# Table of Contents

**Introduction** vii

**Chapter One**  
**Fundamentals of Lighting Design** 1  
- Motivation 2  
- Cheating 5  
- Visual Goals of Lighting Design 9  
- Lighting Challenges 13  
- Your Workspace 15  
- Creative Control 16

**Chapter Two**  
**Lighting Basics and Good Practices** 19  
- Starting the Creative Process 20  
- Types of Lights 24  
- Adjusting Controls and Options 40  
- Exercises 51

**Chapter Three**  
**Shadows and Occlusion** 55  
- The Visual Functions of Shadows 56  
- The Appearance of Shadows 62  
- Shadow Algorithms 73  
- Occlusion 91  
- Faking Shadows and Occlusion 102  
- Exercises 108

**Chapter Four**  
**Lighting Environments and Architecture** 111  
- Creating Daylight 112  
- Working with Indoor Natural Light 124  
- Practical Lights 138  
- Night Scenes 143  
- Distance and Depth 144  
- Exercises 155
Chapter Five Lighting Creatures, Characters, and Animation 157
  Modeling with Light 158
  Three-Point Lighting 164
  Functions of Lights 167
  Issues in Lighting Character Animation 182
  Exercises 199

Chapter Six Cameras and Exposure 201
  F-Stops and Depth of Field 202
  Shutter Speed and Motion Blur 214
  Film Speed and Film Grain 222
  Photographic Exposure 223
  Matching Lens Imperfections 230
  Exercises 236

Chapter Seven Composition and Staging 239
  Types of Shot 240
  Camera Angles 244
  Improving Your Composition 253
  Framing for Film and Video 259
  Exercises 264

Chapter Eight The Art and Science of Color 267
  Working in a Linear Workflow 268
  Color Mixing 278
  Developing Color Schemes 285
  Using Color Balance 294
  Working with Digital Color 301
  Exercises 309
# Table of Contents

## Chapter Nine  Shaders and Rendering Algorithms  311
- Shading Surfaces  312
- Anti-Aliasing  325
- Raytracing  330
- Reyes Algorithms  341
- Global Illumination  343
- Caustics  352
- Exercises  356

## Chapter Ten  Designing and Assigning Textures  359
- Mapping Surface Attributes  10:4
- Aligning Maps with Models  10:17
- Creating Texture Maps  10:24
- Using Procedural Textures  10:50

## Chapter Eleven  Rendering in Layers and Passes for Compositing  361
- Rendering in Layers  362
- Rendering in Passes  378
- Matching Live-Action Background Plates  399
- Managing Colors in Your Composite  405
- Choosing Your Approach  407
- Exercises  409

## Chapter Twelve  Production Pipelines and Professional Practices  411
- Production Pipelines  412
- Lighting on Larger Productions  435
- Advancing in Your Career  441

## Appendix  Getting a Job in 3D Graphics  A:1

Index  443
Introduction

To help you make better 3D renderings, this book fuses information from several fields. In these pages, you will find practical advice based on professional film production experience, concepts and techniques from live-action cinematography, design principles from traditional visual arts, and plain-English explanations of the latest science behind the scenes.

Who Should Read This Book?

You should read this book when you have at least a working knowledge of how to use a 3D software package and are interested in taking your 3D rendering further.

- For professional users of 3D rendering software, this book is designed to help with real-world production challenges and contribute to the ongoing growth of your lighting and rendering work.
- For students of computer graphics, this book will help you develop professional lighting and rendering skills.
- For dedicated 3D hobbyists, this book can help you improve the artistic quality of your 3D renderings and learn more about professional approaches to graphics production.

I wrote this book to be clear, but not condescending. I have made every effort to define terms the first time I use them, and to illustrate every concept and technique with figures and sample renderings. This book is designed to complement, rather than replace, your software’s manuals and help files. Most of the information you find here is not in your software manual, even if some of it should be.

Software Requirements

This book covers techniques and concepts that you can apply in almost any 3D rendering software. I also recommend that you have 2D paint and compositing software on hand.
3D Software

I don’t care whether you use Blender (open-source software from www.blender.org), Maxon Cinema 4D, Side Effects Houdini, NewTek LightWave 3D, Autodesk Maya, Autodesk Softimage, Autodesk 3ds Max, or any other brand of software that lets you light and render 3D scenes. You can use the renderer that comes with your software package or separate rendering software like Solid Angle’s Arnold, NVIDIA Mental Ray, Pixar’s RenderMan, or Chaos Group’s V-Ray. No single program is going to support every feature, function, and rendering algorithm described in this book, so hopefully you won’t mind learning about a few functions that aren’t in your particular software yet. Most sections show several alternate approaches or workarounds so that you can achieve any effect that I describe, no matter which program you use.

Being non-software-specific doesn’t mean that this book doesn’t discuss individual programs, though. If there’s a noteworthy feature in any particular 3D program, or a technique that you need to do differently in one program than in another, I mention it when it comes up.

This book is dedicated to the idea that, if you are aware of the art and computer graphics principles that go into a rendering, and you apply a little bit of creative problem solving, you can accomplish great work in almost any rendering package.

2D Software

You should complement any good 3D system with 2D software that can create and manipulate texture maps, and composite together layers and render passes. You will find that a paint program such as Adobe Photoshop (which I have used in many texture-creation examples in this book) is useful, although free alternatives such as GIMP (www.gimp.org) or Paint.NET (www.getpaint.net) will also work just fine. You may also find a dedicated compositing program (such as The Foundry’s Nuke, eyeon Fusion, or Adobe After Effects) useful when you are compositing together render passes, although you can also do basic compositing in your paint program.
About This Edition

This is the third edition of the popular book *Digital Lighting & Rendering*. The first edition became the standard text on the art of 3D lighting and rendering, and introduced many artists to the field. Since it was published in 2000, it has met with great critical and commercial success. A second edition was released with major updates in 2006. I am sincerely grateful to each teacher who has chosen to use my book, everyone on the Internet who has posted a recommendation, and every artist who has shown my book to a friend or colleague.

Now I have written this new third edition to make sure that the book advances along with changes in technology, software, and the industry. A great deal has changed since the second edition.

I have added sections to cover new technologies and growing trends, such as physically based lights, physically based shaders, Ptex (per-face texturing), and unbiased rendering. In addition, there’s a new focus on the linear workflow, why you need one, and how to maintain it.

I’ve also updated several chapters to reflect how it’s becoming common to use global illumination in feature film lighting, as a part of your character lighting, and also to light environments and architecture. I’m not trying to force everyone to use global illumination for everything, though. I have also expanded the coverage of occlusion, using the occlusion sandwich technique, and more advanced approaches to occlusion passes.

I still cover old-school lighting techniques such as depth map shadows in this edition. Although depth map shadows are going out of style for many purposes, a lighting technical director should still know what they are good for, how to adjust them, and how to fix bias issues and light leaks. Though the third edition retains the same chapter organization as the second edition, it has grown longer in places and contains new sections on lighting atmosphere, participating media, and underwater scenes; new examples of compositing; expanded coverage of simulating natural light; and new character lighting situations. I’ve also included new sections on approaches lighting teams can use to work together in lighting feature films, the state of the computer graphics industry, and new advice for developing your show-reel and finding a job.
In computer graphics, we say our work is never really completed, only abandoned. Shots can always be better, and perfectionists can always find something to tweak and revise a little more—and of course it is the same with books. Crashing into a deadline is what finally forces us to let go of the projects we love. After releasing a book, being able to revisit and revise all the material again gives me great pleasure. It is with great pride that I abandon this new edition to you.

**Download Additional Files**

Throughout the book, you will find references to many of the 3D scenes used as examples. Feel free to download and experiment with those scenes for your own personal work. You can access them at www.3dRender.com.
Lighting Environments and Architecture

To light natural environments and architectural spaces, you need to be aware of the environment around you. Direct light from the sun, soft illumination from the sky, and indirect light blend their colors and tones in subtle ways. This chapter discusses how you can use these three elements to simulate natural light outdoors and indoors, by day or by night. Different kinds of artificial light, from flashlights to desk lamps to streetlights, require equal care to simulate realistic throw patterns and illumination in your scene. You can use atmosphere, from fog and dust in the air to thicker participating media for underwater scenes, to help convey how light
travels through space in your environment. Finally, with global illumination (GI) you can simulate how all of these lights are transmitted from one surface to another, filling your scene with indirectly bounced light. This chapter explores not just how to light with natural and artificial light sources, but how to simulate indirect lighting with or without GI.

Creating Daylight

You can create a simple outdoor lighting setup by adding three elements to your scene: direct sunlight; soft fill light representing light from the sky; and indirect light, simulating light that has bounced off of surfaces in your environment. When you put these three elements together, you can simulate outdoor light at any time of day. This section will explore these three elements and the choices you need to make when creating them.

Adding Sunlight

Think about your scene. What time of day is it? Is there direct sunlight? You’ll want to address the sun first, because the sun will be your key light—the most important, main light that defines your scene. If sunlight is visible at all, it is often the brightest light in your scene and tends to cast the most visible shadows. You determine the angle of the sun depending on the time of day you are trying to re-create, but remember that your audience doesn’t usually know whether the camera is facing east or west, so you have enormous creative latitude in picking an angle for the sun that lights your scene well.

Most of the time, you will use a directional light as the type of light source for the sun. Remember from Chapter 2 that a directional light casts all light and shadows in parallel, which is appropriate for sunlight. If you are using a directional light to cover a full scene with sunlight, you should probably use raytraced shadows to make sure that accurate shadows can be cast by everything in the scene.
Sunlight does not need any decay or attenuation based on distance. The light has already traveled about 150 million kilometers (93 million miles) from the sun to reach your scene, so it is unlikely to wear out appreciably in the last few meters.

Make the sun a yellow color for most of the day; turn it orange or red only during sunrise or sunset. If you test-render your scene with just the sunlight and no other lights, it will appear very yellow and stark, as in Figure 4.1. Before you add any other lights, make sure that you are completely happy with which areas of the scene are in sun and which aren’t. In this example, I pivoted the sun around until the statue’s head was lit by sunlight and the light came from the side, to bring out the shape of the face instead of flattening it with frontal lighting.

[Figure 4.1] Sunlight by itself looks yellow and is full of contrast. Here, the sun angle is adjusted to light the main subject well.
Adjusting Raytraced Shadows

The shadows from the sun are the most important shadows in an outdoor scene. Be sure to adjust and test-render the sun shadows, and make sure you like their shape and direction, before you move on to add any other lights.

Shadows from the sun are not completely sharp. Think of the sun as an area light that casts slightly soft shadows. The sun usually fills an area of about 1% of the sky around us, but the shadows from the sun can become considerably softer on a hazy day or around sunset, so you may use values between 1 and 5 degrees for the shadow's light angle.

It is best to leave the *shadow color* parameter of your sunlight set to pure black. You can add a blue cast to the shadow areas later, when you fill in the scene with skylight.

Using Depth Map Shadows

If you are using depth map shadows, you may need to approach setting up sunlight differently. In order to focus a depth map around an appropriate area, you may choose to use spotlights instead of a directional light.

If you use a spotlight to represent the sun, you need to translate the light a large distance away from the rest of the scene so that the shadows it casts will appear parallel. After you accomplish this, set the spotlight cone to a very narrow cone angle so that it only covers the area where its light and shadows are visible in the scene.

One advantage of this approach is that it is easy to aim cookies from a spotlight. If you want a cookie in the sun—to simulate dappled light shining through tree leaves, for example—you can aim and adjust that cookie by moving the light.

One spotlight might not be enough to cover a large area, however. Stretching a depth map over too broad an area can cause it to lose accuracy. If you want to work efficiently with depth maps in cases like this, sometimes you must represent the sun with an array of spotlights, and each must provide light and shadows to one region of the scene. Using multiple depth maps, each with a reasonable resolution such as 1024 or 2048, is usually more efficient than cranking up the depth map resolution above 4096 or 8192.
In some environments you may have no choice but to use depth maps. Complex elements such as grass, fur, or vegetation greatly add to render times and memory use if you try to render them in raytraced shadows. Depth maps can shadow this kind of subject matter more efficiently. Specialized types of depth maps in some renderers, such as the *deep shadow maps* in RenderMan and the *detail shadow maps* in Mental Ray, are optimized for shadowing fine details such as hair and grass.

