CS 285 Final Project: Bidirectional Path Tracing

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1 Overview

For my final project I implemented bidirectional path tracing with importance sampling. I re-used my old code from homework 3 to read in scenes and do collision detection and acceleration. I created several test scenes and rendered them with importance sampling and bidirectional path tracing turned on/off to compare the results. Importance sampling results in a somewhat noticeable decrease in variance with the same number of samples/pixel, and bidirectional path tracing significantly improves the global illumination for scenes where most of the lighting is indirect, at the cost of increased run time.

2 Implementation

In order to render a specific pixel, my path tracer traces a path from the camera origin through the pixel and into the scene. When it encounters an object it calculates the direct illumination on that object from the light source(s) and then probabilistically scatters the ray off the object. Then it recursively traces the new ray and adds its contribution (weighted according to the pdf of the new ray) to the lighting as well.

In the case of specular reflections, the scattered ray direction is deterministic as the object behaves like a mirror. In the case of diffuse scattering, the ray is sent in a randomly chosen direction within the hemisphere of the surface normal at the point of intersection. If importance sampling is turned off, the distribution of the new ray is uniform within the hemisphere. If importance sampling is turned on the new ray is distributed according to the cosine of the angle between the new ray and the normal. Since rays that hit the surface with a small angle relative to the normal contribute more to the lighting, the importance sampling makes sure that rays that will contribute more to the lighting are more likely to be chosen. This improves the quality of the image.

If Bidirectional path tracing is turned on then before tracing a path from the camera into the scene the algorithm first traces a path from the light source(s) into the scene and calculates the illumination at each point hit. When the algorithm traces a path from the camera to the scene, the points that were hit by the light path are treated as light sources and are accounted for in the lighting calculation. In scenes where there is very little direct illumination this process greatly improves the global illumination by making it much more likely that paths from the camera to a light source are found.

3 Results

I rendered 3 scenes 4 times each, with importance sampling and bidirectional path tracing turned on/off in order to see how much these techniques improve the image quality. For the comparison between importance sampling and no importance sampling I rendered the scenes with a low number of samples per pixel in order to make the difference in variance easier to notice. For the comparison between regular path tracing and bidirectional path tracing I rendered the scenes with a higher number of samples/pixel in order to get higher quality images to compare.

