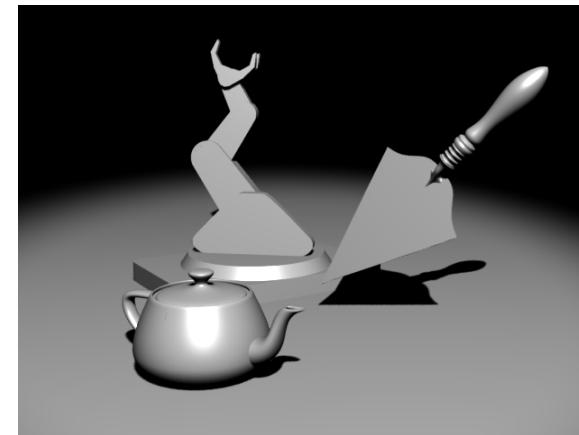
By default, Direct Lights contribute to both the Specular (Shininess) and Diffuse (Matte) properties of a surface. This however can be separated out.



Diffuse Only Spot Light



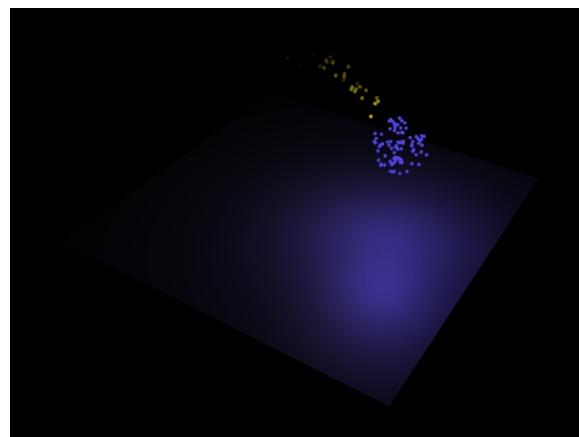
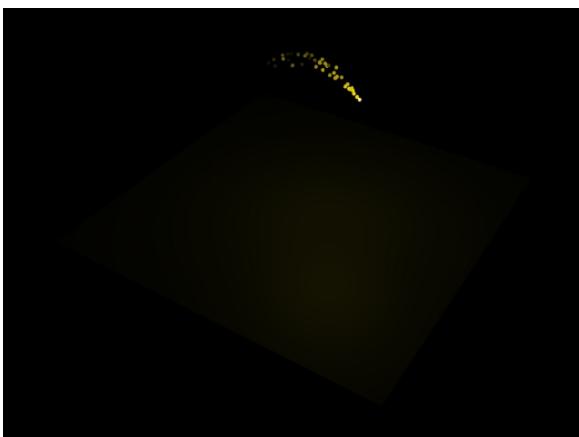
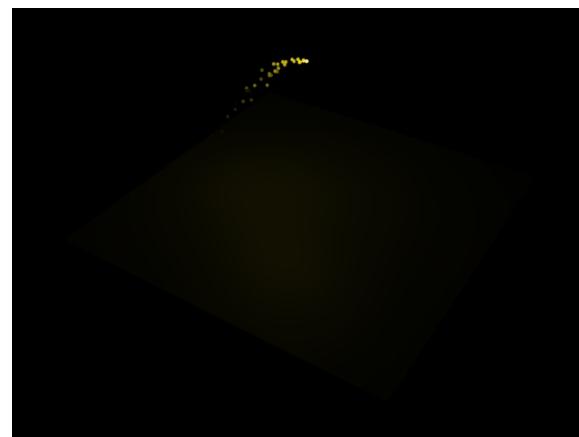
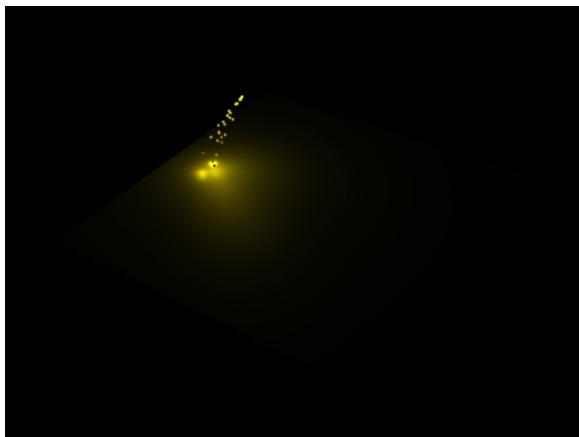
Specular Only Spot Light



Diffuse & Specular Spot Light

LIGHT INSTANCING

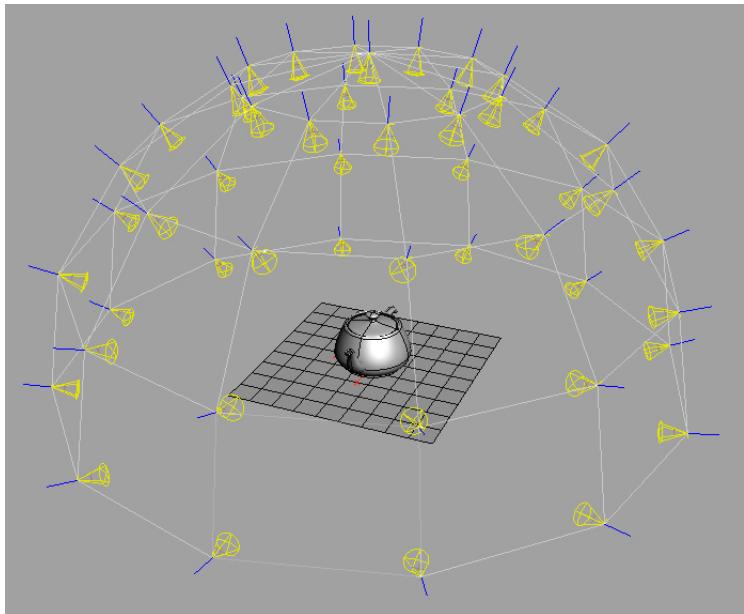
Lights can also be assigned dynamically to objects at Render Time using a process called Light Instancing. In this example a **point light** is instanced onto a simple **particle firework system**, where the colour of the particles is also used to drive the colour of the instanced lights.



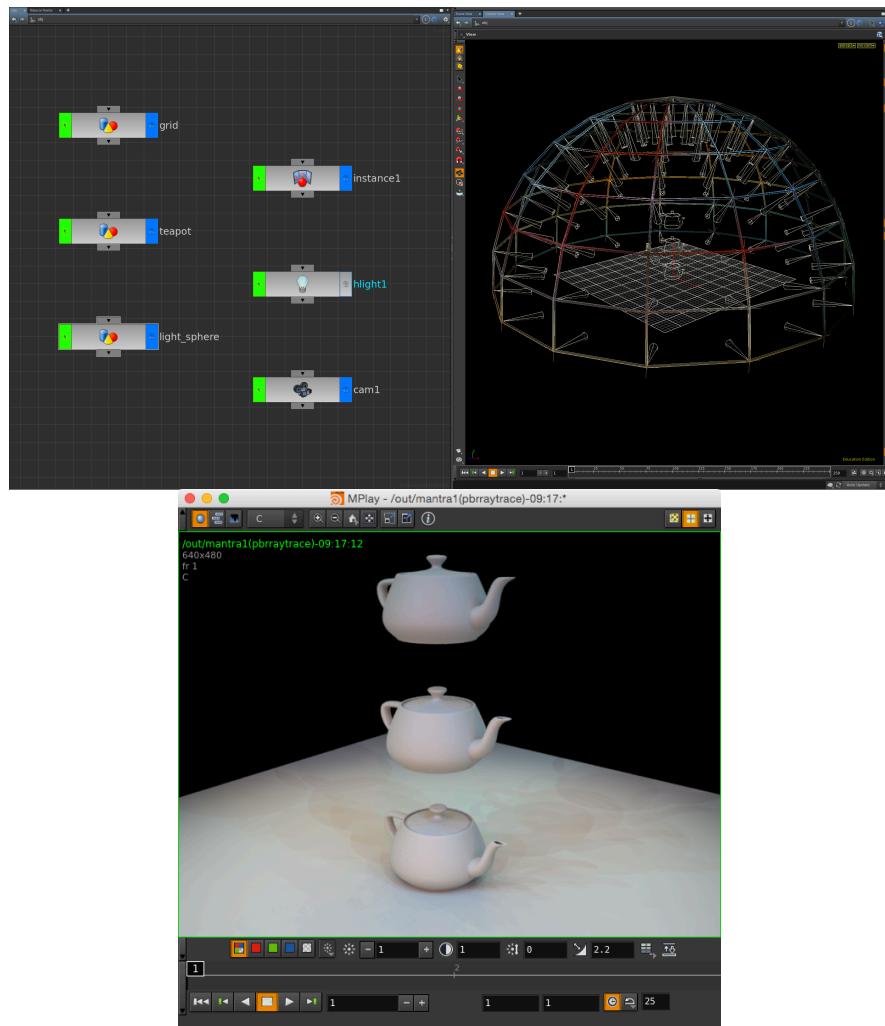
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CONE LIGHTING AND LIGHT INSTANCING

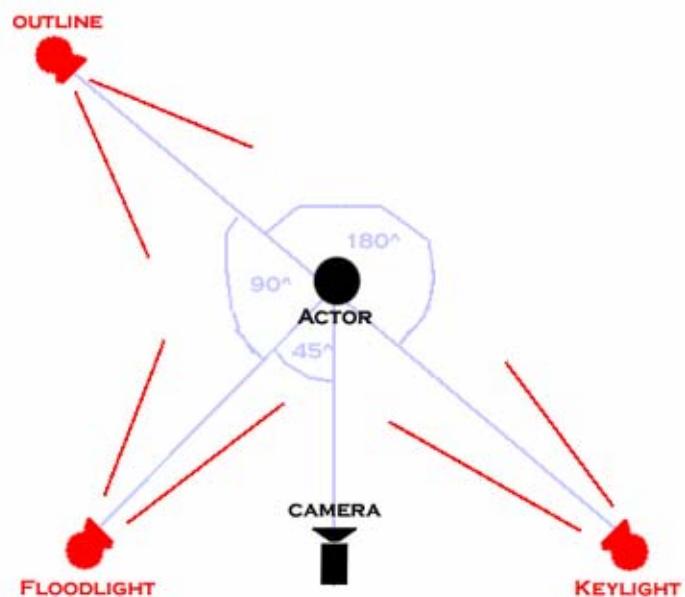
Cone Lights can also be instanced onto point data that has normals information already specified. The instanced Cone Light will always point in the opposite direction of the surface point Normal.