### Adding Spill from the Sun

It is often a good idea to use a second light to represent the spill from the sun. After you have your main sunlight set up and you have test-rendered it to make sure you like what it illuminates and where it casts shadows, you can duplicate a second copy of the sunlight and rename it to become a spill light. Don’t rotate the spill light; leave it aimed the same direction as the main sunlight. Set the spill to have much softer shadows than the sunlight so that it spills out beyond the edge of the sunlight into shadow areas, and make the spill dimmer than the sunlight itself.

In some scenes, it is useful to give the spill a richly saturated color. Around sunset, the sun itself might be an ordinary yellow, but the spill could be a rich red or deep orange. In some midday scenes, the sun is so bright that it should appear overexposed and desaturated; in these cases your sun’s color might be a pale yellow or appear almost white. If you give the spill light a more saturated color than the sun itself, then the overall impression created by your scene will be that the sunlight has a warm tone.

Figure 4.2 compares the scene from Figure 4.1 with sunlight only (left), and with both sunlight and spill light together (right).

Visually, adding a spill light around the sun extends the sunlight into more angles and helps it wrap further around round objects. Because shadows get softer the farther they are cast from the subject, you can still have black shadows close to the objects that cast them, but shadows cast from more distant objects are more filled in. Overall, having spill light around the sun can add both richness and realism to your scene, compared to the starkness of having sunlight that is not visible at all beyond the edge of the shadows.
Adding Skylight

The soft blue light from the sky is another main aspect of your outdoor lighting. It helps to test-render the sky illumination by itself, with the sunlight and sun spill hidden, before you start to put them all together. A single dome light, as discussed in Chapter 2, is usually the best way to simulate sky illumination in an outdoor environment. The left side of Figure 4.3 shows the scene lit entirely by a dome light.

You can map the dome light with gradients to create shaping and variety in your sky illumination. Often a gradient runs from a lighter blue at the horizon up to a deeper, darker blue at the top of the sky. This simulates a bit of haze that makes the sky look brighter and less saturated near the horizon. Often you want a second gradient to run from the bright side of the sky (where the sun is) toward the darker side of the sky. This adds more variety to sky illumination.

In some programs, the sky dome is just the top half of a sphere and does not include the portion of the sphere that would be underground. In other programs, dome lights wrap all the way around your scene, with half of the dome below the ground. Because the ground shadows any illumination that comes from below it, the color of the bottom half of the sphere shouldn’t make a visible difference in your scene. However, you can map the bottom half of the dome to black to prevent potential light leaks if you have holes in your geometry, and possibly to save rendering time in some renderers in case the renderer is optimized to take more samples toward brighter parts of the dome light.
Including an Extra Kick from the Sky

Sometimes you can add more shaping to your scene by augmenting your sky illumination with an extra light. You can use a directional light, set up just like the spill light from the sun, or you can add a spotlight if you want to be able to aim it and focus it on one area. You might give this extra light a blue or gray color, matching whatever colors you see in the sky. This technique not only adds an extra kick of illumination that comes from the sky behind your subject, often on the opposite side from the sun, but it also adds variety and shaping to the side of a subject that isn’t lit by the sun and sun spill, as shown on the right side of Figure 4.3. Notice how the dark sides of the statue and columns are better defined when the kick is added.

Let’s make all of our lights visible now, as shown in Figure 4.4. We now have two directional lights in the same place for the sun and the sun spill (shown in the lower right), a dome light for the sky, and another directional light for a kick from the sky.
Adjusting Color Balance

In a sunlit scene, the warm color of the sun and the cool color of the sky should balance out so that they appear almost white where they overlap. Areas where the sun is blocked so that you see only skylight may look blue. If you render your scene with the sun and all of your skylights visible, you can see the overall color balance of your scene.

You might want a golden yellow overall tint for your scene for a late afternoon or sunset, or a blue tint for dusk or a gloomy overcast day. For a normal daylight balance, however, you don’t want your full scene to look blue tinted or yellow tinted overall. You may need to go back and adjust the sun’s brightness or color to achieve a natural-looking balance and make it cancel out the blue of the sky.

Figure 4.5 shows the result of rendering with the sun, the spill from the sun, and the sky illumination, all together. Although it still lacks the bounce light that will tie it together, you can see the overall daylight look already appearing in the image.

[Figure 4.5]
Sunlight and skylights are combined to create balanced daylight illumination.
Adding Indirect Light

The sunlight and skylights give you most of your illumination, but a realistic daylight scene also requires indirect or bounce light. Light that reflects off the ground and other surfaces back up into the scene is called indirect light because it doesn’t come directly from a light source. Where sunlight and skylight illuminate the ground and other surfaces in your scene, the brightly lit surfaces themselves need to act like light sources. If light has bounced off the ground, then in many scenes most of your indirect light is aimed upward from the ground, illuminating the bottom of other objects.

You have two basic choices for how to simulate indirect light in your scene. You can add your own bounce lights to simulate indirect illumination, or you can use GI to simulate indirect illumination for you. GI adds indirect illumination to your scene automatically, so you don’t need to add any more lights as bounce lights. However, this type of illumination also takes a lot longer to render, especially for scenes like this example that feature grass and vegetation. We’ll come back to GI later in this chapter. For now, the straightforward approach to simulating indirect illumination in this scene is to add some bounce light, aimed upward at the scene through the ground, as shown in Figure 4.6.
The bounce light makes the biggest difference on the bottoms of objects, brightening up the surfaces that face the ground. Figure 4.7 shows the difference that bounce light adds, if you compare the scene without bounce light to the scene with bounce light.

To simulate indirect light, you need to make some delicate adjustments:

- Most of the time, you should set bounce lights not to emit any specular illumination; you don’t want unmotivated specular highlights to appear on the bottom of objects.

- Give your bounce lights colors similar to whatever surface motivates the indirect light. For example, to simulate light reflected off of a green lawn, use a green light.

- To simulate light bouncing off of the ground, position your bounce lights underneath the ground, aimed upward. Use light linking or shadow linking to make sure the ground itself doesn’t shadow the light.

- Sometimes bounce lights don’t need to cast shadows. If your bounce light casts shadows, then the shadows should be very soft and indistinct. Check inside the mouths, noses, and ears of characters to make sure you don’t have unshadowed bounce light visibly shining through them.

- In most scenes, you need more than one bounce light, with different angles and different colors. Even if there’s only one ground color, you
can use different colors based on the colored lights that hit the ground. For example, if yellow sunlight and blue sky fill both illuminate the grass, then you can have a yellow-green light and a blue-green light bouncing back from the grass onto the rest of the scene.

- Whereas most bounce light in many scenes is light aimed upward, you can actually aim bounce lights in any direction. If bright light is aimed at a wall, you can add a bounce light simulating light bouncing off of that wall. If a floor lamp is aimed up at a ceiling, you can aim a bounce light from the ceiling down onto the rest of the scene.

Because bounce lights are dim and subtle, it’s usually a good idea to hide all of your other lights and test-render an image with only the bounce lights so that you can see that they uniformly cover the surfaces of your scene. Make sure you don’t see any harsh shadows or sharp highlights in your bounce lighting, because that would give away the illusion that it comes from indirect light reflecting off large surfaces.

Alternate Approaches

You can simulate sky illumination in three alternative ways in modern software: You can simulate the sky with an array of lights coming from different directions instead of using dome lights; you can use a unified sun and sky shader that is available in many programs; or you can use image-based lighting to illuminate the whole scene with a High Dynamic Range Image (HDRI).

Doing Without a Dome Light

If your renderer doesn’t support dome lights, or you want a solution that renders faster, use a set of multiple lights to simulate sky illumination.

Start with a directional light that casts very soft raytraced shadows (a light similar to your spill light), but give it a blue color. Test-render your scene and see how it looks with one skylight; then duplicate the light so that lights illuminate your scene from all directions. In an open scene you probably need between four and eight lights to represent fill from the whole sky. Figure 4.8 shows a collection of directional lights arranged to simulate sky illumination.
The lights don’t need to have the same brightness and color. You can vary the brightness and color of the lights so that the sun side of the sky is brighter, and the darker side of the sky is a more saturated blue. The lights don’t need to be spaced at equal angles, either. Adjust them however they look best in your particular scene. If you see any visible edges to shadows, use softer shadows, or add more directional lights from more angles, to fill in the unlit areas.

Unlike when you use a dome light, using an array of directional lights does not look very good on shiny or reflective objects. If you used six directional lights to simulate light from the sky, you don’t want six bright highlights to appear on each shiny object. If you have any shiny, reflective objects in your scene, your best bet is to set the lights not to emit specular illumination and then use a separate environment map for their reflections.

For the very cheapest results, you can use an array of spotlights with depth map shadows instead of directional lights with raytraced shadows. This may not look as natural as other approaches, especially for wide-open scenes surrounded by sky, but it can render very quickly without raytracing. And in situations where only a smaller amount of sky is visible, such as within a canyon, a few spotlights may be all you need to create some sky illumination.

Sun and Sky Shaders

Available at the click of a button in many programs, linked sun and sky shaders allow you to create a sunlight and sky fill all in one step. These shaders simulate many effects for you automatically. For example, when you move the sunlight lower in the sky, it automatically changes color to simulate the color of the setting sun, and the sky’s color and brightness changes to match it.

When choosing approaches to lighting, you need to think ahead, beyond the first version that you render. After you render version one, chances are that you will need to show your work to your client, creative lead, director, or art director. At that time, you will get notes on how to proceed to the
next version. Even if physically based sun and sky shaders saved you time on lighting the first version, they can sometimes limit your ability to adapt to art direction after that. For example, if you are asked to make the sun a little pinker as it sets, it’s easier to directly adjust the RGB color of a light than to look through options labeled “Turbidity” and “Ozone” and adjust them to see how the sun’s color happens to respond. Time saved up-front on an easy, preset setup does not always speed up your overall workflow in the long run.

**Image-Based Lighting**

*Image-based lighting (IBL)* provides an alternative approach to simulating sky-light. With IBL, you map an image to a sky dome surrounding the scene, and the colors and tones from that image are used to illuminate the scene. Figure 4.9 is a test-render of the scene lit only by a texture map of a sky and clouds.
When you use a High Dynamic Range Image (HDRI) format, all of the colors and tones from a real environment can be included in one map for IBL. A huge range of HDRI maps are available for free or for low prices over the Internet, or you can make your own. (Chapter 6 describes how to make your own HDRI.)

IBL holds the promise of great convenience and realism if you happen to have a texture map that perfectly matches the environment you are simulating. IBL also lets you use whatever map you make to represent the environment in reflections, potentially increasing the realism of any shiny or reflective objects in your scene.

In a few ways, it is possible to adjust the lighting on a scene lit by IBL: You can adjust the overall diffuse and specular brightness emitted from your dome light; you can rotate the whole map around to face a different way; you can adjust its overall tint; and you can add conventional lighting to it, aiming extra lights into the scene wherever the illumination from the IBL itself doesn’t meet your needs. However, lighting your whole scene based on a premade map is still creatively limiting compared to lighting your scene with fully adjustable individual lights. As with the sun and sky shaders described earlier, sometimes taking this approach makes it easy to create the first version of your lighting, but makes it more difficult to iterate your scene into different versions and adapt your lighting based on creative notes from the director or art director.

**Working with Indoor Natural Light**

Indoor light can be a mix of natural light that comes in through windows, doors, and skylights, and artificial light sources. The artificial light sources simulated in the scene are called *practical lights*, and those are discussed in the next section. As a first step in moving indoors, start with the natural light—including sunlight, skylight, and indirect light—which you can add to interior scenes in almost the same way as you did outdoors.

**Adding Skylight**

When adding natural light to an indoor environment, it sometimes makes sense to start with the light from the sky rather than the sun. Sometimes
you see a sunbeam coming through a window, other times you don’t. Direct sunlight only enters a window when it happens to come from the correct angle. Skylight, on the other hand, always enters through every window, as long as it is daylight outside and you can see out the window.

As it was when we were working with lighting outdoors, sky illumination is a broad, soft light that simulates all of the light coming from every visible part of the sky. It is possible (but not efficient) to put a full sky dome outside of your 3D building and let some of the light from that dome enter through the window; however, this approach can lead to very slow render times, because light from every possible direction is computed, even when most of the sky dome is not visible through the window.

**Area Lights in the Windows**

Area lights aligned with a window are often the most natural way to simulate sky illumination coming inside. Place a rectangular area light just outside of a window, door, or skylight, and give it a color matching the sky. Of course, if the window is round, you can use a disc-shaped area light, and you can use multiple area lights for more complex groups of windows.

