

9.1.3 ATTENUATION

attenuation (n.):

1. a lessening of the amount, force, or magnitude of something;
2. a dilution, thinning, or weakening of a substance.

Attenuation, as noted, is the decreasing intensity of illumination with increasing distance from the light source. As mentioned previously, attenuation is known by the following names: dropoff, decay, or falloff. Since different software packages use different names for this attribute, I'll stick with the scientific name "attenuation" to avoid confusion. In life, all lights attenuate. In the computer, however, most lights don't attenuate by default. If attenuation is desired it must be added by the digital lighter. Not all digital lights need to attenuate. This section covers real-world attenuation, informing the digital lighter as to when, if, and how much attenuation to add to each light and then looks at the ways attenuation is imitated digitally.

Real-World Attenuation

Attenuation in life follows what is known as the *inverse square law*. This formula tells us how quickly the light intensity will decrease with distance. This law states that, as a light source is moved away from a surface, it illuminates; the illumination decreases in an amount inversely proportional to the square of the distance. Specifically, when the distance from the light doubles, the amount of light reaching any given area of surface is reduced to $\frac{1}{4}$. Attenuation isn't due to the light "running out of steam" or energy, rather it's due to the decreased number of photons per unit of volume. You can see in Figure 9.6 that as distance from the light increases, there are fewer photons per unit of volume. When the distance doubles, the same number of photons are spread out over four times the area, thus reducing the density of photons and the intensity of light.

What does this bit of scientific information mean to you, the digital lighter, and how can we better understand it? Visual types will gain more from an image. Figure 9.7 shows a diagram of a light's intensity over a given distance. What you will notice is that closer to the light the intensity is at the highest; farther from the light, the intensity is very low. That makes sense—the farther from the light source, the dimmer the light. But even more notice the *rate of change*,

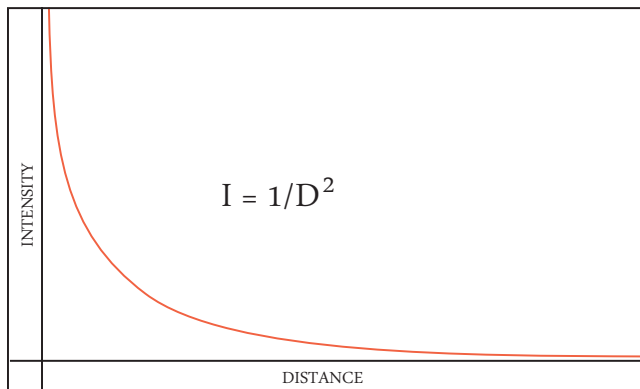


Figure 9.7 The inverse square law of light attenuation.

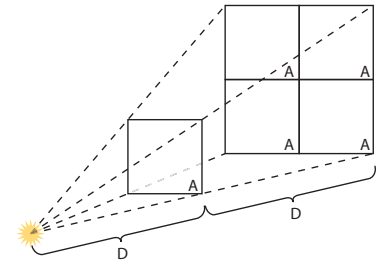


Figure 9.6 As distance doubles, light is spread out over four times the area, reducing intensity.

as evidenced by the slope or the line. The steeper the slope, the faster the rate of change. Near the light, intensity drops off very quickly; far from the light, intensity drops off very slowly. At very great distances the rate of change is negligible and the light's intensity really doesn't change much at all.

The attenuation curve tells digital lighters when they should add attenuation to their lights and how much. When the light source is close in distance to the objects being illuminated (such as nearby lamps, overhead lights, wall sconces and the like), the effect of attenuation will be noticeable. To maintain realism, it must be added by the CG artist. Conversely, if the light is very far away (such as sunlight or moonlight), then the effect of attenuation is negligible, and the digital light doesn't need it. As with so many things, knowing what happens in the real world will aid you in creating illumination that looks accurate.

The inverse square formula for attenuation represents an ideal situation, with the light source being a point. In reality, this ideal formula almost never holds exactly true. Different lights have slightly different attenuation rates. A focused beam will fall off more slowly. Light passing through fog or a transparent medium (like water) will fall off more rapidly. Uniformly scattered light (ambient light), on the other hand, has no decay. That being said, knowing how light falls off in an idealized situation is still very useful to digital lighters, but don't feel limited that you must stick exactly to this formula in all cases to stay realistic. Even in life actual attenuation rates vary depending on the light source and environmental conditions. Not only that, but a viewer will rarely notice if a light falls off exactly how it would in real life or not.