Any image projected onto the instance geometry can also be used to colourise each instanced light. This is a form of Image Based Lighting (see the Indirect Lighting section for more information).



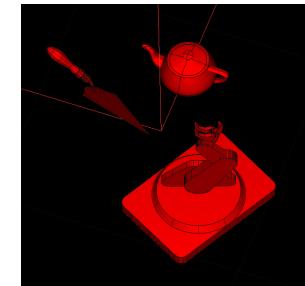
Simple Three Point Lighting



This is a technique where three lights are positioned around the subject to articulate shape and form. Lights are positioned relative to the camera.

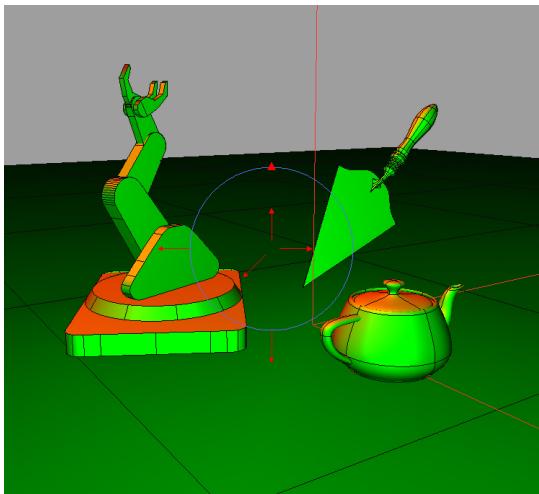
Outline Light (Rim Light, Back Light)

This is positioned high above the scene in order to pick out the edges of the subject from behind. Red is a good starting colour for positioning this light. Suggested light **Distant Light**.



Note: In this example, Light Linking is being used so that the Outline Light does not light the ground, and there are no shadows set. It is also contributing to both specular and diffuse shading (optional).

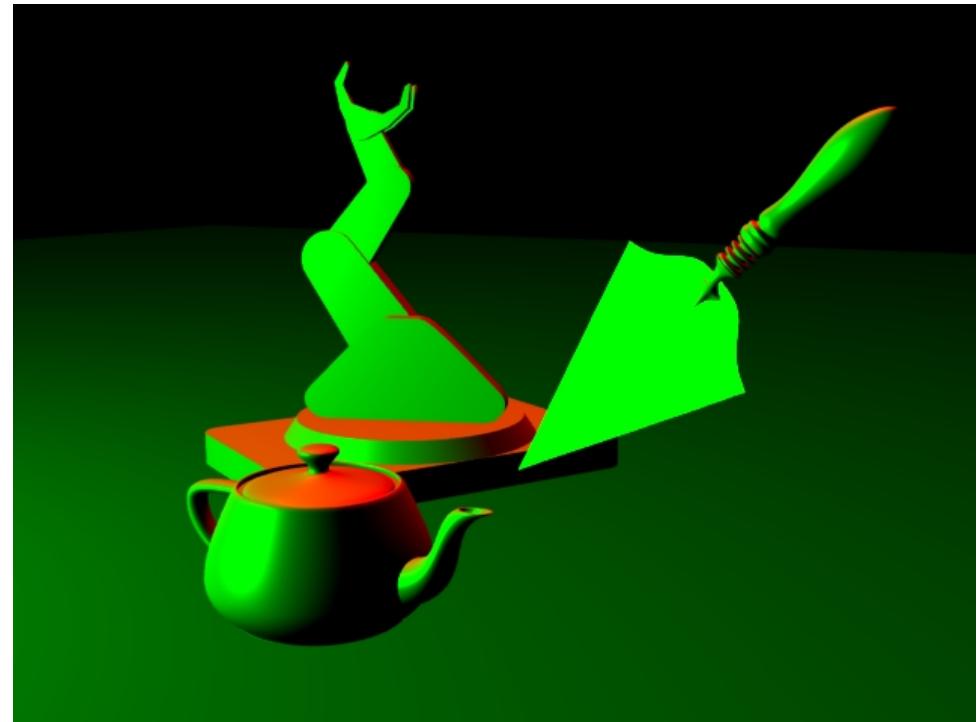
Flood Light (Fill Light)



This light is used to fill in the dark areas and undersides of objects in the scene, so that there are no large areas of absolute black. The height of this light should be relatively low, as it will represent the bounce light. It should be positioned to one side of the camera.

Suggested Light **Point Light**.

If Red is specified as an Outline Light colour, green can be used for positioning the fill light. Using primary colours to position lights allows for their influence to be easily seen.

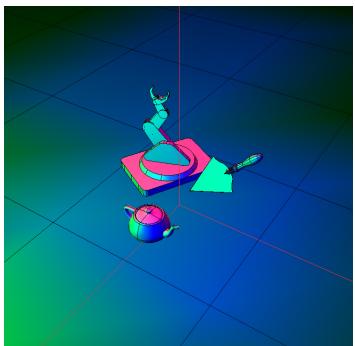


In this example, the Fill Light is illuminating all objects and not casting shadows (optional for a Fill Light). It is also contributing to both specular and diffuse shading (optional).

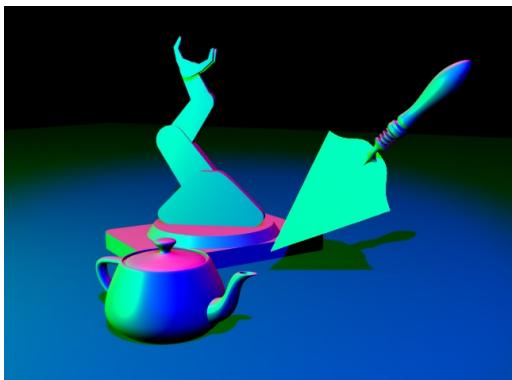
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Key Light (Hero Light)

This is the primary light of the scene. It should be positioned on the opposite side of the camera to the Fill Light, and at a steeper higher angle.

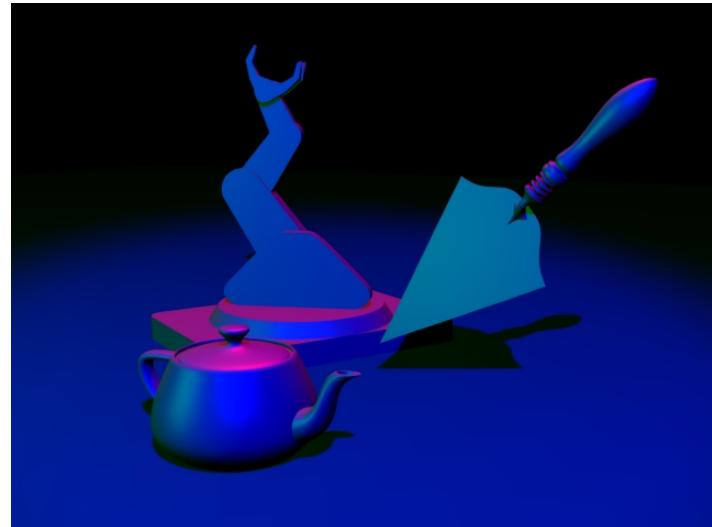


The Key Light should be the most dominant light in the scene, and should be the main source of shadows. Blue can be used as a positioning light colour. Suggested light **Spot Light or Area Light**



3 Point Lighting Intensities & Colour

At present all three lights have the same intensity. This can be modified after the positioning of the lights.



A starting set of values for 3 Point Lighting Intensity could be:

Key Light 0.85

Fill Light 0.25

Rim Light 0.65

When this is complete, more natural lighting colours can be assigned to the lights. A guide for colouring 3 point lighting is assigning an off white for the key light, a darker version of the key light colour for the fill light, and a (light) complimentary colour for the rim light.

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Be careful not to 'over-expose' a render. The more lights in a scene, the brighter a scene becomes.



Three point lighting can also be utilised as an initial setup for matching geometry lighting into filmed background plates. This three point lighting setup can also be added to with an environment light (see indirect lighting tools section).

Shadow Tools

All Direct Lighting is capable of generating shadows for objects. **Note:** Area light shadows can take a long time to render.