If a background image is visible through the window, then use the color of the sky visible outside to guide the color of your area light. If the outdoor area is a 3D scene, use the color from the outdoor sky fill for the area light in your window.

Some renderers have a special kind of area light called a *portal light*, which is like a regular area light except that it gets the brightness and color from a corresponding sky dome that surrounds the scene. A portal light simulates getting light and color from a sky dome without the inefficiency associated with sampling a full sky dome when only a tiny part of the dome is visible.

Even if you only have one window in the scene, it’s OK to use more than one light to simulate skylight from that window. A rectangular area light, matching the shape of the window, is technically a good fit, but sometimes you want to use more lights to help fill more of the room with soft illumination. A spherical area light can create a nice, soft ball of light, emitting soft illumination from just outside the window. In the example kitchen scene, two windows are side by side, so two spherical area lights have been added outside the window, as shown in Figure 4.10.
The spherical area lights in this window overlap with the rectangular area light, and they are partially inside the room to help the fill light spill out to a broader angle. Figure 4.11 shows what the window fill looks like from the rectangular area light by itself (left) compared to how the scene looks with the spherical area lights extending the sky illumination (right).

Rectangular area lights in each window (left) simulate sky illumination around the window, but adding the spherical area lights (right) extends the illumination to fill more of the scene.
Usually it’s best to test-render the skylights without any GI activated. The scene will have high contrast but images can render faster, and such an image shows you what the sky fill looks like by itself, without any light in the scene. You may come across exceptions to this rule if a technical option on the area light or portal light requires GI to be turned on, but in general it’s best to get a clear look at what the light does by itself when you are first setting it up.

Check the area immediately around the window and make sure surfaces near the window appear to be convincingly lit by the window light. The light should spill out into the room so that any surfaces immediately above, below, or beside the window receive some light from outdoors.

**Excluding Window Geometry**

If you have a 3D model of glass in the window, then use light linking to remove the glass from your lights. Otherwise a light very close to the glass itself or intersecting with the glass might create unnatural highlights on the glass, or the glass might block or shadow the light.

You can sometimes use shadow linking to remove thin pieces of geometry in the window itself (such as window frames, bars on the window, or blinds) from the fill light’s shadow. When a soft area light illuminates the whole room, the shadow of a thin bar on the window spreads out so that it no longer looks like a shadow of a bar; instead it just creates extra noise in the area light, and can require more shadow samples if it isn’t removed from the shadow completely.

You may wish to set the clear glass in the window so it does not to cast any shadows. You should not do the same thing for window frames or other opaque geometry, however. Even if you prevent this geometry from casting shadows in the sky fill, you still want it to be able to cast shadows in a sunbeam if sunlight enters the window.

**Adding Sunlight**

Check your background image (or whatever you see through the window) to see what direction the sun seems to be coming from and if it’s sunny outside. Windows don’t always have a sunbeam, especially if the sun is coming from the other side of the building.
Create a bright, warm directional light, just as you did for sunlight outside. If you don’t want to use a directional light, a spherical or disk-shaped area light can work just as well, but make sure to position it far away from the window to achieve the kind of distant perspective that people expect from sunlight. Test-render your scene to see where the sunbeam is cast into your room, and rotate or move the light until it hits where you want. Figure 4.12 shows the room with a sunbeam added.

[Figure 4.12]
A directional light adds a sunbeam to the room.

Adding Spill Light
The sunlight shouldn’t cut off completely at the edge of the sunbeam. Just like when you were working outside, the spill light should be outside the sunbeam, simulating the extra light that comes from the bright parts of the sky around the sun itself. Figure 4.13 shows the difference that spill light can make.
If you are using a directional light for your sun, then to create a spill light, you only need to duplicate the directional light, modify the shadows to be much softer, and reduce the intensity of the light. Often it looks good to use a rich, saturated color (more saturated than the sunlight itself) for the spill from the sun.

**Adding Indirect Light**

When light hits each surface in your interior scene, any brightly lit surface essentially functions as a light source, illuminating other objects with indirect light that has reflected off of it. The floor, the walls, and certainly any object hit by a sunbeam motivate indirect light that needs to illuminate the rest of the scene.

**Adding Global Illumination**

By far the easiest and most realistic way to render indirect light indoors is by using global illumination (GI). Turning on GI in your renderer allows the color and brightness of each surface in your scene to help illuminate other surfaces around it; this gives you naturalistic results without your having to work to set up extra lights to simulate indirect light.

Figure 4.14 shows the difference that GI makes to the scene. Using only the sky fill, sunlight, and sun spill lights coming through the window, GI extends the natural light from the window to fill the entire room.
[Figure 4.14]
The sunlight and skylights through the window (top) are augmented by indirect light bounces (bottom) when global illumination is turned on.
When you turn on GI, it is not just another source of fill light. When you activate global illumination or indirect illumination in your renderer, you are fundamentally changing how the lighting in your scene works.

Consider a test scene illuminated by a single light source, as shown in Figure 4.15. Without GI, surfaces are only lit by the light source itself. Parts of the scene that don’t directly face the light remain black.

Figure 4.16 shows the same scene rendered with GI. When you use GI, surfaces are lit by other surfaces. One brightly lit surface can indirectly brighten other surfaces that face it. This is why shadow areas of the scene are brightened and filled in.
One nice feature you can achieve through GI is secondary levels of shadowing, where shadows are created even within other shadows. Look at the three balls in Figures 4.16. Without GI, there you would have only a single level of shadowing, and the balls would be hidden in the shadows cast by the cubes. With GI, you get secondary shadowing, even though the scene only has one light. Not only do the indirect light bounces make the balls visible, they also provide secondary shadowing, casting soft shadows from the balls onto the floor.

Also notice the colors of light that illuminate the three balls: The first ball appears red because of the light that has bounced off of the red wall; the second ball appears green because of light that has bounced off the two green cubes; and the third ball appears blue from the light that has bounced off the blue wall. This feature of GI, the way the indirect light picks up the colors of surfaces that it bounces off of, is called color bleeding.

One area where you can inspect any architectural rendering for quality is in the corners, where two walls meet, or where a wall meets the floor or the ceiling.
Corners are the areas where light most closely inter-reflects between walls. As a result, your scene should show continuity at the corners—a continuation of tones from one wall to another, rather than a sudden jump in brightness. GI tends to provide this, so that you can see a smooth, continuous sharing of illumination where two walls meet. When you are lighting without GI, even if you add extra bounce lights to the scene, you need to put in a lot of effort to achieve really convincing corners.

We use the term local illumination to describe rendering without GI, and call GI global illumination, which refers to how many other surfaces in the scene are taken into account when a surface’s illumination is rendered. Without GI, each surface is rendered by itself; this process takes the light sources into account but not the brightness of nearby objects. With GI, illumination is computed taking all the geometry in the scene into account, so light hitting any surface may indirectly brighten other surfaces in the scene. The inclusion of all the geometry in the scene is what gives the “global” perspective to the illumination process.

GI rendering allows indirect light to contribute to diffuse illumination. In other words, GI can indirectly brighten even matte-finished surfaces—surfaces that are not shiny or reflective. With GI turned off, you can still use conventional raytraced reflections for reflective objects, but raytraced reflections by themselves don’t transport light from diffuse surfaces to other diffuse surfaces. Only GI gives you true diffuse-to-diffuse light transport. Only GI allows any brightly lit surface to brighten other objects, not just as a reflection but as a light source.

The idea that reflected, indirect light can function as a light source is something that GI lighting has in common with live-action filmmaking. Especially when working outdoors, where bounced sunlight can be a brighter light source than many types of artificial light, filmmakers often use bounce cards or reflectors to light their

[Figure 4.17] Reflectors are used to bounce light onto actors or sets.
Digital Lighting and Rendering

scenes, instead of doing all of their lighting with lights. On a sunny day, reflectors, as shown in Figure 4.17, can provide all of the fill light filmmakers need when filming scenes outdoors.

Chapter 9 will come back to global illumination to discuss the different types of GI algorithms that your software may support. Although these algorithms can add to the quality of your imagery and may save you many hours of work as a lighting artist, they all come at the expense of slower overall rendering times. As computers get faster and software becomes more advanced and efficient, there are fewer and fewer reasons to render architectural interiors or realistic indoor scenes without using GI. However, for some extremely complex scenes, short-deadline projects, and some types of subject matter—such as hair, fur, grass, and vegetation, which are difficult to include in a full GI solution—the limited nature of rendering time still makes some people work without GI.

**Working Without GI**

If you want to simulate indirect light without using GI, often the easiest starting point is the *occlusion sandwich* approach, which was discussed in Chapter 3.

Figure 4.18 shows a fill light layer that includes two light colors: Blue light is coming from the window area and warmer light is coming from inside the room where the sunbeam would be hitting.

The fill light layer is a great place to add bounce lighting, because it does not need to include shadows. The occlusion layer adds shading later, but for this layer you can use area lights positioned outside each wall to light the scene. A blue area light is positioned outside of the window and warm colored lights illuminate the scene from other directions. The bright area where the sunbeam hits the table and walls motivates extra bounce light, so extra area lights are added coming from those parts of the scene. Figure 4.19 shows the area lights used in rendering the fill layer.
A fill light pass is evenly lit, but it does feature some color variation.

Area lights from every major surface are used to illuminate the fill pass.
As a quality-control check on your fill light layer, take a look at the corners where two walls meet, or where the walls meet the ceiling or floor. The illumination on the different surfaces should be roughly equal, without any big jump in brightness between the connected surfaces. Although some variation in color and tone is good, the fill light pass should be smoothly, evenly lit, without any high-contrast jumps in the brightness.

Also check your fill light layer to make sure no noticeable specular highlights or extremely bright spots are in the scene. By using broad, soft area lights as fills instead of tiny point-source lights, you help avoid unmotivated highlights that come from what should be bounce light from a wall. The fill layer also should not have any completely black areas unless you are sure an area in your scene would receive absolutely no fill or bounce light.

The middle layer in the occlusion sandwich is the occlusion pass of the room, as shown in Figure 4.20. Note that corners are softly darkened, and alcoves, such as the area under the upper cabinets, go much darker. This shading helps your bounce lighting look more like real global illumination.
We already have the lights that go into the key layer of the occlusion sandwich. We render an image lit by the sunlight, sun spill, and sky fill lights, all as described earlier. The result still has dark areas because of the lack of GI, but otherwise it should be a fully lit scene, as shown in Figure 4.21.

Assemble the occlusion sandwich in your compositing software or a paint program starting with the fill layer as the base. *Multiply* the occlusion layer and then *add* the key layer on top. Figure 4.22 shows the occlusion sandwich assembled in Photoshop.

The result is shown in Figure 4.23. Although it might not match the output with global illumination, it gets pretty close, and the scene can be rendered much more quickly.
Practical Lights

Practical lights are the light sources that are visible as models within your scene. Indoor examples of practical lights include lamps, light fixtures, television sets, or any other model you’ve built that emits light. Outdoors, practical lights include street lamps, vehicle headlights and taillights, illuminated signs, and lights on buildings.

There are two different aspects to simulating the illumination from a practical light. You need to light the source itself (such as the actual lamp or lightbulb), and then you need to light the surrounding set as if the lamp is casting illumination into the scene.

Lighting the Light

If you want to illuminate a bulb model using a light, you can position a point light in the middle of it where a filament would be located, and give
the outside of the bulb a translucent shader that gets brighter when backlit by the interior light source. As discussed in Chapter 2, inverse square (also called a quadratic decay rate) is the most physically correct setting for a light. To get realistic variation in brightness across the bulb’s surface, give the light source inverse square attenuation.

As an alternative to adding a light within the bulb, you can shade 3D models of lightbulbs with a luminosity, ambient, or incandescence map so that they appear bright without regard to the local lighting. The real drawback to adjusting the shader to make the bulb bright is that when you try to isolate your lights and render with only a single light visible, the glowing shader is still present, even when lights around it are hidden. Bulbs need to be texture mapped if they are to be seen up close. A lit bulb may have a bright middle area, but it can become less bright where the glass is attached to the metal base and near the top, as shown in Figure 4.24.

The immediate area around a light source often requires some dedicated lighting. For example, a lamp surrounded by a lamp shade receives a great deal of bounce light as light is reflected off the interior of the shade. With GI you can allow the lamp shade to bounce light back onto the lamp, or you can add bounce lights to illuminate the lamp itself with simulated indirect illumination.