Figure 9.8 The effects of light attenuation are clearly visible in this scene from *The Incredibles*. (©2004 Disney/Pixar.)

RULES OF THUMB FOR ADDING DIGITAL ATTENUATION

- When the light is near, attenuation is noticeable and should be added by the digital artist.
- When the light is far, attenuation is negligible and isn't needed.

Digital lighters have several options for how to add attenuation to their lights. In computer graphics, many lights will have three options: no attenuation, linear attenuation, or quadratic attenuation.

No attenuation means that the intensity is constant and doesn't change with distance from the light. In Figure 9.9, no decay is represented by the greenline. Many applications have this as the default for the lights. I prefer this setting initially, even with lights that I later plan to add attenuation so that I can roughly position the light without having to constantly adjust its intensity.

Linear attenuation decreases in intensity at an even rate. In Figure 9.9, linear decay is represented by the blue line. When using linear decay, the light will attenuate at the same rate whether it is near or far from the subjects being lit. Linear attenuation is less likely to produce hot spots near the light source since there is no dramatic change in intensity near the light. Linear is often a good choice for spot or point lights that are very near their subjects.

Quadratic, or exponential attenuation, has a falloff the most like real-world decay. It replicates the inverse square law. In Figure 9.9, quadratic decay is represented by the red line. While the most accurate to real-world point lights, this attenuation is often "too much" for the typical CG scene. The light falls off too dramatically, causing overly hot illumination near the light (called "hotspots") and not enough illumination farther from the light. In many cases, it doesn't look realistic; it looks overdone. When adding attenuation to a CG light, linear attenuation generally delivers a better look than quadratic.

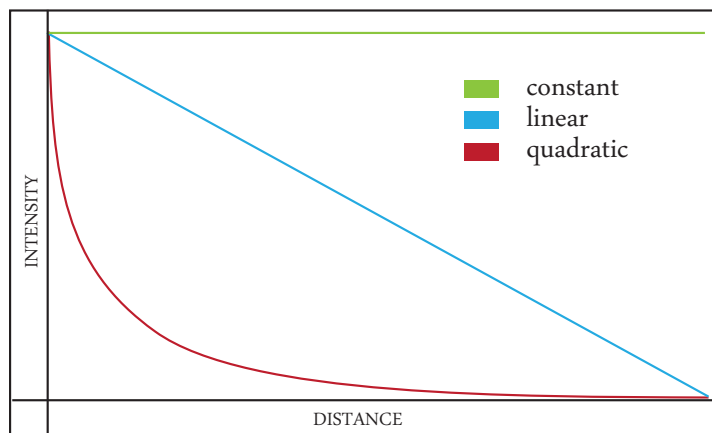


Figure 9.9 Graph of common digital attenuation presets.

Figure 9.10 No attenuation.



Figure 9.11 Linear attenuation.



Figure 9.12 Quadratic attenuation.



Quadratic attenuation, like real light, falls off more rapidly when close to the source and less rapidly when far from the source. A light with quadratic decay that is near to its subject will fall off *extremely* rapidly (Figures 9.13 and 9.14). Yet when the same light is pulled farther from its subject, the rate of decay will lessen and begin to look like linear decay (Figure 9.15). If you were to pull the light far, far away, the rate of decay would become negligible and appear like no decay. Savvy digital lighters can change the rate of decay by moving a light with quadratic decay farther or nearer and adjusting the light intensity accordingly.

Figure 9.13 Quadratic decay, with a light very near.



Figure 9.14 Quadratic decay with a light faraway.



Figure 9.15 Linear decay, any distance.



When adding attenuation, you will have to put a very high number in as the light's intensity setting, as the intensity finally reaching the surface will be much less. This can make it difficult to really know just how much illumination the light is casting relative to other lights or to estimate the lighting ratio. Such high numbers seem to have little relevance to the actual illumination in the scene. Experienced lighters can often estimate their lighting ratio just from the light's intensity setting, but this becomes much harder or even impossible when using a standard decay. One solution to this problem is what is known as *metered decay*.