There are two types of shadows in CG:

Ray Traced Shadows (including transparent shadows)



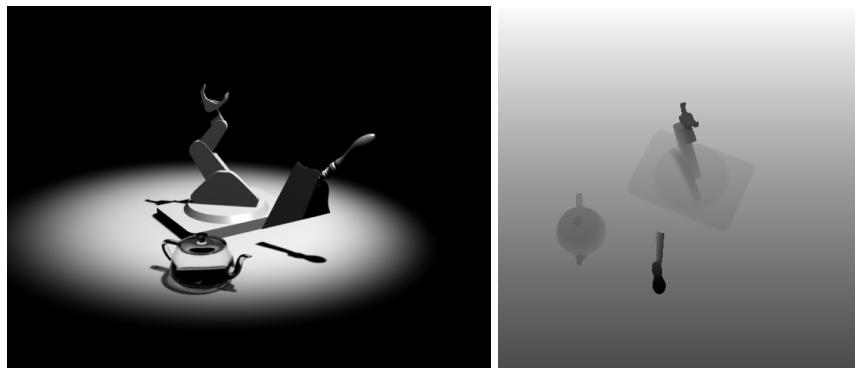
Sharp Shadows

(NOTE: the edge of the spot light is however set with a soft falloff)

Depth Map Shadows

An image of the shadow is rendered to disk before the main scene is rendered. For animated objects, a shadow map per frame per light is required.

If a shadow map sequence is rendered to disk and the animation is subsequently changed, the shadow map sequence must be re-rendered before the final sequence is rendered out.



A Shadow Map

If a shadow map sequence is pre-rendered, it can speed up final rendering time, as the shadow information has been pre-calculated. A shadow map is always rendered in a square format.

The visual quality of Shadow Maps also rely on how accurately the map is calculated. This is both in terms of the resolution (size) of the shadow map, and its sampling (ie how accurately have the shadows been drawn).



Pixel Sampling 1 1



The resulting shadow information is jagged.

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Pixel Sampling 3 3



The resulting shadow information is smoother due to higher samples.

Depth Map Shadows can also be softened:



Shadow Softness 5

The Quality of shadows is also key to making a scene ‘well lit’. Shadow quality is as much as a character as any direct light.

In the Shadow Softness example, the shadows have been softened to match the softness of the spotlight edge. This manual configuration and visual paralleling significantly improves the ‘richness’ of the render.

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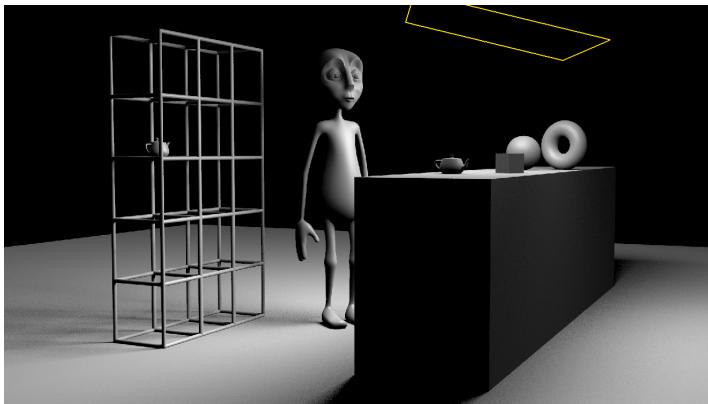
AREA LIGHTS AND SHADOWS

Area lights give soft shadows by default. If however an area light is scaled down in terms of its area size, the shadows become much sharper and have a similar aesthetic to a point light.



Grid Area light set to 0.5 x 0.5 (with Ray Traced Shadows activated)

When the area is larger, shadows become much softer and diffused.



Grid Area light set to 10 x 10 (with Ray Traced Shadows activated).

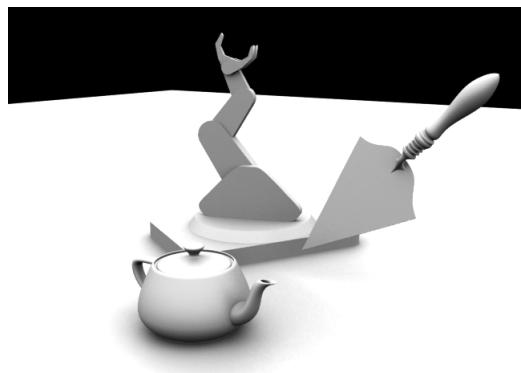
A variant on Area Lights is a Portal Light. This is where specific geometry can act as lit windows to illuminate the scene. This restricts the area light calculation only to the window geometry areas, making rendering more efficient.



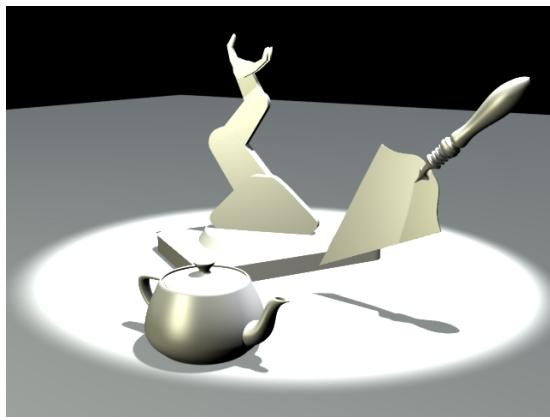
In the above example, coloured text has been assigned as geometry for a Portal Light. The visual end result is that only light is emitted and calculated from the text itself.

Ambient Occlusion

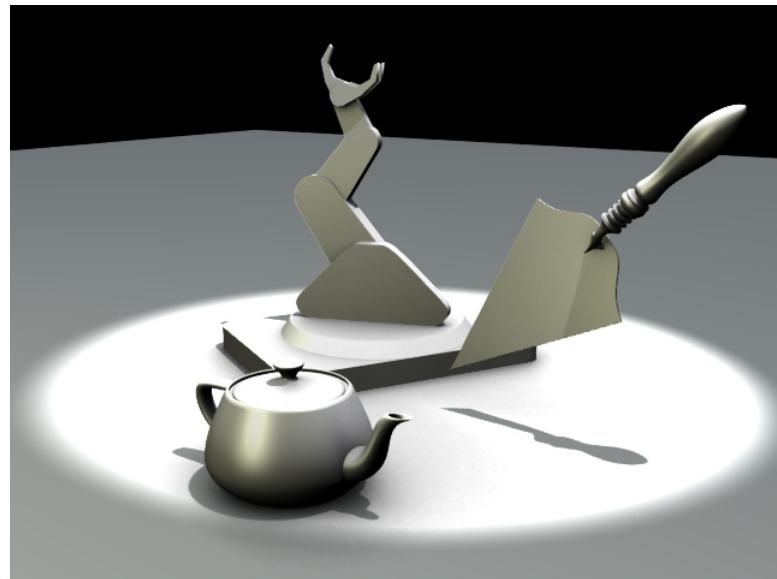
Fine shadow detail can be added to an image using Ambient Occlusion (a Photon Mapping technique). This is usually created as render pass multiplied into the final image in the compositing stage.



Ambient Occlusion Pass



standard render



Ambient Occlusion and Standard Render multiplied together

As renderers become more accurate relative to real world phenomena, the role and usage of ambient occlusion is beginning to diminish. It does however still have some use for adding realism to a scene render.

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Tool Name: **Ray Tracing**

Description: A rendering process tracing the path of light through pixels in an image plane

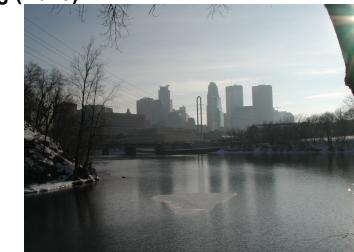
Usage: Reflections, Refractions, Scattering (Haze) & Chromatic Aberration. It is also used for generating shadows.

Real World Examples:

Reflections:



Scattering (Haze):



Chromatic Aberration:



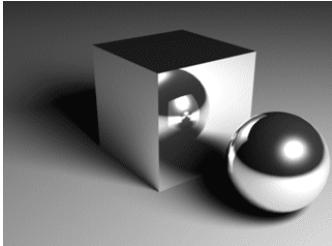
Refractions:



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CG Examples:

Reflections:



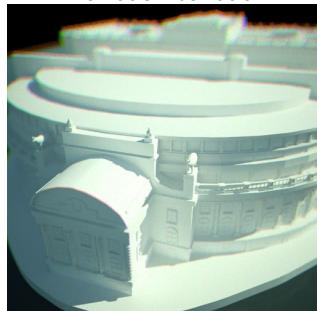
Refractions:



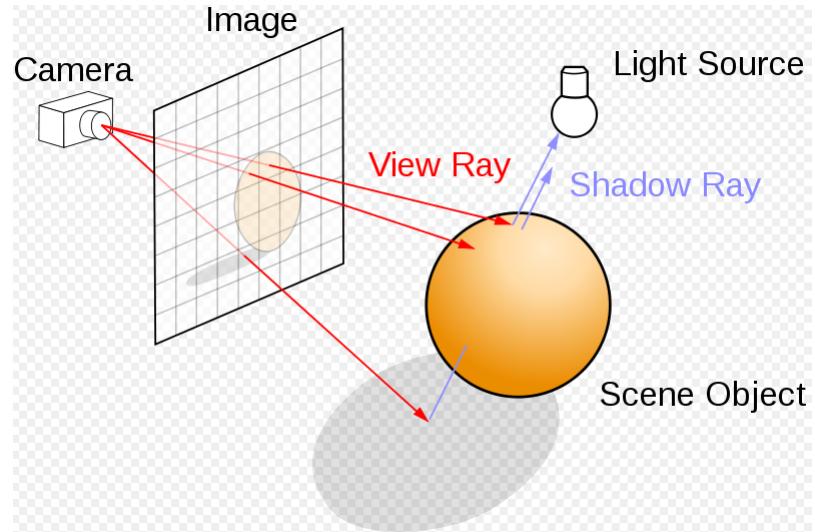
Scattering (Haze):



Chromatic Aberration:



RAY TRACING CONFIGURATION



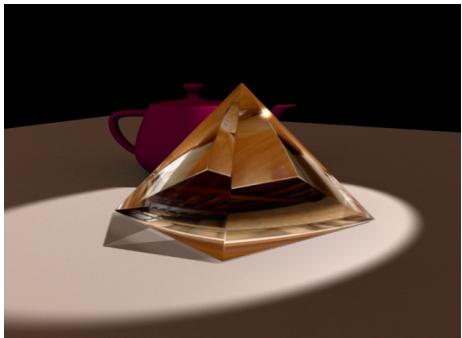
Ray Tracing is where rays are sent out from the camera at Render Time and used to backwards calculate how scene lights contribute to the look of the scene. This is computationally less expensive than calculating light contributions directly from the light itself.