If you are positioning any light inside a 3D model of a lightbulb and that light casts shadows, then you may want to unlink the light from the bulb model so that it can shine through the bulb and illuminate the surrounding area. Otherwise the bulb model may cast a shadow that effectively blocks any of the light from reaching the rest of the scene.

**Set Lighting from Practical Lights**

Just because you are simulating a single practical light source doesn’t mean that you need to light it with a single light in 3D. Often you will observe several different effects on the set from a single practical light and use a light in 3D for each of these effects. For example, the lamp in Figure 4.25 emits a soft glow through the shade, a cone of light aimed up through the top of the shade, and a cone of light aimed down from the bottom. You simulate this using a point light that shines out through the shade, plus spotlights aimed upward and downward to simulate the upward and downward cones.
Adding Spill

Often, projecting one spotlight in a particular direction isn’t enough. You usually see a broader, dimmer cone of light around the main light source, which is a kind of spill light. For example, if you use one spotlight for the illumination cast upward from a lamp, you may need another spotlight, with a broader cone angle and a much dimmer intensity, to add a spill around the area. Figure 4.26 shows how the lighting in Figure 4.25 was created: Two spotlights aim upward and two aim downward, including the main cones and the outer spill lights. The outer spill lights can simulate light that bounces off the lamp shade instead of being aimed directly from the bulb.
Lighting Larger Areas

When you want to add illumination to larger areas of your set, sometimes individual lightbulbs in a light fixture just aren’t enough. For example, suppose you have a chandelier in the middle of a room. It may have many individual bulbs within it, and you need one practical light for each bulb in the chandelier. However, turning up the brightness of these lights too high can spread hard-edged shadows all over the set and cause bright highlights on any surface that is shiny or reflective. Instead, you can create a softer type of light motivated by the chandelier, as shown in Figure 4.27, by adding a larger spherical area light above the chandelier.

You can use shadow linking to prevent the ceiling, and the chandelier itself, from casting shadows in the large area light. This way, the area light fills the room with soft, even illumination, without lots of noise from sampling soft shadows through the complex geometry of the chandelier.
Throw Patterns

The *throw pattern* is the shape or texture of the light that is cast into the scene from a light source. We can recognize distinctive throw patterns from car headlights, flashlights, burning torches, and many other light sources. In real life, often a complex throw pattern is caused by reflection or blocking by structural elements within the light fixture. Figure 4.28 shows a throw pattern cast by a flashlight. Interestingly, when you study different flashlight throw patterns, you see that no two models of flashlight cast exactly the same pattern into the scene.

In 3D graphics, you can create throw patterns by applying a cookie or map on the light source. If you use an image such as Figure 4.28 as a cookie on a light, it will help simulate a flashlight’s beam as well as its outer spill light both from the same spotlight. Another way to simulate different throw patterns is to model geometry around the light source. The shape of the geometry can cast a shadow, or the geometry can be transparency-mapped with an image, creating an effect very similar to a cookie directly mapped onto the light.

You can also use a cookie to tint the edges of a spotlight’s beam. In many real spotlights, a more saturated or reddish tint appears near the edge of the beam, just before it falls off to black. A cookie with a reddish edge can help simulate this and make softer, more naturalistic throw patterns for your spotlights. If all you want out of a cookie is to tint the outer edges of a spotlight, then you can also use a procedural ramp or gradient texture, and you don’t even need to paint a map.

Any time you are tempted to aim a spotlight into your scene and have it add just a plain circle of light, stop and think whether a more complex throw pattern could be more natural looking.
Night Scenes

You can create night scenes by combining techniques I have described so far in this chapter. You can create natural light coming from the moon and night sky using the same basic principles as with daylight, with just a few modifications. Practical lights, such as streetlights, light from buildings, and car headlights, also add to most nighttime scenes.

You can create light from the moon the same way you did for the sun. Usually light from the moon appears much dimmer than other lights such as streetlights. Only when you get far away from cities and towns does the moon start to become a dominant light source like the sun. Moonlight can appear either blue or yellow. Most often it appears yellow in scenes where light comes only from the moon and the night sky. If you see moonlight in addition to light from lightbulbs, the moonlight appears bluer.

At night, usually light from the sky should be a very soft blue glow. As with light from the moon, you don’t want the sky to appear too bright. In cities or indoor scenes, natural light can disappear, and many night scenes are lit entirely by practical lights. At nighttime, even light coming in through a window is as likely to be light from a streetlight or car headlight as it is to be natural light.

The key to lighting night scenes is not to underexpose the entire scene, but to use a lot of contrast. The scene may be dominated by shadows, but you need to break up the darkness with bright highlights and selectively apply rims and glints of light.

You may have noticed that many night scenes in Hollywood movies feature wet pavement, making them look as if it has just rained. This is often the case even in dry cities like Las Vegas. Cinematographers are always looking for ways to capture extra glints of light and reflections in their night scenes. Since they have discovered that spraying water on the streets is a great way to get the city lights to reflect off the street, and since this makes prettier night scenes with more highlights in them, they do this even when it is obviously a cheat.
If you have any surface in your scene that can be reflective, feel free to use it wherever you need more contrast or visual interest. In Figure 4.29, for example, I added an extra light to the porch in the background. I set it to emit specular only and linked it to the street itself, so that it makes the street glisten without adding brightness to the surrounding buildings. I also used light linking to add a light that exclusively illuminates the hanging cables. These extra glints of light create interesting lines and contrast, even within a scene that is made up mostly of dark tones.

Distance and Depth

You can divide up space and show distance with your lighting in many ways. Instead of lighting all parts of a natural environment uniformly, you can depict natural variation in color and tone that exist in different parts of a scene.
Dividing Up Space

Many scenes let you look through a door or stairway so you can view more than one room, area, or floor of a building. Each area of a scene like this can have different lighting. If one room has a window that lets in daylight and another room is lit by a lamp or a ceiling light, then you’d expect the room lit by daylight to be brighter and have cooler, more blue-colored light, whereas the room lit by the ceiling light would appear less bright but have warmer colored illumination, as shown in Figure 4.30.

Even within a room, corners can receive different light than the middle of the room, or there can be a transition of color and brightness between the area around a window and the parts of the room farther from the window.

If you can create a distinction between areas that are in direct sunlight and areas that are in the shade, then that’s another good way to divide up your scene. Indoors, parts of your scene can be in a sunbeam while other parts are outside of it. Often, a scene split between sunlight and shade serves to
highlight the objects or characters that appear in the sunlight, but this isn’t always true. It’s possible to have a central subject that stands prominently, entirely in the shade, and have it set apart from a brightly overexposed background that is in direct sunlight. No matter where your center of attention is positioned, it’s the contrast between the subject and the background that helps it pop out.

Even small differences between rooms—such as differently adjusted blinds or shades on the windows, or different color curtains or walls can lead to differences in the lighting in different rooms. Although light can flow through doors, windows, and stairways within your scene, the light cast through an opening only lights one part of a room, and where a scene is divided into different spaces you always have the opportunity to vary your lighting.

**Defining Depth with Lighting**

When designing the lighting for any larger set, you need to choose a strategy for how to portray the distance as you head away from the camera, into the background. Many approaches are possible: You can move from a bright foreground to a dark background, you can have a dark foreground and a bright background, you can alternate light-dark-light, or you can separate areas with color. Different designs work for different spaces. The important part of this issue is that you are creating a two-dimensional image that needs to depict three-dimensional space, so your viewers are able to see the difference between things that are close to camera and things that are farther away.

Figure 4.31 starts with a simple version of this: It has a bright, colorful foreground area, full of warm light, and a background that gets darker and uses cooler, blue tones.

In Figure 4.31, the background itself is broken up into different regions. Although the whole background is dominated by blues and cool tones, the middle hallway is lit from above, with light coming down through a fan, whereas the far background is less saturated, with more blue-colored instrument lights.
Whenever the background is a different color from the foreground, or you have bright light visible in the background, you can think about adding some rim light to the subjects in the foreground motivated by the background light. A few highlights or some rim light that match the background color can help tie together the background and foreground. In this case, the blue rim light along the robot’s back also helps separate the robot from the darker background area behind it.

In real cinematography (unlike computer graphics) the camera is a physical object that can cast a shadow. Because of this, objects often appear darker when they get extremely close to the camera. For example, if a door...
is opened or closed in the foreground, the door itself often looks very dark when it shuts into a position near the camera, as if the scene itself were being wiped to black. Or if a ball is thrown directly at the camera, the ball becomes darker as it reaches the camera and fills the frame. You can avoid this effect in real cinematography in several ways (you can attach a ring light to the camera lens, brightening what’s right in front of the camera, for instance), but the convention of objects in the foreground becoming darker, or turning into silhouettes, is seen in many films.

Adding Atmosphere
Atmosphere plays a role in many scenes, tinting and changing the appearance of more distant objects. In any situation in which it might be appropriate, you should look for a chance to use atmosphere to add variation with distance.

• Dust adds to the atmosphere of many outdoor environments and sometimes is visible in the air indoors in barns or old buildings.

• Any room with smoke in it, including rooms lit by torches or candles or places where people smoke or burn incense, can have a lot of visible atmosphere.

• Underwater scenes are essentially scenes with a lot of atmosphere that tints and desaturates and causes distant objects to fade away.

• Almost all outdoor scenes, if you can see all the way to a distant horizon or distant hills, have atmospheric perspective that shifts the more distant parts of the scene into a bluer, less saturated tone, as shown in Figure 4.32.

• Many kinds of weather conditions make the atmosphere more visible. Rain adds the drops themselves, plus extra mist and fog as well. Snow in the air also creates atmospheric perspective as distant objects become whiter.

• Even depictions of outer space sometimes have something like an atmosphere, in the sense that dust particles or the emissions from a rocket can float in space in between the objects in your scene.
Modern rendering software offers you a whole range of different approaches for adding atmosphere to your scenes.

One simple, but somewhat limited, option is to turn on a fog effect from an individual light. This allows you to create a visible light beam easily, such as a beam of light coming through a window. However, it can sometimes look unrealistic because in real life, atmosphere tends to be spread through an entire room so that areas in the light or not in the light are all filled with the same amount of dust or smoke. If you set individual lights to emit visible fog effects, then you should also think about adding an overall atmosphere to the whole room, including the areas outside of the light beam.

An efficient approach to adding overall atmosphere to a scene is covered in more detail in Chapter 11. If you render a depth pass of your scene, which shows the distance from the camera to each object, then the compositor can use that information to tint, desaturate, or soften distant parts of the scene. This approach lets you simulate the overall look of atmospheric perspective in your scene, although it doesn’t visibly respond to each light.
For atmosphere that responds realistically to each light, by forming visibly brighter areas or light beams in the air wherever the light is brightest, you can apply \textit{volumetric fog} shaders, which are available in many programs. Volumetric fog makes the air (or water) in your scene respond realistically to light so that shafts of light or visible light beams can form where light and shadows cut through space, as shown in Figure 4.33. Using volumetric fog can add greatly to your rendering time, but the results often look much more realistic than what you can create in compositing software from an overall depth pass.

Finally, moving into a full particle simulation within your environment is an option that can simulate not only the presence of atmosphere, but also the movement of smoke or dust through the scene, as it responds to wind or character movements. When you fill a dusty barn with a particle system of floating bits of dust, you give a tremendous boost to the dimensionality and realism of the overall space, and you also add to the overall effect of fading out and desaturating more distant surfaces.

\textbf{Figure 4.33}
Volumetric fog makes light filtered through stained glass windows visible in the air. This scene is Lighting Challenge #8, modeled by Dan Wade, concept by Gary Tonge.
You can render using a depth of field (DOF) effect that simulates selective camera focus to complement and enhance the effects of atmospheric perspective while diffusing more distant objects and drawing our attention to the foreground (or to whatever object is in focus). If your final scene will be rendered with DOF, then it’s a good idea to turn it on when you test your atmospheric effects, because the two effects work together to create the final look of your scene.

**Going Underwater**

Being underwater is like having a very thick "atmosphere" around you. Even though we are trying to simulate water instead of air in this section, we can apply all of the same rendering techniques to create an underwater environment. Some computer scientists use the term *participating media* instead of *atmosphere* to describe whatever gas, liquid, or solid particles fill space in the scene and influence and respond to illumination.

You begin creating an underwater scene just as if it is above water. Add a directional light to simulate the sun. In a shallow pond or a swimming pool, you might need some fill light from the sky as well, although deeper in the water this might not be necessary. You can aim a bounce light upward to simulate light bouncing off the bottom of the pond to illuminate the bottom of objects. Figure 4.34 shows the humble beginnings of an underwater scene that still looks as if it is above water.