Metered decay is a more advanced digital attenuation that allows for the lighter to set the intensity of the light at a specified distance. The light will become darker when farther than this distance and will likewise brighten in intensity when closer than this distance. The advantage of metered decay is that the lighter can specifically set the light intensity at the approximate distance the light reaches the subject rather than just "eyeballing" it. For example, if your light is 10 units from its subject and you want it to strike its subject with an intensity of 1, metered decay allows you to set the meter distance to 10 and the illumination to 1. If your light moves closer than 10 units, the light will brighten quickly. Metered decay often also has a maximum

intensity setting for the light, so that the illumination never becomes higher than a certain intensity. Using metered decay and a max intensity will generally eliminate hotspots, another common problem with digital attenuation. Not all software has metered decay available.

Another option commonly available are decay regions. Decay regions allow you to specify certain distances from the light source for the illumination to begin and to stop. The light will decay inside these regions. The user can then set arbitrary ranges, and craft the attenuation of his scene more artistically. One nice use for decay regions is to begin the illumination only once the rays have left the geometric model representing their source. This can be useful with spotlights when they are imitating a focused beam of light such as a flashlight or car headlights, especially if the entire beam of light is seen due to fog. In these cases you want the illumination to begin just when the light leaves the glass covering. To obtain the correct shape, you will want to pull your spotlight back a bit, then use decay regions to “turn on” the light right when it leaves the model of the light source.

As yet another option, some programs allow you to craft your light's intensity with distance according to a curve, similar to an animation curve but over distance instead of time. A feature such as this offers the maximum control. Not only can you specify the intensity of the light at every distance, you often can set the red, green, and blue channels independently, meaning the light can even change in hue with distance. When crafting your attenuation with tools such as decay regions or an intensity curve, be careful not to make your scene look unrealistic. The good news is that audiences will not notice if the attenuation is not 100% real and will easily accept a more creative version...as long as you don't deviate too far.

COMMON METHODS FOR CG ATTENUATION

- No decay
- Linear decay
- Quadratic decay
- Metered decay
- Decay regions
- Arbitrary decay

Tips on Adding Attenuation

- If the light is near, use attenuation.
- If the light is very distant, don't use attenuation.
- When using quadratic or linear attenuation, don't forget to greatly increase the intensity of the light.
- Quadratic attenuation, while the most realistic, is often “too much” for the average scene.
- Linear attenuation often gives better results than quadratic attenuation.
- The use of arbitrary decay provides the most creative control and, if not overdone, will not be perceived by the viewer as unrealistic.

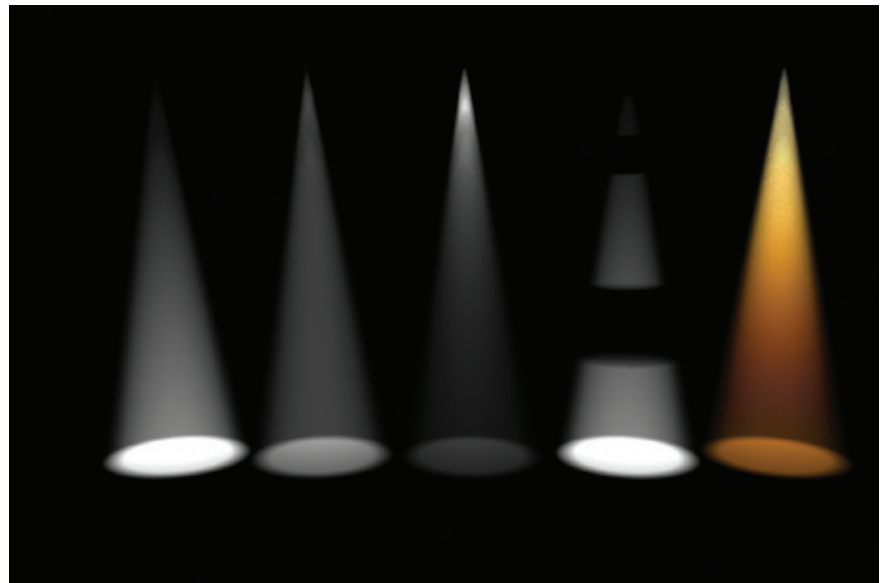


Figure 9.16 CG attenuation lineup. From left to right: no attenuation, linear, quadratic, decay regions, and using distance curves.