As computers have become more powerful, this method has been added to by Physically Based Rendering (PBR), that does calculate light to camera contributions.

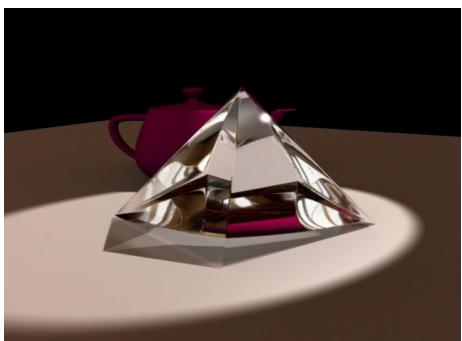
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Ray Tracing Reflection and Refraction Limits

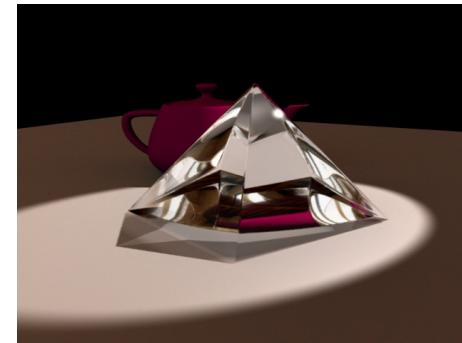
As ray tracing is computationally expensive, default limits are set on the number of times light can be internally reflected or refracted. These limits can be increased to improve renders.



Reflection Limit 1 Refraction Limit 1



Reflection Limit 5 Refraction Limit 5



Reflection Limit 10 Refraction Limit 10

Part of the skill of Lighting is understanding the optimal settings for all parameters. In this example there are minor visual differences between the Limit 5 and Limit 10 render; however there are big time differences between rendering them. Optimal settings can be found by setting a high value and then halving it. If the result is the same, halve it again. If the result is visually diminishes, increase by half. Repeat this until the optimum setting is found.

Refractive Index

Refractive Materials have an **Index of Refraction** parameter. Varying this value will vary how light bends through the object. Different materials have different refractive properties.

Vacuum	1.0
Air	1.0 (tiny fraction more than 1)
Water	1.33
Glass	1.45-1.48
Lithium niobate	2.25
Gallium arsenide	3.35
Silicon	3.5
Germanium	4.0

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Indirect Lighting Tools

Tool Name:

Photon Mapping

Description:

Photons (points) sent from both the camera and light, are their meeting point is accumulated on the surfaces of geometry to produce a given effect

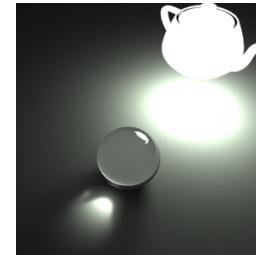
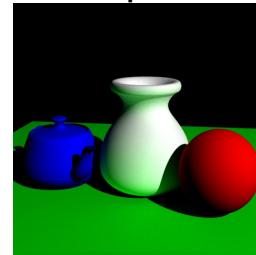
Usage:

Bounce Light (Colour Bleed)
Caustics
Sub Surface Scattering

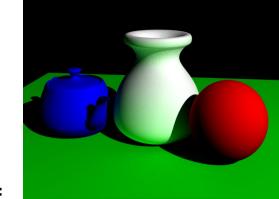
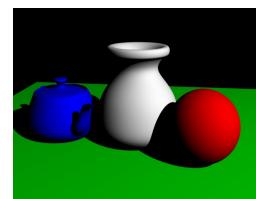
Real World Examples:



CG Examples:



Photon Mapping generally produces image results as render passes which are then added into the final image during the compositing stage.



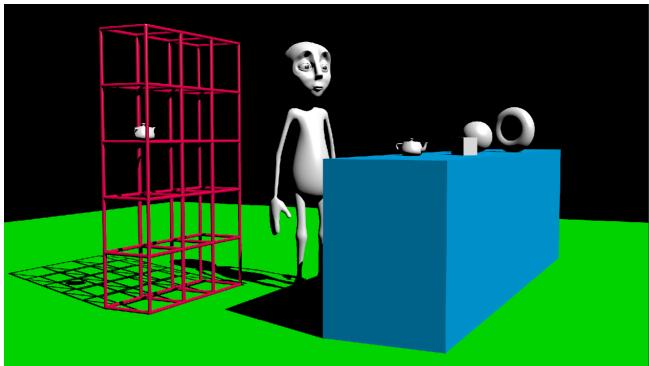
There are however renderers which can do photon mapping techniques as part of a standard render (Final Gathering or PBR - Physically Based Rendering).

While render passes such as the above are used for photoreal compositing; a more recent trend is to render everything in one pass (the beauty pass) with the light matching of the CG element (most notably creatures) being extremely accurate. This is due to the advent of Physically Based Rendering and the cost overheads of creating Render Passes. Lights can also be exported as separate Render Passes for compositing purposes.

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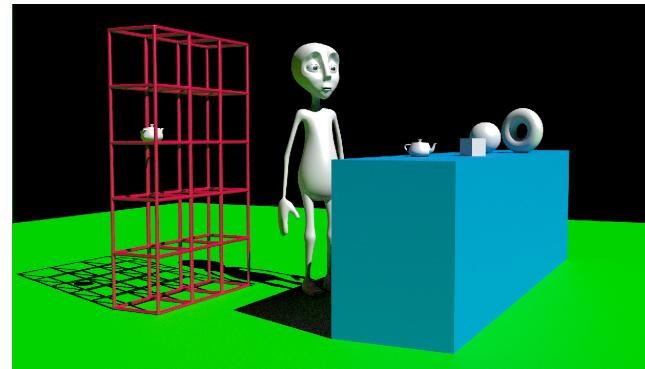
Distant Light rendered in Houdini using **Micro Polygon Rendering**.

The standard render has no colour bleed interaction between the objects.

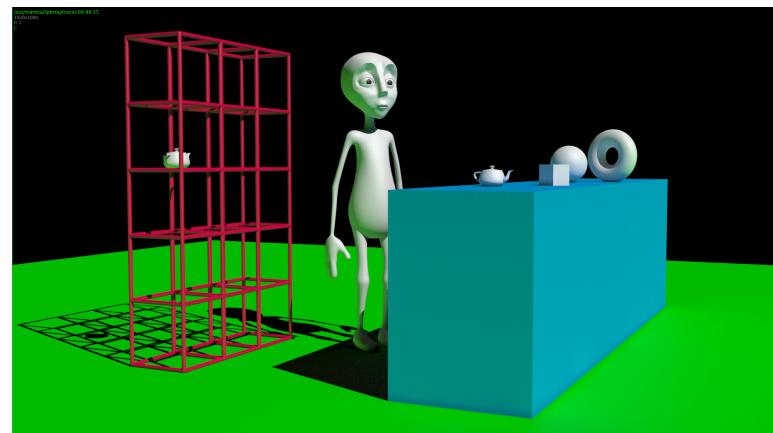
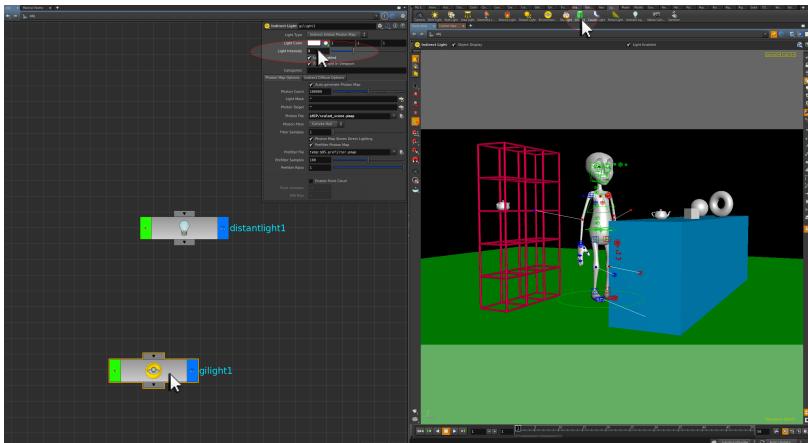


Distant Light rendered in Houdini using **Physical Based Rendering**.

The PBR render now has bounce light colour bleed interaction between the objects. PBR rendering does however take longer as a result.