When we look out into an underwater landscape, the entire surface of the water looks just like a rippling mirror above us. Even if you make the water surface both transparent and reflective, giving it a realistic index of refraction of about 0.75 causes it to show mostly reflections. Only one area of the water surface above us, called Snell’s Window, lets us see through to the sky and the world above the water.

The sunlight in such a scene should appear dappled, as if it is refracted caustics that have passed through the water surface. Although it might be possible to render this in a physically correct manner, you can save time by applying a cookie to the sunlight instead. If you want the sun to appear dappled below the water but not to appear dappled above the water, then you can transparency-map the caustic texture pattern onto a plane at the level of the water surface, and you can set that plane so it casts shadows but is not directly visible in the rendering.
Figure 4.35 shows the scene with the water surface above and the dappled effect on the key light. However, it still doesn’t appear to be underwater. What’s missing is the atmosphere.

You can use a volumetric fog shader contained within a cube that fills the entire underwater area to add the atmosphere that really makes it look as if we are underwater, as shown in Figure 4.36. You need to tweak this to make sure the fog color (or scatter color) is bright enough to respond to light, which creates shafts of light where the dappled sunlight comes through the scene, and to make sure the shader absorbs light or darkens with distance enough so that the more distant parts of the water fade naturally and don’t become too white. The best approach to this process is to set the resolution of your scene very low, with very low anti-aliasing quality and low quality for volumetric rendering; then you render small postage stamp–sized tests until you get the overall colors and brightness right. At this stage, the fill light can be turned down if you want to focus on the shafts of light from the key, or you can turn it up if you can’t see enough of the foreground. Only once you like the overall colors and tones in the scene should you move into higher-resolution renderings.
Adding a reflective water surface and dappled light gets this scene closer, but an essential ingredient is still missing.

Adding atmosphere (or participating media) to the scene creates the impression of being underwater.
You can add a whole range of different effects beyond this. Sometimes you can use particles to simulate dirt and debris in the water, or add bubbles that float upward. Sometimes you can add pieces of sediment as individual polygons with transparency-mapped textures, thus scattering organic detail through the space.

In a pond, you don’t want the view through the water to be too clear. Although the compositor can achieve other effects (blurring based on distance, or blurring what is seen through floating particles or bubbles), using DOF on your camera also helps blur the background and add realism to an underwater scene, as shown in Figure 4.37.

[Figure 4.37]
Rendering with DOF nicely complements the underwater effect.
Exercises

There’s no shortage of interesting environments to light and interesting ways to light them. I used several of the Lighting Challenge scenes as examples in this chapter, and most of them can give you experience lighting interior or exterior environments. Try to collect reference images that show a similar interior or exterior space at a similar time of day or night, and study the lighting in your reference image as you light the scene.

1. Between 1888 and 1891, Claude Monet painted image after image of haystacks. He captured the same subject over and over, in different times of day and in different seasons; he captured different lighting and colors each time he went back into the fields. If you’re looking for exercises to improve your skills and your portfolio, don’t be afraid to relight the same scene several times. Imagine what it would look like at night, early in the morning, or on a foggy day, and relight and rerender the scene.

2. Ambient occlusion is not dead. Some people are so accustomed to using GI that they already regard occlusion passes as a thing of the past. In reality, you will come across many situations in which you might need a faster technique than full GI. If you’ve never tried the approach that I call the “occlusion sandwich,” try using it and see how you like the workflow.

3. Volumetric fog (also called volume shaders or environment fog) is a useful tool that’s tricky to set up and adjust well in a lot of renderers. If you haven’t done so before, then use your favorite rendering software to try to fill a scene with a fog or haze that responds to light.
Index

In this index, the page numbers for Chapter 10 begin with “10:” and pages are numbered sequentially for that chapter.

Numbers
1.33 aspect ratio, 259–260, 262–263
1.66 aspect ratio, 259, 262
1.78 aspect ratio, 259, 261
1.85 aspect ratio (widescreen), 259, 261–262
2D
casting into 3D space. see Projections
paint program for creating texture maps, 10:25–10:26
procedural textures, 10:51
2.35 aspect ratio, 259–262
3:2 pulldown, 222
3D
building 3D models, 422
casting 2D into 3D space. see Projections
cheating in, 5–9
paint program for creating texture maps, 10:25
pass management software, 399
procedural textures (solid textures), 10:51
reference spheres, 401–402
sculpting tools, 422
surfaces. see Texture maps
texture map resolution and, 10:49–10:50
3ds Max, shadows-only light, 69
8-bit color, 302
16-bit color, 302–303
32-bit color. see HDRIs (High Dynamic Range Images)
35 millimeter film, 260
180-degree rule, for camera angle, 245

A
Acceleration structures, retracing, 332
Adaptive oversampling, 327–328
Additive color, 278–280. see also RGB (red, green, blue)
Adobe After Effects. see After Effects
Adobe Photoshop. see Photoshop
After Effects
color management, 405
compositing with straight alpha channels, 375
noise reduction filters, 214
rendering with, 362
viewing alpha channels, 372
Algorithms
for calculating shadows, 73
for rendering. see Rendering software and algorithms
Alpha channels
adjusting contrast thresholds, 328–329
compositing with premultiplied alpha channels, 376–378
compositing with straight alpha channels, 374–376
layering and, 10:39
matte objects and, 367
rendering issues, 372–374
working with digital color, 302
Alpha mapping, 10:10–10:11
Alpha passes. see Mask passes, in rendering
Ambience mapping, 10:7–10:9
Ambient (color) rendering passes, 386–389
Ambient light, 38–39
Ambient occlusion, 91–92
Ambient shade option, from Maya, 39
American Standards Association (ASA), 222
Anamorphic lens, for 2.35 aspect ratio, 260
Angles
camera angles. see Camera angles
controlling spotlights, 26–27
increasing dramatic impact, 188
occlusion and spread or sampling angle, 94
shadows revealing alternate, 57–58
for soft raytraced shadows, 88
Animated feature
layout of, 414–415
planning, 412
storyboard for, 412–414
visualizing production pipeline for, 434
Animation
character animation, 427
illuminating characters. see Character illumination
procedural textures and, 10:51
setting keyframes for focal distance, 206
when to applying lighting to project, 21
Anisotropic highlights, 321–322
Anisotropic shading, 321–322
Anti-aliasing
filtering, 329
oversampling, 326–329
overview of, 325–326
rendering at higher resolution to achieve good, 330
undersampling, 326–329
Aperture of lens, 202. see also F-stops
Aperture priority, 223
Aperture ring, on cameras, 203
Area lights
indirect light without global illumination, 135
lighting large areas, 141
in simulation of sky illumination, 125–127
for soft raytraced shadows, 87
types of lights, 32–34
Art department, 420–423
Art directors, 422
Art work, basing scene lighting on, 20
Artifacts, depth map bias and, 77–78
ASA (American Standards Association), 222
Aspect ratios, 259
Atmosphere (participating media)
creating with lighting, 148–151
underwater effect, 151–154
Attenuation. see Decay
B
Background, rendering in layers and, 363–364
Background plates
light probe images, 403–404
matching live action to, 399–400
matte balls as reference object, 400–401
mirror balls as reference object, 402–403
other approaches to matching lighting, 404–405
reference objects in, 400
starting creative process and, 20
Baking
procedural textures into maps, 10:53–54
shadows and occlusion, 104–106
Banding problem, 8-bit and 16-bit color and, 302
Barn doors, spotlight options, 28–29
Barrel distortion, in camera lens, 230, 232
Beauty rendering passes, 391–392
Bidirectional path tracing, 351
Bidirectional reflectance distribution function (BRDF), 323–324
Bidirectional surface scattering reflectance distribution function (BSSRDF), 324
Black and white images, tinting, 293
Blooms (glows), rendering in layers, 369–372
Blue. see RGB (red, green, blue)
Blur. see Motion blur
Bokeh effects
   camera lens and, 209–212
   computational expense of, 213–214
   with Photoshop, 369
Bounce lights. see also Indirect lighting following character movement, 185–186
   functions of, 173–175
Bracketing approach, to exposure, 229–230
BRDF (bidirectional reflectance distribution function), 323–324
Breaking the 180, camera angles and, 245
Brightness
   of area lights, 32
   EV (Exposure Value) in calculating, 228
   key-to-fill ratio and, 166
   physically based lights and, 35–36
   qualities of light, 4
BSSRDF (bidirectional surface scattering reflectance distribution function), 324
Buckets, of pixels, 342
Bump first strategy, for painting texture
   following character movement, 185–186
   functions of, 173–175
Bracketing approach, to exposure, 229–230
BRDF (bidirectional reflectance distribution function), 323–324
Breaking the 180, camera angles and, 245
Brightness
   of area lights, 32
   EV (Exposure Value) in calculating, 228
   key-to-fill ratio and, 166
   physically based lights and, 35–36
   qualities of light, 4
BSSRDF (bidirectional surface scattering reflectance distribution function), 324
Buckets, of pixels, 342
Bump first strategy, for painting texture maps, 10:42
Bump mapping, 10:13–10:15

C
Camera angles
   high-angle and low-angle shots, 249
   line of action, 245–246
   motivation for camera moves, 251–252
natural camera moves, 252–253
   overview of, 244
perspective and, 246–249
shutter angle, 215–216
types of camera moves, 250–251
Camera moves
   motivation for, 251–252
   naturalness of, 252–253
types of, 250–251
Camera projections, 10:23–10:24
Cameras
   3:2 pulldown, 222
   blurring rapidly rotating objects, 218–219
   bokeh effects, 209–212
   bracketing approach to exposure, 229–230
   chromatic aberration of lens, 233
   comet tail myth, 217–218
   computational expense, 213–214
   depth of field and hidden image areas, 212–213
determining area in focus, 208
   EV (Exposure Value), 228–229
   exercises, 236–237
   film speed and grain, 222–223
   first frame problems, 217
   focus pull, 205–206
   focusing, 204–205
   f-stops and depth of field, 202–204
   histograms in setting exposure, 225–227
   hyperfocal distance, 209
   interlaced and progressive scans, 219–220
   lens breathing, 207–208
   lens distortion, 230–232
   lens flares and halation, 234–235
   lighting matching and, 404
   match focal length of real lenses, 206–207
   overview of, 201–202
   reciprocal in exposure settings, 223–224
   rendering motion in separate video fields, 221
   shutter speed and shutter angle, 214–216
   vignetting flaw in lens, 233–234
   Zone System of exposure, 224–225
Career as graphic artist, 441–442
Cathode-ray tube (CRT) monitors, 269
Character design
   adding definition to, 161–163
   characters, 420
   character technical directors (TD), 425–427
   characters, adding definition to, 161–163
   Cheating
      in 3D, 5–9
      defined, 5
      light linking and, 49–50
      in live actions, 9
   Chromatic aberration (CA)
      color refraction and, 339
      of lens, 233
   Clipping, HDRIs and, 304–305
   CLUT (color look-up table), 307–308
   CMYK (cyan, magenta, yellow, and black), 280
   Color
      balance. see Color balance
digital. see Digital color
dramatic impact of, 188–189
   exercises, 275–277
   managing in composition, 405–407
   mixing. see Color mixing
      overview of, 267
   picking from pictures, 301
   refraction, 339–340
   rendering linear data, 275–277
   schemes. see Color schemes
   specular color, 317–318
   starting linear workflow, 274–275
   of sunlight, 113
   temperature. see Color temperature
   understanding gamma, 268–269
   Color (ambient) rendering passes, 386–389
   Color, of shadows
      as diagnostic tool, 67–68
      natural color, 64–66
      shadow color parameter, 66–67
   Color balance
      adjusting, 118
      caveats regarding color temperature, 299–301
      color temperature and, 296–297
      overview of, 294–296
      picking colors from pictures, 301
      simulating indoor/outdoor color balances, 297–299
   Color bleeding, 132, 344–345
   Color contrast
      complementary colors and, 287
      exclusivity and, 286
      over time, 287–288
      overview of, 286–288
   Color first strategy, in painting texture maps, 10:41–10:42
Index

