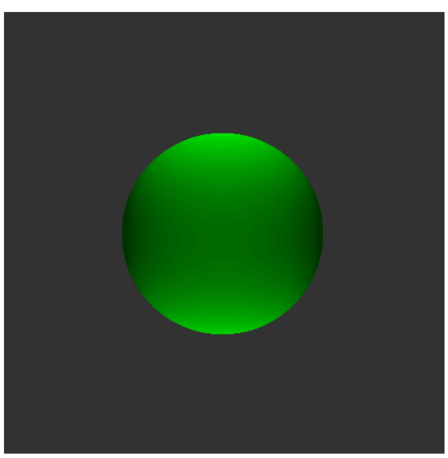
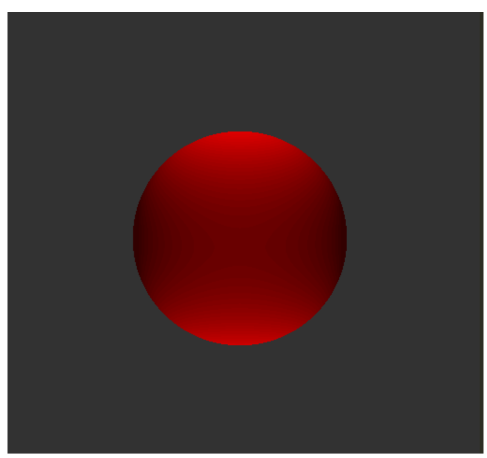
Note
There is a bug with my illumination that, despite the attempts of myself and one of the TAs in debugging, is impacting how light is represented on the spheres. I've reached out to the professor about this issue and will continue to try to fix it, but I'm submitting what I have at this point since the shadows and light attenuation are working. However, as such, it is difficult to fully represent some of the questions below with my images.

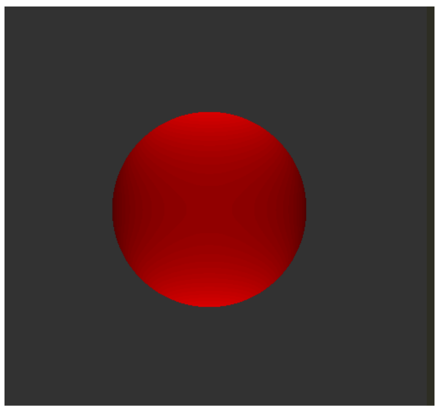
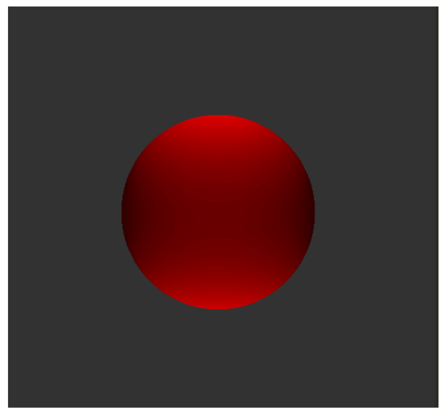
Impacts of the terms:

Increasing k_a increases the ambient term and makes for a more intense color. Similarly, k_d impacts the diffuse term, which causes a flatter color when its value is lower. Changing k_s makes the material seem more reflective, which is helpful for metallic materials. The exponent i decreases the size of the specular highlight as its value increases. $O_{s\,lambda}$ affects the color of the specular highlight and can be utilized to make objects appear to be made of different materials, such as plastic or metal. $O_{d\,lambda}$ relates to the "actual" color of the object—the color it would have without any lighting or shadows. It provides a base color for the object. The image below on the left has a $O_{d\,lambda}$ term of 0 1 0 and a $O_{s\,lambda}$ term of 0 1 1, while the image on the right is 1 0 0 and 0 0 1, respectively.

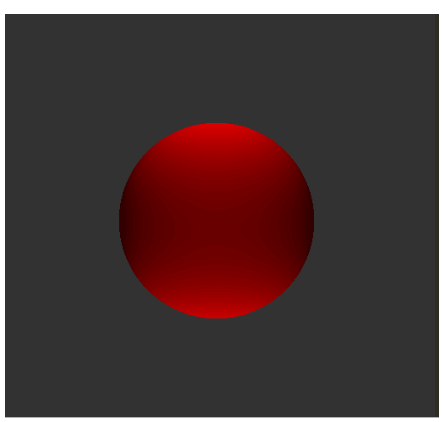
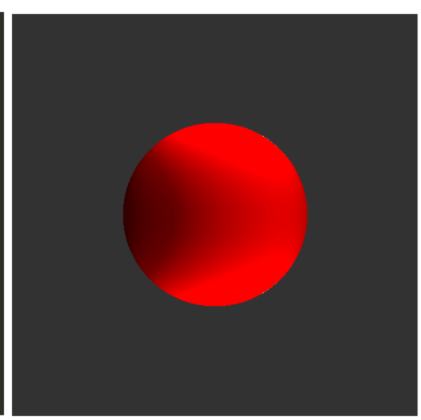
Directional light vs point light:

When a directional light is implemented, the direction to the light from any given point is constant. In contrast, the direction to a point light from any given point on the shape is different. A sphere lit by a directional light will have a larger, more constant, lit area than one lit by a point light. In the pictures below, the one on the left is lit by directional light and is more constant in color. The one on the right is lit by a point light and the smaller section of influence before the light falls off can be seen.

Multiple lights vs a single light:

Adding multiple lights means that light is hitting the sphere from multiple directions, which can be accomplished by using a for loop to sum up the diffuse and specular terms for each individual light. It is important to keep the intensity of each light less than 1, in order to not overload the operations. The image on the left is with a single light, while the image on the right has two lights—one from the top and one from the right.

Extra credit:

I implemented light attenuation, which allows the light to fall off with distance. In the example below, I used the values of c1 = 0, c2 = 0.05, and c3 = 0 to get the slight light attenuation on the image to the right. In the image at the bottom left, I used c1 = 0, c2 = 0.1, and c3 = 0. In the bottom right, I used c1 = 0, c2 = 0, and c3 = 0.05, at which point the presence of any light at all is barely noticeable (it only shows up as a thin line). This demonstrates the impact of multiplying by d^2 instead of d. (These pictures also show the functionality of shadows.)