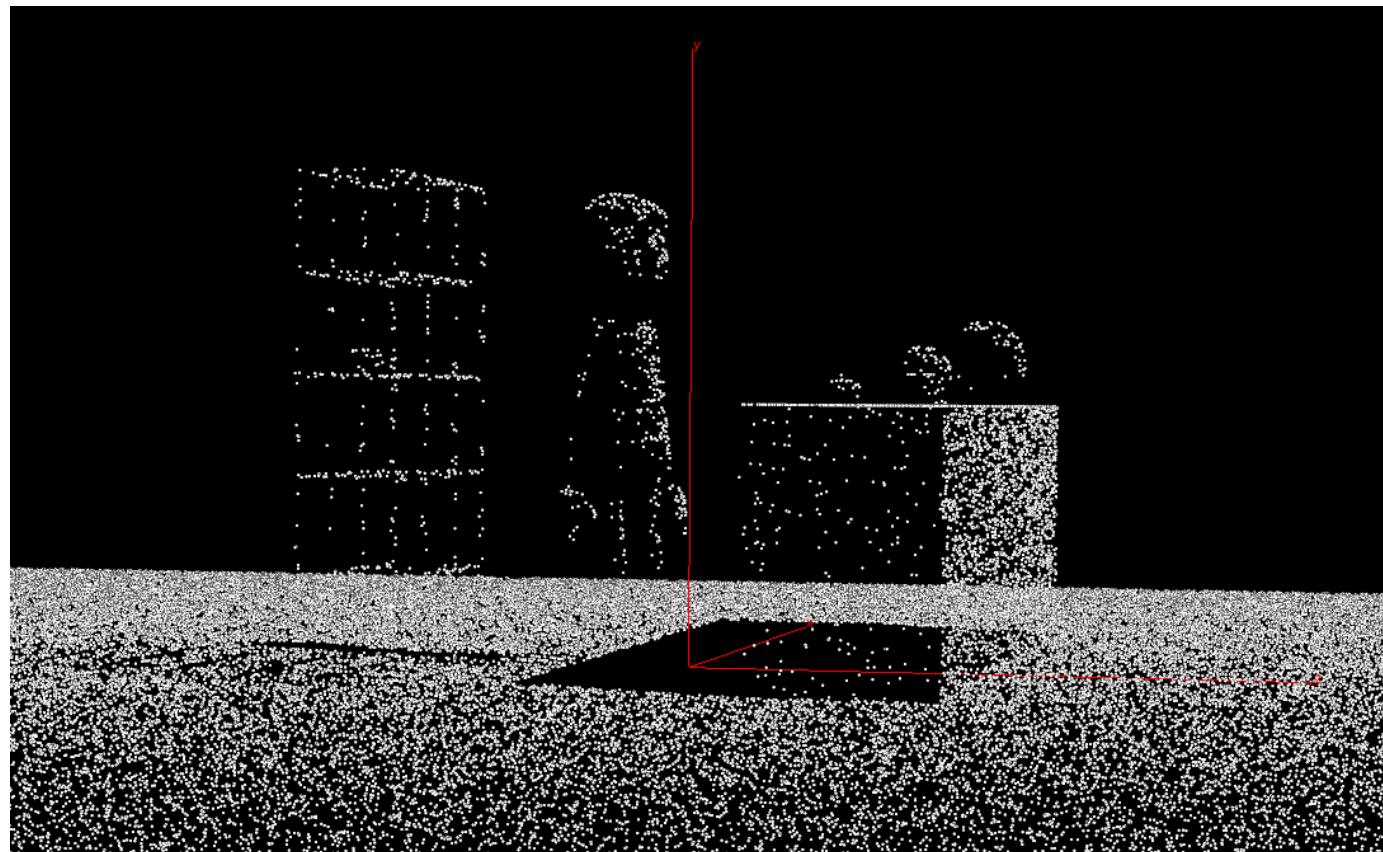


The effect of the Bounce Light can also be amplified in Houdini by activating a **GI Light**.



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A **Photon Map** is essentially **scattered points over the surface geometry** relative to the light direction. At render time, these scattered points are used to determine how much bounce light should be added over the scene.



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Tool Name:

Ambient Light

Description:

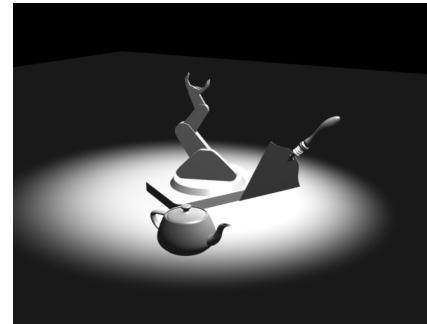
Emits light from all directions to illuminate the scene (source-less light).

Usage:

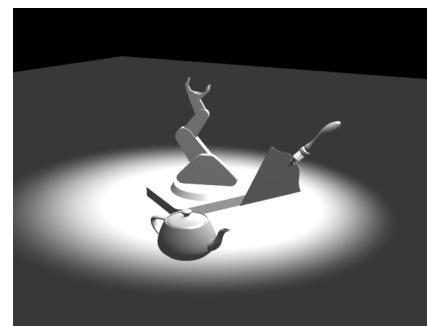
Uniformly lightening the dark areas of a render. Can also be utilised for interesting texturing tricks

The effect of an ambient light is best observed with a second direct light source in the scene (for example a spotlight).

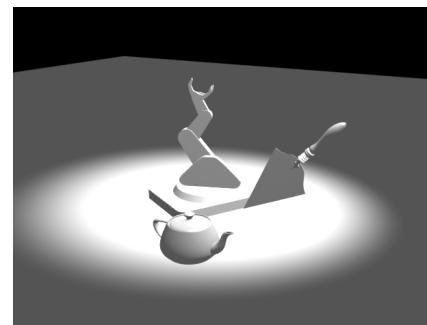
Real World Example:



Ambient Light Level 0.1



Ambient Light Level 0.2



Ambient Light Level 0.3

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Tool Name: Environment Light (Area Light - Sphere)

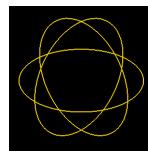
Description: Casts light into the scene from an image mapped onto an invisible surrounding hemisphere or sphere

Usage: Bounce Light / Environmental Light

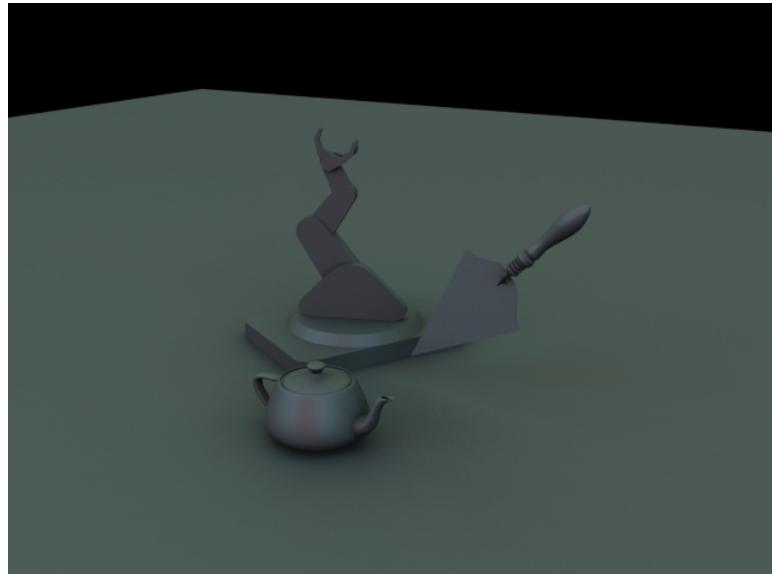
Real World Example:



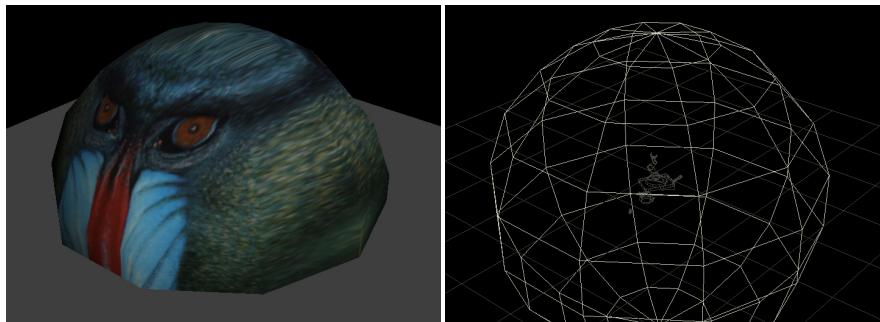
Tool Icon:



A giant textured invisible sphere surrounds the scene and casts light based upon image colour



How it works:



This technique is also known as Image Based Lighting (IBL). Environment Lights can also assign HDRI (High Dynamic Range Image) images as well as regular environment images. They can also be used to generate Ambient Occlusion.

Environment Lights are a very powerful way of adding environment lighting to a scene not provided by the scene bounce light occurring from one object onto another.

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Environment Lights can also assist with **light matching**, where a HDR Image is used to light scene geometry relative to a background plate.

Original Background Plate



Polar HDR Image



Teapot Render



Ambient Occlusion



HDRI Render x Ambient Occlusion Composite



HDR Image based renders will not by default generate hard shadows. If this is required additional scene lights need to be added.