Color grading production department, 432–433
Color look-up table (CLUT), 307–308
Color mapping
  color first strategy, 10:41–10:42
  overview of, 10:4–10:6
Color mixing
  additive color (RGB), 278–280
  HSV (hue, saturation, and value), 280–281
  light color and surface color, 281–284
  overview of, 278
  subtractive color (CMYK), 280
Color schemes
  color and depth and, 291–292
  color contrast and, 286–288
  contextual associations and, 290–291
  cool colors, 289–290
  overview of, 285–286
  tinted black and white images, 293
  warm and hot colors, 288–289
Color temperature
  adjusting color balance, 118
  caveats regarding, 299–301
  color schemes and, 288–289
  dividing space into different lighting treatments, 147
  physically based lights and, 35
  qualities of light, 3
  simulating indoor/outdoor color balances, 297–299
  understanding, 296–297
Colorists, 432–433
Comet tail myth, 217–218
Compact data formats, 306
Complementary colors, 280, 284, 287
Composite, from Maya, 362
Composition.
  see also Rendering
    adapting widescreen to standard video, 262–263
    camera angles and, 244
    core production departments, 431–432
    cropping and overscan, 263–264
    examining dominant lines, 257–258
    exercises, 264–265
    formats and aspect ratios and, 259–262
    graphic weight and, 256–257
    high-angle and low-angle shots, 249
    line of action, 245–246
    in linear workflow, 278
    motivation for camera moves, 251–252
    natural camera moves, 252–253
    OSS (over-the-shoulder) shots, 244
    overview of, 239
    perspective, 246–249
    POV (point-of-view) shots, 242–243
    with premultiplied alpha channels, 376–378
    rule of thirds, 253–254
    shadows enhancing, 58–59
    shot sizes, 240–241
    with straight alpha channels, 374–376
    tangency of lines, 258
    two-shots, 243
    types of camera moves, 250–251
    use of positive and negative space, 254–255
    z-axis blocking, 241–242
Compositors, 431–432
Compression, image compression, 308
Computational expense, of DOF and bokeh effects, 213–214
Concept artists, 420–421
Cone angle, controlling spotlights, 26–27
Constant mapping, 10:7–10:9
Contextual associations, color schemes and, 290–291
Continuity, maintaining on long projects, 12
Contrast
  adaptive oversampling and, 327
  adjusting contrast threshold, 328–329
  letting performance guide the lighting, 188
  shadows adding, 59
Control, creative.
  see Creative control
Cookies
  creating light effects with, 50–51
  creating throw pattern of light with, 142
  faking shadows, 107–108
Cook-Torrance shader, 315
Cool colors, 289–290
Coordinates.
  see UV coordinates
Creative control
  in computer graphics, 16–17
  vs. unnecessary tweaking, 325
Creative process, starting, 20
Crop regions, saving rendering time, 22
Cropping, overscan and, 263–264
CRT (cathode-ray tube) monitors, 269
CU (close-up)
  combining close-ups and wide shots using z-axis blocking, 241–242
  shot sizes, 240–241
Cubic projections, 10:24
Cucoloris. see Cookies
Custom (deformable) projections, 10:24
Custom shaders, 10:53
Cyan, magenta, yellow, and black (CMYK), 280
Cylindrical projections, 10:22–10:23
Daylight
  adding indirect light, 119–121
  adding skylight, 116–118
  adding sunlight, 112–113
  overview of, 112
  representing spill from sun, 115–116
  simulating skylight using IBL, 123–124
  simulating skylight without using dome lights, 121–122
  using depth map shadows, 114–115
  using raytraced shadows, 114
  using sun and sky shaders, 122–123
Decals
  adding realistic dirt to model, 10:40–10:41
  creating for texture maps, 10:38–10:39
Decay
  inverse square (quadratic) decay, 41–44, 139
  options, 44–46
  overview of, 41–42
  softness of light and, 4
  sunlight and, 113
  types of, 42
  when to use no decay, 44–45
Deep focus, DOF (depth of field) and, 203
Deep shadow maps, in RenderMan, 80, 115
Depth
  color and, 291–292
  defining with lighting, 146–148
Depth map bias
  artifacts and, 77–78
  light leak issues, 78–79
Depth map shadows
  advantages of raytraced shadows, 82–83
  creating daylight, 114–115
  raytraced shadows compared with, 336
  raytraced shadows compatibility with, 336–337
Depth maps
  depth map bias, 77–79
  framing, 75–77
  light leak issues, 78–80
  overview of, 73–74
  resolution and memory use, 74–75
  soft shadows using, 80–82
  transparency support and, 80
Depth of field.
  see DOF (depth of field)
Depth passes
  atmospheric perspective from, 149
  overview of, 396–397
  types of, 397–398
Design
challenges in lighting, 13–14
cheating in 3D, 5–9
cheating in live action, 9
creative control and, 16–17
direct and indirect light, 5
directing the viewer’s eye, 12
emotion impact of, 13
enhancing shaders and effects, 11
maintaining continuity, 12
making things believable, 10–11
making things read, 10
motivation and, 2
qualities of light, 3–5
visual goals, 9
workspace setup, 15–16

Detail shadow maps, from Mental Ray, 115
Diffuse mapping, see Color mapping
Diffuse passes, rendering in, 379
Diffuse reflection
controlling, 46–48
microfacet model of reflection
shaders, 315
overview of, 312–313
shaders and, 313–315

Digital backlot, 424–425
Digital color
8-bit and 16-bit, 302–303
compact data formats, 306
compressed images, 308
half floats, 306
HDRIs (High Dynamic Range Images) and, 303–305
indexed color, 307–308
overview of, 301–302

Digital intermediate process
compositing and, 431
in film creation, 299

Direct lighting, 5
Directional lights
adding spill light, 128–129
augmenting sunlight, 117
matching natural light, 403
simulating sunlight without using
dome lights, 121–122
simulating sunlight, 127–128
for soft raytraced shadows, 88
types of lights, 29–30
when to use no decay, 44

Directionality, modeling with light, 158–161
Dispersion. see Chromatic aberration (CA)
Displacement first (bump first) strategy, for
painting texture maps, 10:42

Displacement mapping
overview of, 10:11–10:12
special cases in occlusion passes, 95–96

Displays. see Monitors
Distance, using lighting to show, 144
Distance falloff. see Decay
Distant lights. see Directional lights
Dmap filters, softening depth map
shadows, 80–82
Dmaps. see Depth maps
DOF (depth of field)
  atmospheric perspective from DOF
effect, 151, 154
  computational expense of, 213–214
  f-stops and, 202–204
  hidden image areas and, 212–213
  overview of, 202
  reciprocity between exposure controls, 223–224
Dolly, types of camera moves, 250–251
Dome lights
  simulating skylight, 116–117
  simulating skylight without using, 121–122

Drop off. see Decay

E
ECU (extreme close-up) shots, 240–241

Effects
core production departments,
427–428
enhancing, 11
Effects TD (technical director), 427–428

Emotional impact, lighting design and, 13

Environmental lighting
adding global illumination, 128–134
adding illumination to point light
source, 138–139
adding indirect light, 119–121, 128
adding sunlight, 116–118, 124–125
adding spill light, 128–129
adding sunlight, 112–113, 127–128
avoiding spills, 140
creating atmosphere, 148–151
creating distance effect, 144
defining depth, 146–148
dividing space into different
lighting treatments, 145–146
excluding elements of window
geometry, 127
IBL (image-based lighting)
approach, 123–124
for large areas, 141
night scenes, 143–144
practical lights, 138
representing spill from sun, 115–116
set lighting, 139–140
simulating skylight using area lights,
125–127
simulating skylight without using
dome lights, 121–122

ESR (Exposed Shutter Ratio)
simulating skylight using area lights,
125–127
simulating skylight without using
dome lights, 121–122

Everson, 228–230

F
Faking
shadows, 102
subsurface scattering, 192
Falloff angle, controlling spotlights,
26, 28
Feedback loop, in scene refinement,
21–23
Fill lights
functions of, 171–173
indirect light and, 135
key-to-fill ratio, 166
lighting multiple characters
simultaneously, 186–187
making lights move with character,
185–186
occlusion sandwich technique and,
97–99
sky domes for, 31
in three-point lighting, 164–167
Film formats, 260–262
Film speed
defined, 202
EV (Exposure Value) and, 228–230
grain and, 222–223
reciprocity between exposure controls, 223–224
Filters
- anti-aliasing and, 329
- exposure settings and, 224
- noise reduction filters, 214
- softening depth map shadows, 80–82
Final gathering, 349–350
First frame problems, 217
Flatbed scanners, 10:30–31
Floating point values, depth map shadows and, 74
Focal length
- DOF (depth of field) and, 203
- lens breathing and, 207
- match focal length of real lenses, 206–207
- setting the focus, 204
Focus pull, 205–206, 250–251
Focusing cameras. see F-stops
Follow focus, 205
Foreground, rendering in layers, 363–364
Formats
- adapting widescreen to standard video, 262–263
- aspect ratios and, 259
- compact data formats, 306, 406
- digital color and, 301
- film formats, 260–262
Frame rates, 214
Frames, testing, 189
Fresnel effect, 318–321
Fresnel shaders, 320
Front projections, 10:23–10:24
F-stops
- bokeh effects, 209–212
- computational expense and, 213–214
- defined, 202
- depth of field and hidden image areas, 212–213
- determining area in focus, 208
- EV (Exposure Value) and, 228
- focus pull, 205–206
- hyperfocal distance, 209
- lens breathing, 207–208
- matching focal length of real lenses, 206–207
- overview of, 202–204
- reciprocity between exposure controls, 223–224
- setting the focus, 204–205
Gamma
- correction, 275
- problems with incorrect gammas, 269–272
- understanding, 268–269
Gels, color temperature and, 299–300
GI (global illumination)
- adding indirect light, 119–121
- ambient light compared with, 38–39
- caustics, 352–356
- creating indoor natural light, 128–134
- creating indoor natural light without using, 134–138
- final gathering and, 349–350
- inverse square (quadratic) decay and, 42
- models as light source and, 37
- overview of, 343–346
- photon mapping approach to, 347–349
- problems with incorrect gammas, 270–271
- reciprocity between exposure controls, 223–224
- setting the focus, 204–205
H
Hair, character illumination and, 192–193
Halation (specular bloom), 234–235
Half floats, color formats and, 306
Hard shadows
- compared with soft, 69–71
- when to use, 71–72
HDR (High Dynamic Range), 405–406
HDRIs (High Dynamic Range Images)
- bracketing approach to exposure and, 229
- creating, 201
- digital color and, 303–305
- IBL (image-based lighting) and, 124
- illuminating scene with, 121
- light probe images, 403
- working with digital color, 302
HDTV
- interlaced and progressive scans, 219–220
- resolution of texture maps and, 10:48
Hemispheric sampling, ambient occlusion and, 91–92
High Dynamic Range (HDR), 405–406
High Dynamic Range Images. see HDRIs (High Dynamic Range Images)
High-angle shots, in composition, 249
Highlight passes, in rendering, 379–380
Highlights. see also Specular highlights
- light linking for, 48
- specular lights and, 181–182
Highpass filters, correcting luminance and color shifts, 10:34–10:36
Histograms, adjusting exposure, 225–227
Holding layers, 366–367
Horizontal tiling, 10:38
Hot colors, 288–289
HSV (hue, saturation, and value), 280–281
 Hue, saturation, and value (HSV), 280–281
Hyperfocal distance, 209

I
IBL (image-based lighting)
- simulating skylight, 123–124
- sky domes and, 31
Icons
- for directional lights, 29
- for point lights, 25
IES (Illuminating Engineering Society), 35–37
Illustrations, basing scene lighting on, 20
Image compression, 308
Image planes, in 3D software, 399
Image-based lighting (IBL)
- simulating skylight, 123–124
- sky domes and, 31
Incandescence mapping, 10:7–10:9
Index of refraction (IOR), 337–339
Indexed color, 307–308
Indirect lighting
- adding global illumination, 128–134
- caustics and, 352–356
- creating daylight, 119–121
- creating indoor natural light, 128
- overview of, 5
- without global illumination, 134–138
Indoor film, color balance and, 294–295
Indoor lighting
- adding global illumination, 128–134
- adding indirect light, 128
- adding skylight, 124–125
- adding spill light, 128–129
- adding sunlight, 127–128
- area lights in simulation of sky illumination, 125–127
- dividing space into different lighting treatments, 145–146
Indoor lighting (continued)
excluding elements of window geometry, 127
working without global illumination, 134–138
Infinite lights, 128–129
Interlaced scan, 219–220
International Organization for Standardization (ISO), 222
Inverse square decay
adding illumination to light source, 139
overview of, 41–44
problems with incorrect gammas, 270
ISO (International Organization for Standardization), 222
Isotropic reflection, 322