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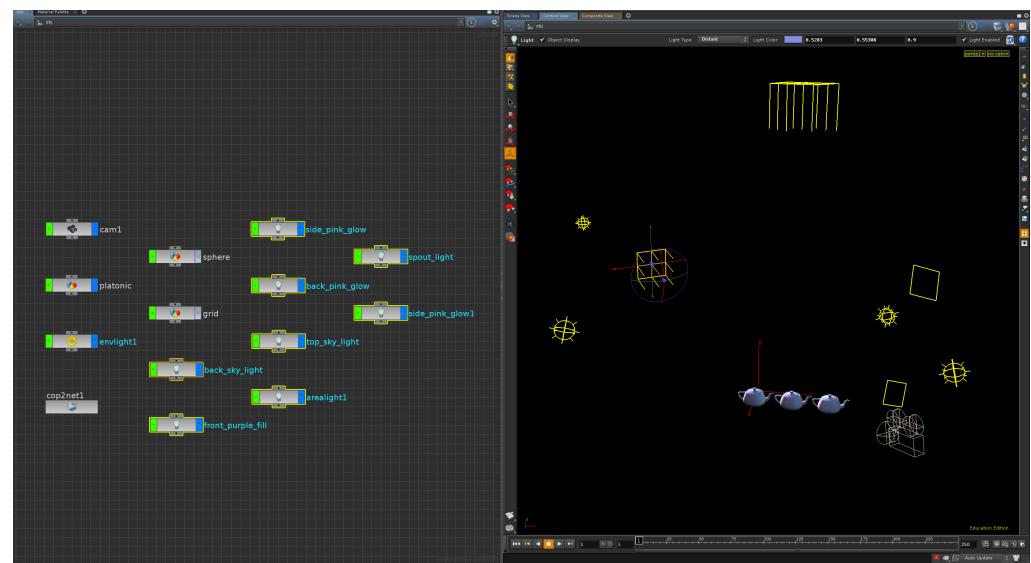
Creating a light match with no HDRI

The environment light can accept any images, regardless of if they are HDRI or not. This means that if no HDRI map is available, the original scene background plate can be used as an environment map image instead.

This will give some environmental colour information to the render approximating what the HDRI map was doing.



The same teapot scene is rendered again, but this time using the original background plate as the environment image (instead of the HDRI).



Additional lights have also been manually added to the scene to help create the light and shadow match.

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Environment Light Alternative

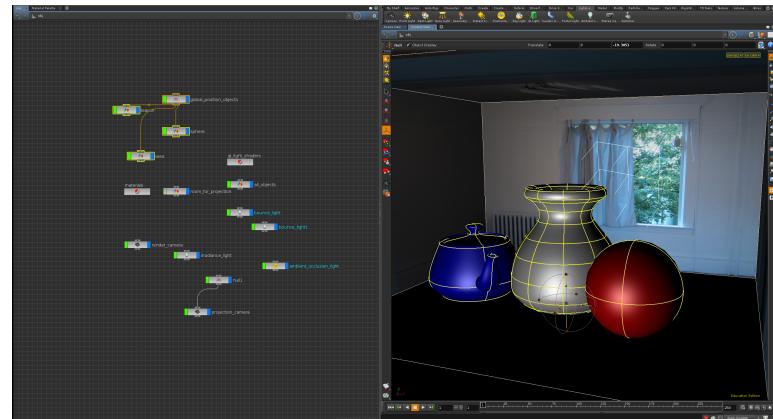
Using spherical maps for Image Based Lighting will return good results; however sometimes CG objects need to be integrated into the corners of a scene (beyond the limits of the spherical map).

If this is required, the scene itself can be recreated in CG as a small theatre set where the background image is projected onto the set geometry and used to generate a light match.



The original background image...

The original background image is projected onto a simple box theatre set using **camera projection**... This dummy geometry theatre set information can then be told to influence the rendering of the scene objects either as reflections or bounce light information.

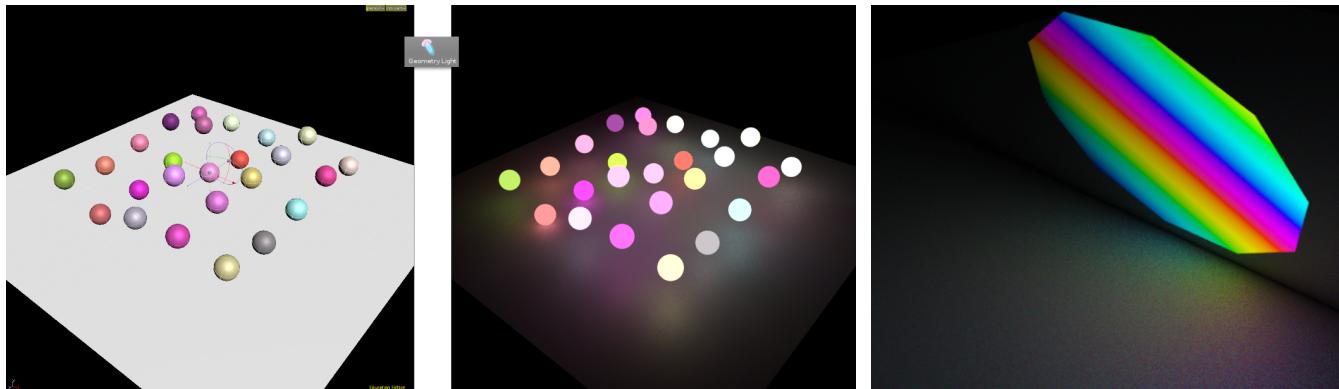


This can result in a light match that also allows objects to be placed right into the corners of the background environment; retaining reflection matching integrity.

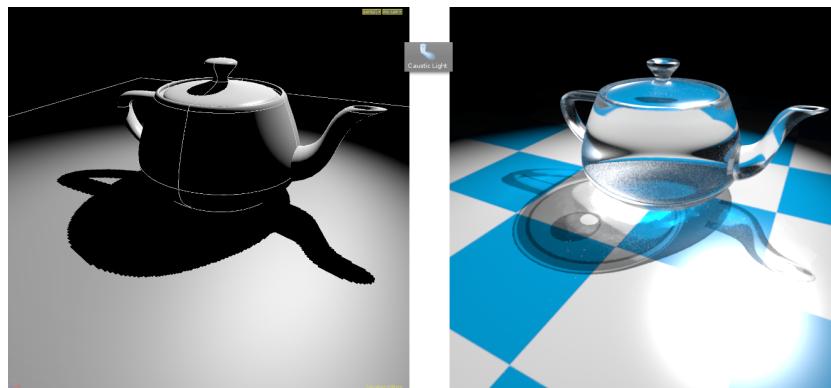
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LIGHTING TOOL EVOLUTION

Lighting tools are also becoming more bespoke and advanced. Now at the click of a button it is possible to create illuminating geometry by using a **Geometry Light**. The **Geometry Light** will accept both **coloured** and **textured geometry** to create the illumination effect.



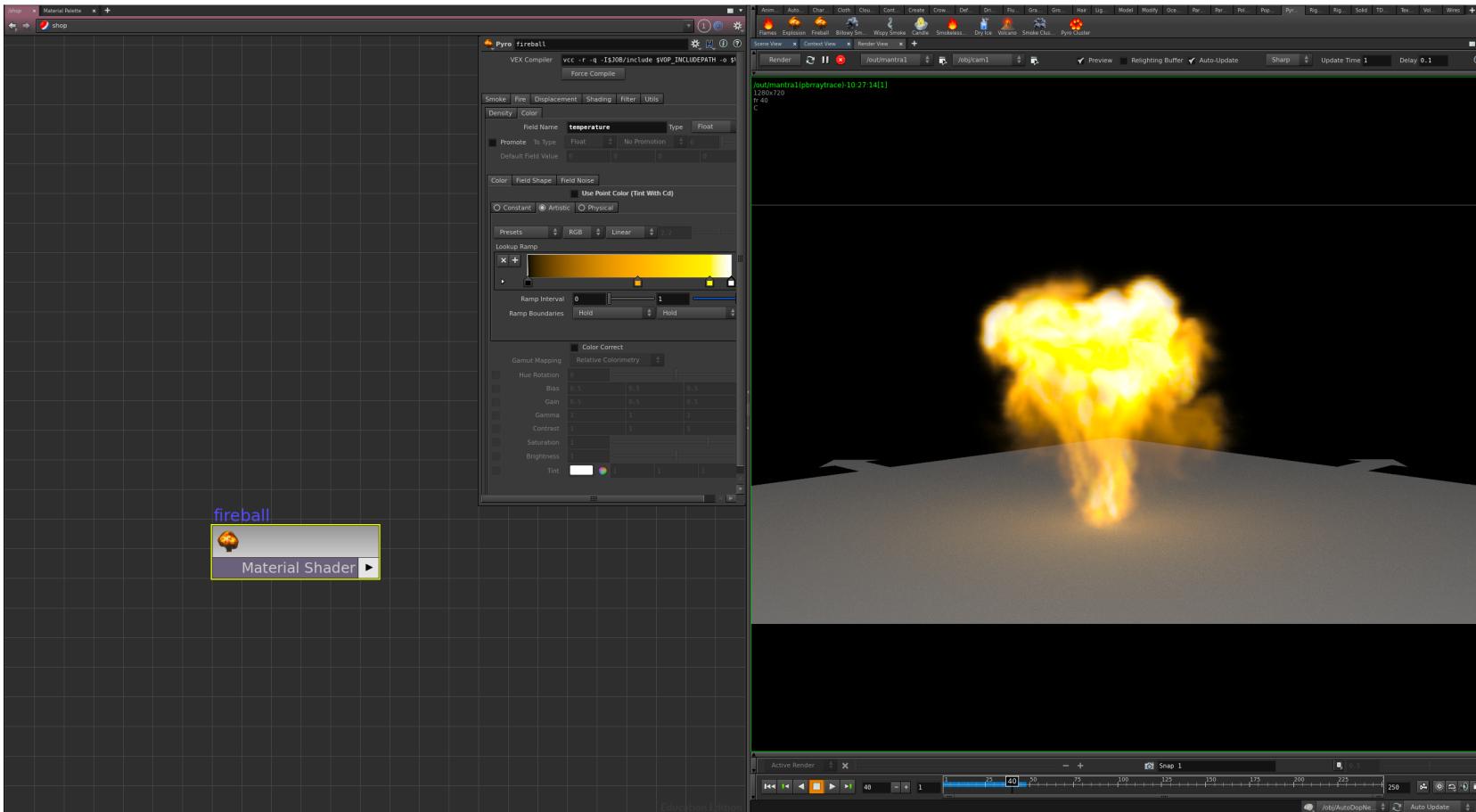
Similarly, Caustics can now easily be added to a scene using a **Caustics Light**.