J
Jitter frames, caused by 3:2 pulldown, 222
JPEG files
8-bit color, 302
compact data formats, 306
lossy compression, 308
understanding gamma, 269

K
Kelvin, color temperature measured in, 296
Key lights
creating daylight effect, 112
functions of, 168–171
key-to-fill ratio, 166
lighting multiple characters simultaneously, 186–187
occlusion sandwich technique and, 99–101
testing, 171
in three-point lighting, 164–167
Key shots, defining for large production, 435–436
Keyframes, setting for focal distance, 206
Kick lights
functions of, 180–181
lighting multiple characters simultaneously, 186–187

L
Label maps, see Decals
Layer overrides, rendering in layers, 365–366
Layered textures, see Decals
Layout
of animated feature, 414–415
when to applying lighting to, 21
Lens breathing, 207–208
Lens distortion, 230–232
Lens flares, 234–235
Lenses, camera
bokeh effects, 209–212
chromatic aberration, 233
distortion, 230–232
flares and halation, 234–235
match focal length of real lenses, 206–207
vignetting flaws, 233–234
Letterboxing, 262
Levels tool, Photoshop, 226–227
Light angle, for soft raytraced shadows, 88
Light color, vs. surface color, 281–284
Light functions
bounce lights, 173–175
fill lights, 171–173
key lights, 168–171
kick lights, 180–181
overview of, 167–168
rim lights, 176–180
specular lights, 181–182
spill lights, 175–176
Light leaks, fixing, 78–80
Light linking, 48–50
Light Material, from VRay, 38
Light meters, for setting exposure, 224
Light probe images, 403–404
Light radius, for soft raytraced shadows, 87–88
Light rigs
creating, 183
sharing for large production, 436–437
Lighting, on large productions
defining key shots, 435–436
mixed approach to, 440
overview of, 435
referencing and, 437–440
sharing light rigs, 436–437
Lighting artist, 430–431
Lighting basics
ambient light, 38–39
area lights, 32–34
cookies, 50–51
decay, 41–46
diffuse and specular light reflection, 46–48
direct and indirect light, 5
directional lights, 29–30
exercises, 51–53
feedback loop in scene refinement, 21–23
light linking, 48–50
models as light source, 37–38
naming lights, 23
overview of, 19
physically based lights, 35–37
point (omnidirectional) lights, 24–26
qualities of light, 3–5
sky dome light source, 31
soloing and testing lights, 40–41
spotlights, 26–29
starting creative process, 20
types of lights, 24
version management, 24
when to applying lighting to project, 21
Lighting department, 430–431
Lighting passes, 392–394
Line of action, camera angles and, 245–246
Linear workflow
compositing and, 278
inverse square decay and, 44
overview of, 268
problems with incorrect gammas, 269–272
rendering linear data, 275–277
starting with textures and colors, 274–275
steps in problem correction, 272–273
understanding gamma, 268–269
Lines
examining dominant lines in graphic images, 257–258
tangency of, 258
Live action
cheating in live action cinematography, 9
matching to background plates, 399–400
starting creative process for live-action footage, 20
studying real life in process of creating believable lighting, 10–11
Local illumination, contrasted with global, 343, 345–346
Look-up tables (LUTs)
color look-up table (CLUT), 307–308
displays and, 405
Lossless compression, 308
Lossy compression, 308
Low-angle shots, in composition, 249
Lumens
area light intensity in, 35–36
brightness settings of physically based lights, 35–36
Luminance, correcting in tiling maps, 10:34–10:36
Luminosity mapping, 10:7–10:9
LUTs (look-up tables)
color look-up table (CLUT), 307–308
displays and, 405

M

Macro lens, 207
Mapping surface attributes. see Texture maps
Maquettes, concept work by art department, 420
Mask passes, in rendering, 395–396
Match move department, in production pipeline, 415–419
Materials, 36, 312. see also Shaders
Matte balls, as reference object, 400–401
Matte passes. see Mask passes, in rendering
Matte
drawing animated (rotoscoping), 419–420
rendering in layers and, 367–369
Maximum distance, occlusion and, 93–94
Maya
ambient shade option, 39, 387
Composite, 362
Hypershade window, 321
Ray Depth Limit parameter, 86
shadows-only light, 68–69
support for linear workflow, 273
MCU (medium close-up) shots, 240–241
Medium close-up (MCU) shots, 240–241
Medium shot (MS), 240–241
Medium shot (MS) shots, 240–241
Mental Ray
ambient shade option, 39, 387
Composite, 362
Hypershade window, 321
Ray Depth Limit parameter, 86
shadows-only light, 68–69
support for linear workflow, 273
Microfacet model
of anisotropic surface, 322
of reflection shaders, 315
Micropolygons, in Reyes rendering, 341
Mirror balls, as reference object, 402–403
Mirrors, occlusion passes and, 96
Modelers, 423–424
Modeling department, in production pipeline, 423–424
Modeling with light
adding definition to character, 161–163
directionality of light, 158–161
making things read, 10
overview of, 158
Models
aligning maps with, 10:17
as light source, 37–38
Monitors
calibrating, 15–16
CRT (cathode-ray tube), 269
LUTs (look-up tables), 405
Motion blur
blurring rapidly rotating objects, 218–219
comet tail myth, 217–218
First frame problems, 217
shadows and, 89–90
shutter angle and, 216
shutter speed and, 214
Motivation
for camera moves, 251–252
cheating as departure from, 5
direct and indirect light, 5
lighting design and, 2
off-screen space impacting lighting, 2–3
qualities of light, 3–5
MS (medium shot) shots, 240–241

N

Naming lights, 23
Negative lights, faking shadows and occlusion, 102–104
Negative space, in composition, 254–255
Night scenes, creating, 143–144
Noise reduction filters, 214
Normal mapping, 10:15–10:16
Nuke
color management, 405
compositing with premultiplied alpha channels, 376
compositing with straight alpha channels, 375
inspecting alpha channels, 372
as node-based compositor, 362
noise reduction filters, 214
occlusion sandwich technique and, 97
NURBS surfaces
implicit UV coordinates, 10:19–10:20
poles and, 10:43–10:45
Reyes rendering curved surfaces and, 341
subdivision surfaces, 10:12, 332
O

Occlusion, see also Shadows
ambient occlusion, 91–92
baking, 104–106
distance settings, 93–94
faking, 102
negative lights in faking, 102–104
occlusion sandwich technique, 97–102, 136–138
overview of, 91
rendering in separate pass, 92
sampling and, 95
special cases, 95–97
spread (sampling angle) setting, 94
Occlusion passes, 92, 389–390
Off-screen space
lighting shaped by, 2–3
shadows indicating, 59–60
Offset filters
correcting luminance and color shifts, 10:34–10:36
creating tiling maps and, 10:33
Omnidirectional lights.
see Point lights
Opacity settings, shaders and, 367
OpenEXR, 306, 406
OSS (over-the-shoulder) shots, 244
Outdoor film, color balance and, 294–295
Overrides, using layer overrides, 365–366
Oversampling
adaptive, 327–328
adjusting contrast threshold, 328–329
overview of, 326–327
Overscan, cropping and, 263–264
Over-the-shoulder (OSS) shots, 244

P

Packets, breaking shots into, 438–440
Painting texture maps
color first strategy, 10:41–10:42
displacement first strategy, 10:42
in layers, 10:42–10:43
Paint programs, 10:25–10:26
stylized textures, 10:45–10:48
Pan, types of camera moves, 250–251
Pan and scan technique, in adapting widescreen to standard video, 263
Path tracing, 351
Penumbra angle, controlling spotlights, 26, 28
Penumbra of light, softness and, 4
Per-face texturing (Ptex), 10:20–10:21
Performance, guiding lighting, 187–189
Perspective
positioning camera and, 246–249
POV (point-of-view) shots, 242–243
of shadows, 63
Perspective projections, 10:23–10:24
Photographic textures
capturing, 10:27
flatbed scanners for capturing, 10:28–10:30
shooting tips, 10:28–10:30
Photometric lights, 35–37
Photon mapping
approach to GI, 347–349
final gathering used in conjunction with, 349–350
Photorealism, 10–11
Photoshop
adding glows, 369
alpha channel issues, 372
compositing in, 362
compositing reflections, 381
compositing with premultiplied alpha channels, 377
compositing with straight alpha channels, 375
creating texture maps, 10:25–10:26
Levels tool, 226–227
occlusion sandwich technique and, 97
Polar Coordinates, 10:43–10:45
rendering with, 362
tone mapping and, 406–407

Physically based lights, 35–37
Physically based shaders
BRDF/BSSRDF, 323–324
creative control vs. unnecessary tweaking, 325
energy conservation and, 323
Pincushion distortion, 230
Pixar RenderMan. see RenderMan
Pixels
dividing images into buckets or groups of, 342
oversampling, 326–327
undersampling, 329
Planar projections, 10:21–10:22
PNG files
color management, 406
compact data formats, 306
Point lights
adding illumination to light source, 138–139
area lights contrasted with, 32
types of lights, 24–26
Point-of-view (POV) shots, 242–243
Poles, in texture maps, 10:43–10:45
Polynomial texture mapping (PTM), 10:16–10:17
Portal lights, 33
Positive space, in composition, 254–255
POV (point-of-view) shots, 242–243
Practical lights
adding illumination to light source, 138–139
avoiding spills, 140
defined, 124
for large areas, 141
overview of, 138
set lighting, 139–140
splitting out lights, 184–185
throw pattern of, 142
Premultiplied alpha channels, 373–374
Previsualization, preparing for visual effects shots, 415
Primary colors, additive, 278
Procedural textures
3D textures, 10:51
animation of, 10:51
appearance of, 10:52–10:53
baking into maps, 10:53–54
overview of, 10:50
resolution independence, 10:50–10:51
Production pipelines
art department, 420–423
character animation, 427
character rigging, 425–427
compositing, 431–432
effects, 427–428
grading and final output, 432–433
lighting, 430–431
match move and virtual sets, 415–419
modeling, 423–424
overview of, 412
previsualization, 415
rotoscoping, 419–420
set decorating, 424–425
shading, 428–429
storyboard, 412–414
texture painting, 429
visualizing, 433–434
Progressive scans, shutter speed and, 219–220
Projections
camera, 10:23–10:24
other types, 10:24
overview of, 10:21
planar, 10:21–10:22
spherical and cylindrical, 10:22–10:23
Prex (per-face texturing), 10:20–10:21
PTM (polynomial texture mapping), 10:16–10:17