The methods for creating these types of lighting tricks are becoming simpler and better. Convoluted photon mapping setups created by hand are now being replaced by automated processes.

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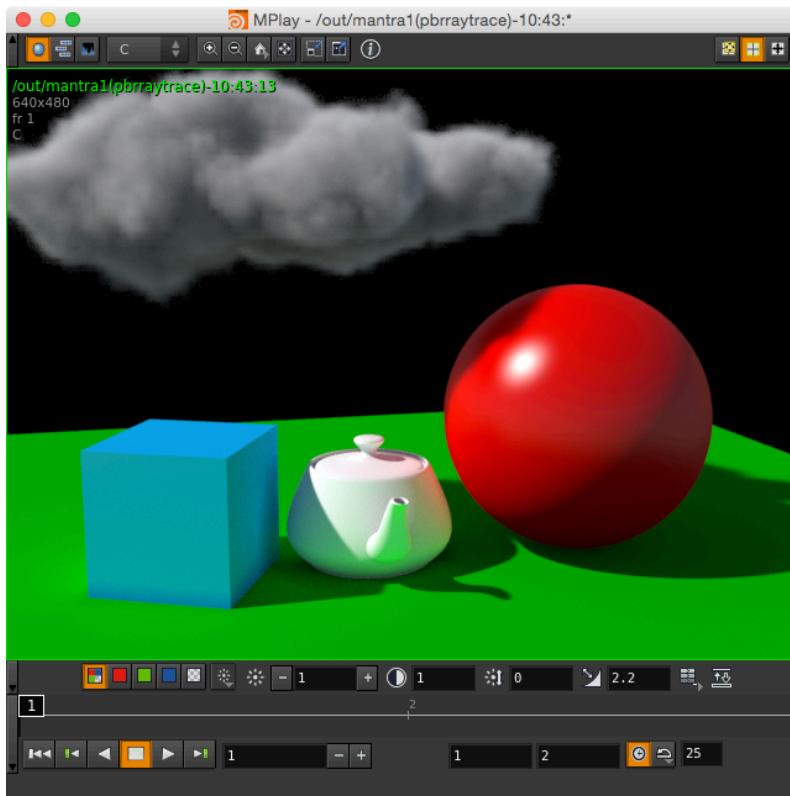
VOLUME LIGHTING



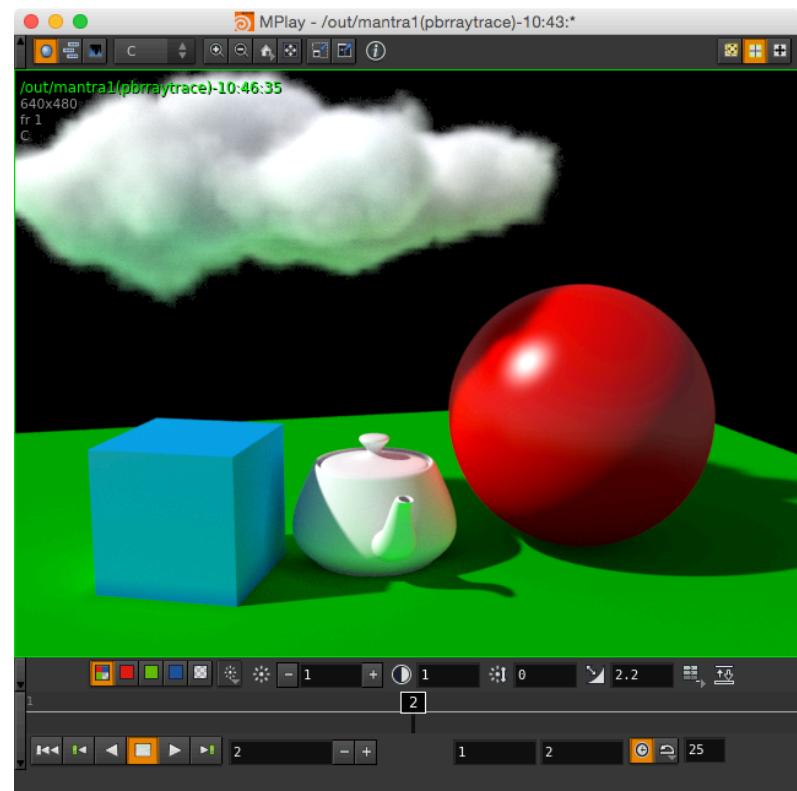
Volumes such as **Pyro Fire effects** will also add **interactive lighting** to a scene **automatically**.

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Volumes such as **cloud** and **smoke effects** can also be **activated to interact with scene lighting**. Increasing the **Mantra ROP > Volume Limit** parameter allows for **light photons to bounce internally inside the volume causing internal illumination**.



Volume Limit 0

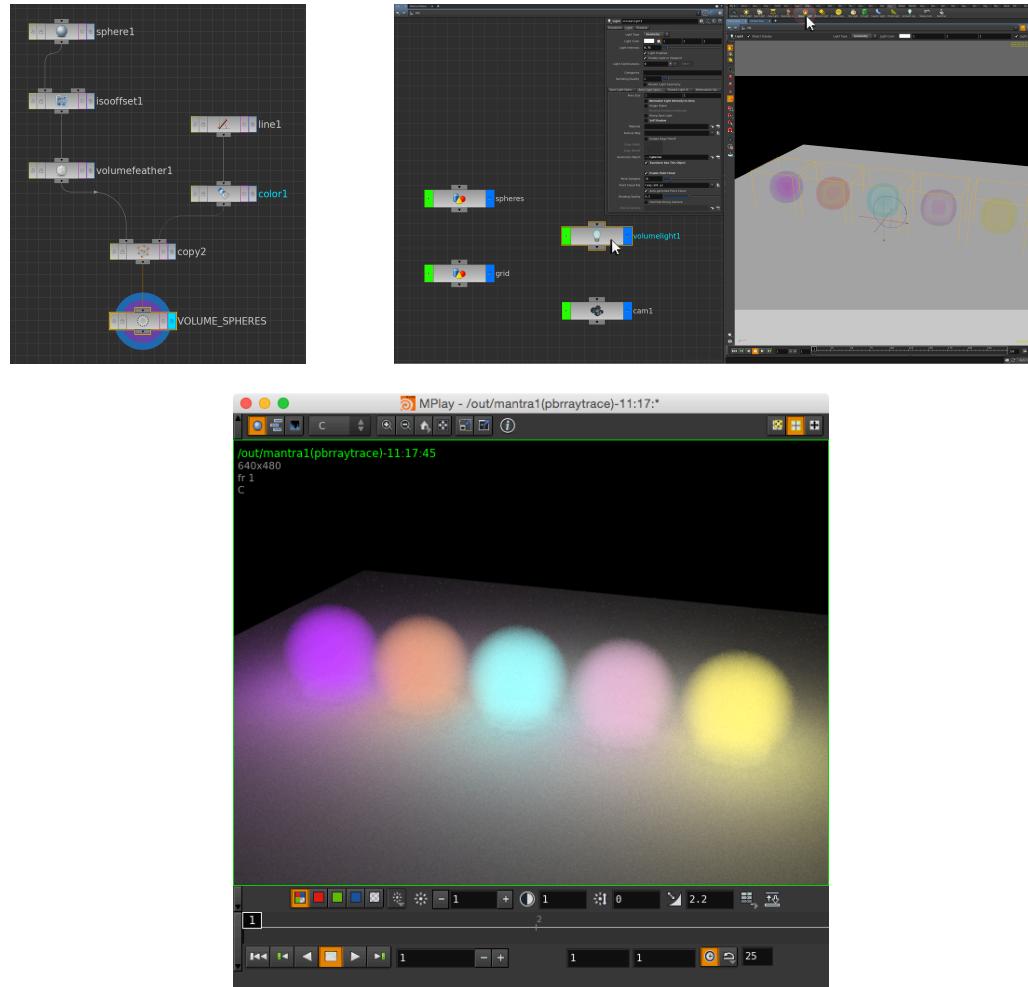


Volume Limit 1

NOTE: Due to computational expense, this aspect of volume rendering is normally deactivated until specified by the end user.