Q
Quadratic decay. see Inverse square decay
Qualities of light, 3–5

R
Raccoon eyes, issues in character illumination, 170
Rack focus, 205, 250–251
Radiosity, approach to GI, 346–347
Ray depth limit, 337
Ray Depth Limit parameter, Maya, 86
Raytraced reflections
glossiness and, 334
integrating with specular highlights, 333
overview of, 332–333
perfectly specular nature of, 314
reflection limits, 334–336
surrounding environment and, 334
Raytraced shadows
area lights and, 87
compatibility of depth map shadows with, 336–337
creating daylight, 114
deepth map shadows compared with, 336
how they work, 84–85
light angle and, 88
light radius and, 87–88
overview of, 73, 82–83
sampling and, 88–89
soft raytraced shadows, 86–87
trace depth and, 85–86
Raytracing
acceleration structures, 332
overview of, 330–331
reflections. see Raytraced reflections
refraction and, 337
Reyes algorithm and, 342–343
shadows. see Raytraced shadows
transparency and refraction, 337–340
Reaction shots, 241
Realism
area lights and, 33
inverse square decay and, 42
photorealism, 10–11
physically based lights and, 36
of specular highlights, 316
Rect lights. see Area lights
Recursion depth, raytraced reflections and, 335–336
Red. see RGB (red, green, blue)
Reference images (or objects)
in background plates, 400
light probe images, 403–404
making things believable, 10
matte balls as, 400–401
mirror balls as, 402–403
Referenced lighting, approach to large production, 437–440
Reflection blur. see Glossy reflection
Reflection limits, raytraced reflections, 335–336
Reflection of light
adding to real objects, 382–383
anisotropic highlights, 321–322
BRDF/BSSRDF, 323–324
diffuse and specular, 46–48, 312–315
Fresnel effect, 318–321
global illumination. see GI (global illumination)
glossy, 312–315
isotropic reflection, 322
Raytraced reflections, 332–336
Reflected lights, 374
Reflexive objects, in occlusion passes, 96
Reflections, 378–379
Reflection passes, 380–383
Reflection softness. see Glossy reflection
Reflective objects
creating night scenes, 144
in occlusion passes, 96
Refractive objects
creating night scenes, 144
in occlusion passes, 96
Refractive objects, in occlusion passes, 96
Renderers, 37
Rendering, see also Composition
choosing approach to, 407–408
exercises, 409
layered approach. see Rendering in layers
linear data, 275–277
motion in separate video fields, 221
pass approach. see Rendering in passes
saving rendering time, 22–23
software and algorithms for.
see Rendering software and algorithms
Rendering in layers
adding glows (blooms), 369–372
advantages of, 364–365
alpha channel issues, 372–374
compositing with premultiplied alpha channels, 376–378
compositing with straight alpha channels, 374–376
holding layers, 366–367
matte objects and, 367–369
overview of, 362–363
using layer overrides, 365–366
Rendering in passes
ambient passes, 386–389
beauty passes, 391–392
depth passes, 396–398
diffuse passes, 379
global illumination passes, 394–395
lighting passes, 392–394
management features, 398–399
mask (matte) passes, 395–396
multiple passes simultaneously, 399
occlusion passes, 92, 389–390
overview of, 378–379
reflection passes, 380–383
shadow passes, 384–386
specular passes, 379–380
Rendering software and algorithms
anisotropic highlights, 321–322
anti-aliasing, 325–326
cautics, 352–356
diffuse, glossy, and specular reflection, 312–315
diffuse, glossy, and specular refinement, 312–315
diffuse, glossy, and specular reflection, 312–315
exercises, 356–357
filtering, 329
final gathering, 349–350
Fresnel effect, 318–321
global illumination, 343–346
microfacet model of reflection shad
shaders, 315
oversampling, 326–329
overview of, 311
photon mapping approach to GI, 347–349
physically based shaders, 323–325
radiosity and GI, 346–347
raytraced reflections, 332–336
raytracing, 330–331
raytracing acceleration structures, 332
rendering at higher resolution to achieve good anti-aliasing, 330
Reyes algorithm, 341–343
shaders, 312
shadows, 336–337
specular color, 317–318
specular highlights, 316–317
transparency and refraction, 337–340
unbiased renderers, 350–351
undersampling, 326–329
RenderMan
AOVs (Arbitrary Output Variables), 408
deep shadow maps, 80, 115
interface standard, 342
Reyes algorithm and, 341–342
tessellation and, 10:12
Resolution
depth map shadows and, 74–75
interlaced and progressive scans and, 219–220
rendering at higher resolution to achieve good anti-aliasing, 330
resolution independence with procedural textures, 10:50–10:51
saving rendering time, 22
of texture maps, 10:48–10:50
Resolution independence, 10:50–10:51
Revisions, feedback loop in scene refinement, 21–23
Reyes algorithm
overview of, 341–342
raytracing and, 342–343
RenderMan Interface standard, 342
tessellation and, 10:12
RGB (red, green, blue)
additive color, 278–280
adjusting contrast threshold, 328–329
color matching from reference balls, 401
HSV compared with, 280–281
light color and surface color and, 282–284
models as light source and, 37
premultiplied alpha channels and, 374
scale for, 282
simulating indoor/outdoor color balances, 297–299
Rim lights
color matching from reference
character definition and, 163
functions of, 176–180
lighting multiple characters simultaneously, 186–187
making lights move with character, 186
in three-point lighting, 164–167
Rotoscope background, in 3D software, 399
Rotoscopying, drawing animated mattes, 419–420
Roughness property, specular highlights and, 315
Rule of thirds, in composition, 253–254

S
Sampling
occlusion and, 95
raytraced shadows and, 88–89
Saturation, in HSV, 280–281
Scaling up area lights, 32
Scanners, 10:30–31
Secondary colors, additive, 279
Selective lighting, 48–50
Set decoration department, 424–425
Set decorators, 424–425
Set lighting, practical lights, 139–140
Set of lights, in character illumination, 183–184
Shaders
alpha or opacity settings, 367
anisotropic highlights, 321–322
controlling diffuse and specular reflection, 46–47
custom, 10:53
diffuse, glossy, and specular reflection, 312–315
enhancing, 11
Fresnel effect, 318–321
microfacet model of reflection shad, 315
overview of, 312
physically based lights and, 36
physically based shaders, 323–325
specular color, 317–318
specular highlights, 316–317
sun and sky shaders, 122–123
transparency support and, 189–191
volumetric fog shader, 150, 152
VRay's Light Material, 38
Shading

- core production departments, 428–429
- overview of, 311–312

Shading TD (technical director), 428–429

Shade color parameter, 114

Shadows

- adding contrast, 59
- adding drama with, 188
- algorithms for calculating, 73
- appearance of, 62
- area lights and, 32–33
- in background plate, 404
- baking, 104–106
- cookies in faking, 107–108
- defining spatial relationships, 56–57
- depth map, see Depth map shadows
- directional lights and, 30
- disclosing new angles, 57–58
- enhancing composition, 58–59
- exercises, 108–109
- faking, 102
- hard and soft, 69–72
- indicating off-screen objects, 59–60
- integration function of, 60–61
- motion blur and, 89–90
- natural color, 64–66
- negative lights in faking, 102–104
- point lights and, 23
- raytraced, see Raytraced shadows
- shadow color parameter, 66–67
- shadow objects, 106–107
- size and perspective of, 63
- sky domes and, 31
- soft shadows, 4
- spotlights and, 26
- using shadow color as diagnostic tool, 67–68
- using shadows-only light, 68–69
- walls creating, 61–62

Shadows-only light, 68–69

Shots

- defining key shots for large production, 435–436
- OSS (over-the-shoulder) shots, 244
- packets of, 438–440
- POV (point-of-view) shots, 242–243
- preparing for visual effects shots, 415
- shot sizes, 240–241
- two-shots, 243
- z-axis blocking, 241–242

Shutter angle, 215–216

Shutter speed

- 3:2 pulldown, 222
- blurring rapidly rotating objects, 218–219
- comet tail myth, 217–218
- defined, 202
- EV (Exposure Value) and, 228
- first frame problems, 217
- interlaced and progressive scans, 219–220
- overview of, 214–216
- reciprocity between exposure controls, 223–224
- rendering motion in separate video fields, 221

Sky dome light source, 31

Skylight

- adding to daylight effect, 116–118
- adding to indoor natural light, 124–125
- area lights in simulation of, 125–127
- IBL simulation of, 123–124
- night scenes, 143–144
- simulating without using dome lights, 121–122

Soft reflections, 314

Soft shadows

- compared with hard, 69–71
- depth maps and, 80–82
- raytraced shadows, 86–87
- softness of light and, 4
- when to use, 72

Softness

- area lights and, 32–33
- controlling spotlights, 28
- qualities of light, 4
- sky domes and, 31

Soloing lights

- making adjustments and, 40–41
- saving rendering time, 22

Spatial relationships, shadows defining, 56–57

Specular (spec) lights, 181–182

Specular bloom (halation), 234–235

Specular color, 317–318

Specular highlights

- anisotropic highlights, 321–322
- Fresnel effect, 318–321
- integrating raytraced reflections with, 333
- overview of, 314, 316–317
- realism of, 316
- roughness property and, 315
- size of highlights, 316–317
- specular color and, 317–318
- specular mapping and, 10:6–10:7
- specular mapping, 10:6–10:7
- specular passes, in rendering, 379–380

Specular reflection

- controlling, 46–48
- microfacet model of reflection shaders, 315
- overview of, 312–313
- shaders and, 313–315

Spherical projections

- overview of, 10:22–10:23
- poles and, 10:43–10:45

Spill lights

- adding spill from sun, 115–116
- avoiding spills, 140
- creating indoor natural light, 128–129
- functions of, 175–176

Splitting out lights

- character illumination, 184–185
- separating diffuse and specular reflection, 47–48

Spotlights

- depth map shadows and, 75–76
- types of lights, 26–29
- using cookie to tint edges of, 142

Spread angle

- controlling spotlights, 26, 28
- occlusion and, 94

SRGB standard, 269, 272

Staging, 239. see also Composition

Stencils. see Decals

Storyboard, for animated feature, 412–414

Subsurface scattering

- faking, 192
- mapping variation, 191–192
- overview of, 189–191

Subtractive color (CMYK), 280

Sunlight

- adding spill light, 128–129
- creating daylight effect, 112–113
- creating indoor natural light, 127–128
- directional light simulating, 29
- when to use no decay, 44

Surface color, vs. light color, 281–284

Surface normal, bump mapping and, 10:13

T

- Tangency, of lines in graphics, 258
- Telephoto lens, 206

Terminator

- as edge of visible illumination, 160
- subsurface scattering, 190

Tessellation, 10:12, 332

Testing frames, 189

Testing lights, 40–41

Texture maps

- aligning with models, 10:17
- assigning UV coordinates, 10:17–10:19
- baking shadow into, 104–105
bump mapping, 10:13–10:15
capturing photographic textures, 10:27–10:31
color first strategy, 10:41–10:42
color mapping (diffuse mapping), 10:4–10:6
converting into linear color values, 274–275
correcting luminance and color shifts in tiling maps, 10:34–10:36
creating with paint programs, 10:25–10:26
decals and, 10:38–10:41
displacement first strategy, 10:42
displacement mapping, 10:11–10:12
exercises, 10:55
extending tiling maps, 10:36–10:38
horizontal and vertical tiling, 10:38
incandescence mapping (luminosity, ambience, or constant mapping), 10:7–10:9
making maps for multiple attributes, 10:41
normal mapping, 10:15–10:16
overview of, 10:3–10:4, 359
painting in layers, 10:42–10:43
painting stylized textures, 10:45–10:48
poles and, 10:43–10:45
polynomial texture mapping, 10:16–10:17
procedural textures, 10:50–10:54
projections, 10:21–24
Ptex (per-face texturing), 10:20–10:21
resolution of, 10:48–10:50
specular mapping, 10:6–10:7
tiling maps, 10:31–10:33
transparency mapping, 10:9–10:11
using implicit UV coordinates, 10:19–10:20
Texture paint department, 429
Textures, in linear workflow, 274–275
TGA file format, 301
Three-point lighting
avoiding formulaic approach, 167
overview of, 164–165
tweaks and modifications, 166
Throw pattern
of practical lights, 142
shape of light, 4
TIFF file format, 301
Tiling maps
correcting luminance and color shifts, 10:34–10:36
extending tiling, 10:36–10:38
horizontal and vertical tiling, 10:38
overview of, 10:31–10:33
Tilt, types of camera moves, 250–251
Tinted black and white images, 293
Tone mapping, HDR (High Dynamic Range), 406–407
Trace depth
overview of, 337
raytraced reflections and, 335–336
raytraced shadows and, 85–86
Transparency
refraction and, 337–340
shaders and, 189
shadows and, 80
special cases in occlusion passes, 96
Transparency mapping, 10:9–10:11
Turntable tests, 10:7
Two-shots, 243
Unbiased renderers, 350–351
Undersampling, 329
Underwater effect, creating, 151–154
Upstage key, 166
UV coordinates
aligning texture maps with models, 10:17–10:19
Ptex (per-face texturing) and, 10:20–10:21
using implicit, 10:19–10:20
Video
3:2 pulldown, 222
adapting widescreen to standard video, 262–263
frame rates, 214
interlaced and progressive scans, 219–220
rendering motion in separate video fields, 221
View-dependent shading, specular highlights and, 316
Viewer, directing eye of, 12
Vignetting, lens flaws, 233–234
Virtual radius, for soft raytraced shadows, 87–88
Virtual set models, in production pipeline, 417
Visual effects, visualizing production pipeline for, 434
Volumetric fog shader, 150, 152
VRay’s Light Material, 38
Wagon wheel effect, 219
Walls, shadows created by, 61–62
Warm colors, 288–289
Watts, vs. lumens in measuring brightness, 36
White balance, 294
WIDE shot. see WS (wide shot)
Wide-angle lens, 206
Widescreen, adapting to standard video, 262–263
Wild walls, 9
Workspace, checking lighting and setup of, 15–16
WS (wide shot)
combining close-ups and wide shots using z-axis blocking, 241–242
shot sizes, 240–241
Z-axis blocking, 241–242
Z-depth. see Depth passes
Zone System, of exposure, 224–225
Zoom, types of camera moves, 250–251