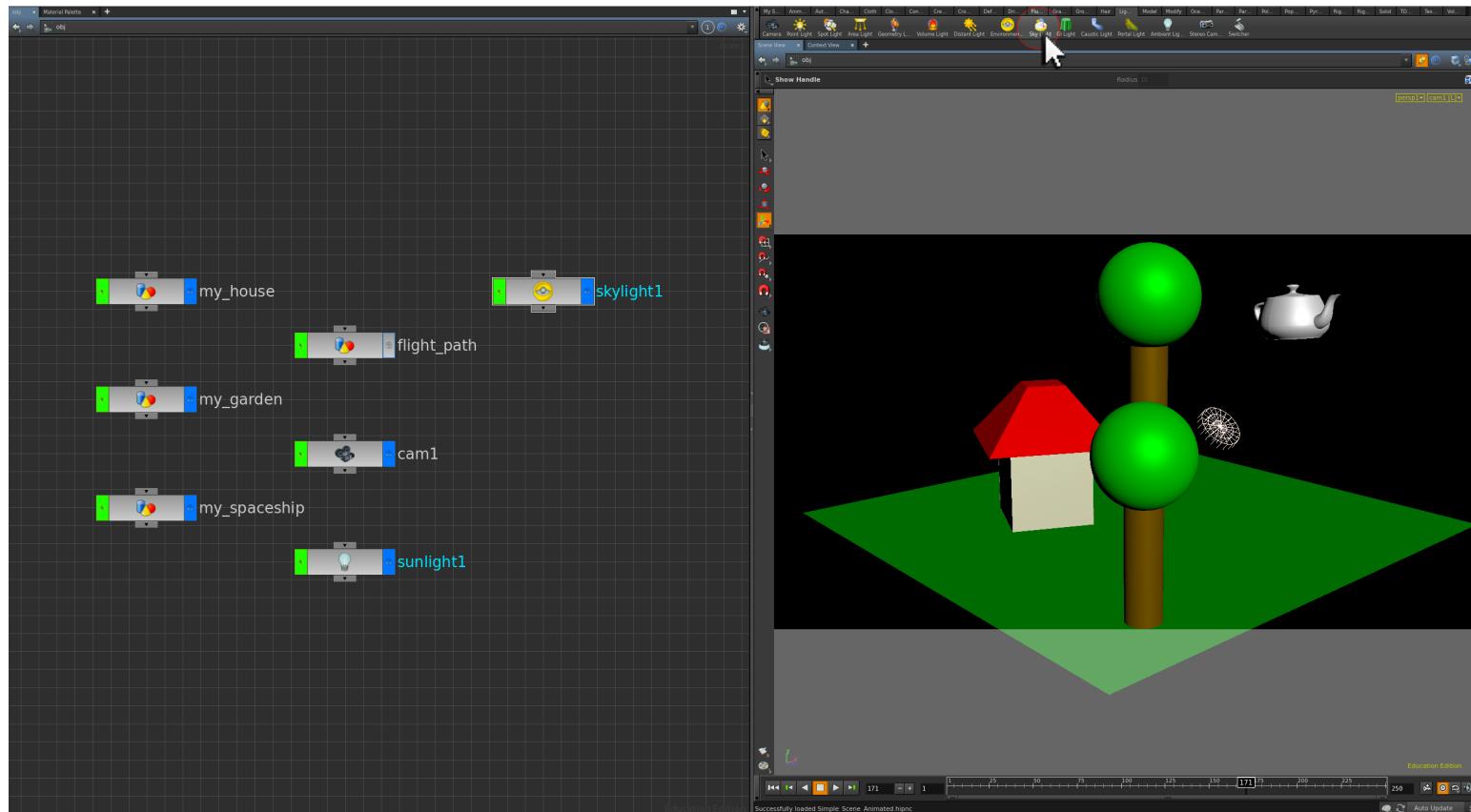
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Volumes can also be activated as **light sources** in their own right, by converting geometry to volumes and then activating the **Volume Light**.



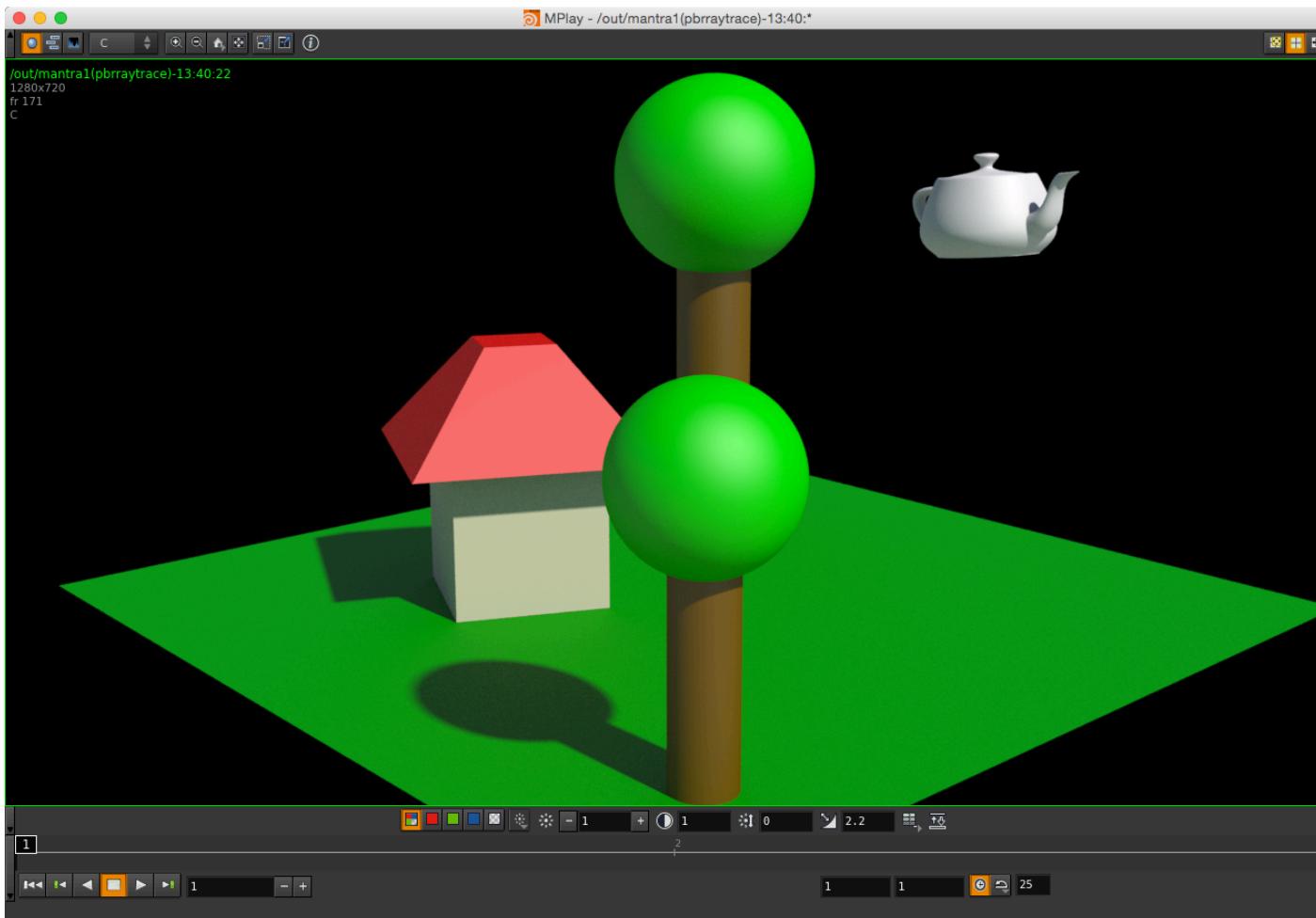
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Other emerging light tools in Houdini include the **Sky Light**.



This tool automatically generates both a **Sun Light** (a **Distant Light**), as well as an **Sky Light** (an **Environment Light**); allowing for quick configuration of outdoor lighting. This saves having to hand-configure such lights separately.

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Simple Scene rendered with the Sky Light Tool.

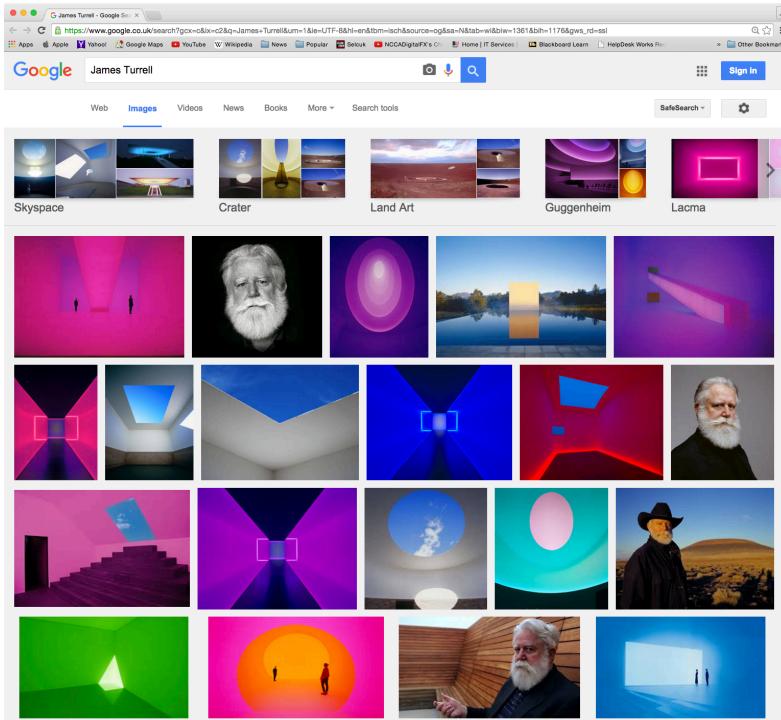
It is worth investigating your own 3D software to discover what it can offer in terms of lighting tools.

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FINE ARTISTS USING LIGHT AS THEIR PRIMARY MEDIUM

James Turrell

<http://www.google.co.uk/search?gcx=c&ix=c2&q=James+Turrell&um=1&ie=UTF-8&hl=en&tbo=isch&source=og&sa=N&tab=wi&biw=1361&bih=1176>



Dan Flavin

<http://www.google.co.uk/search?gcx=c&ix=c2&q=dan+flavin&um=1&ie=UTF-8&hl=en&tbo=isch&source=og&sa=N&tab=wi&biw=1361&bih=1176>