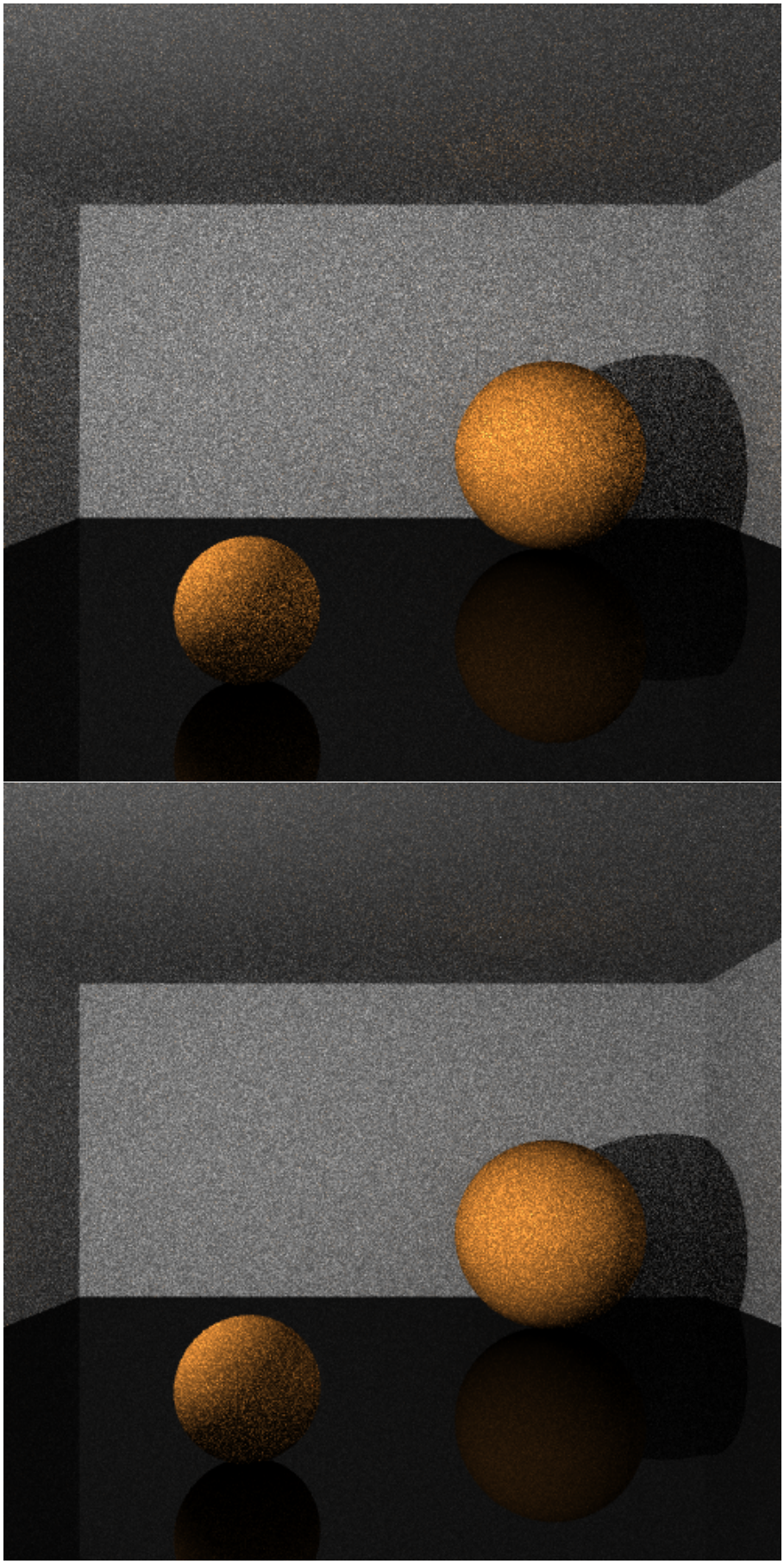

Figure 1: Top: 4 samples/pixel without importance sampling. Bottom: 4 samples/pixel with importance sampling

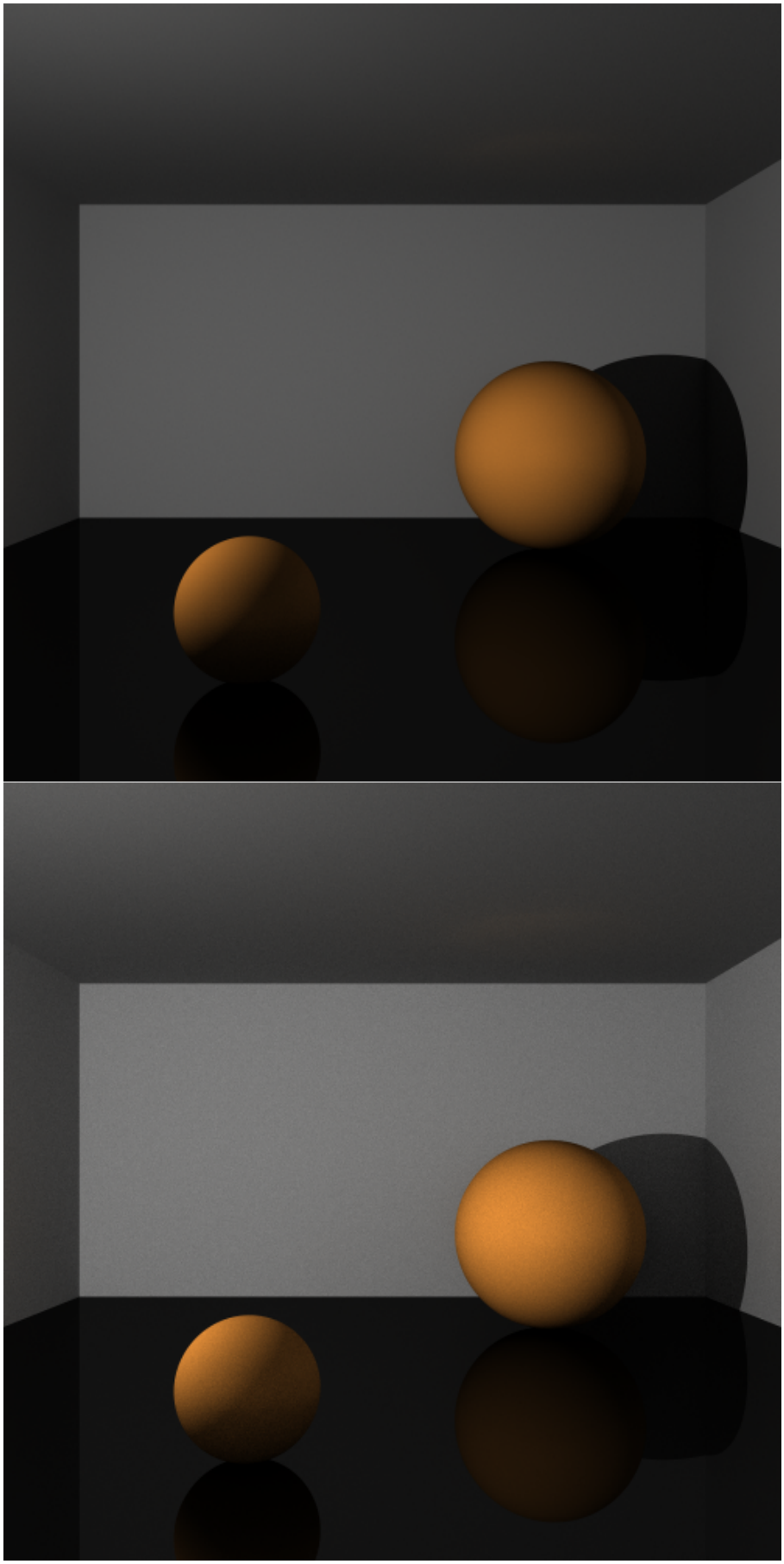

Figure 2: Top: 256 samples/pixel with regular path tracing, 2m 37s render time. Bottom: 256 samples/pixel with bidirectional path tracing, 7m 19s render time.

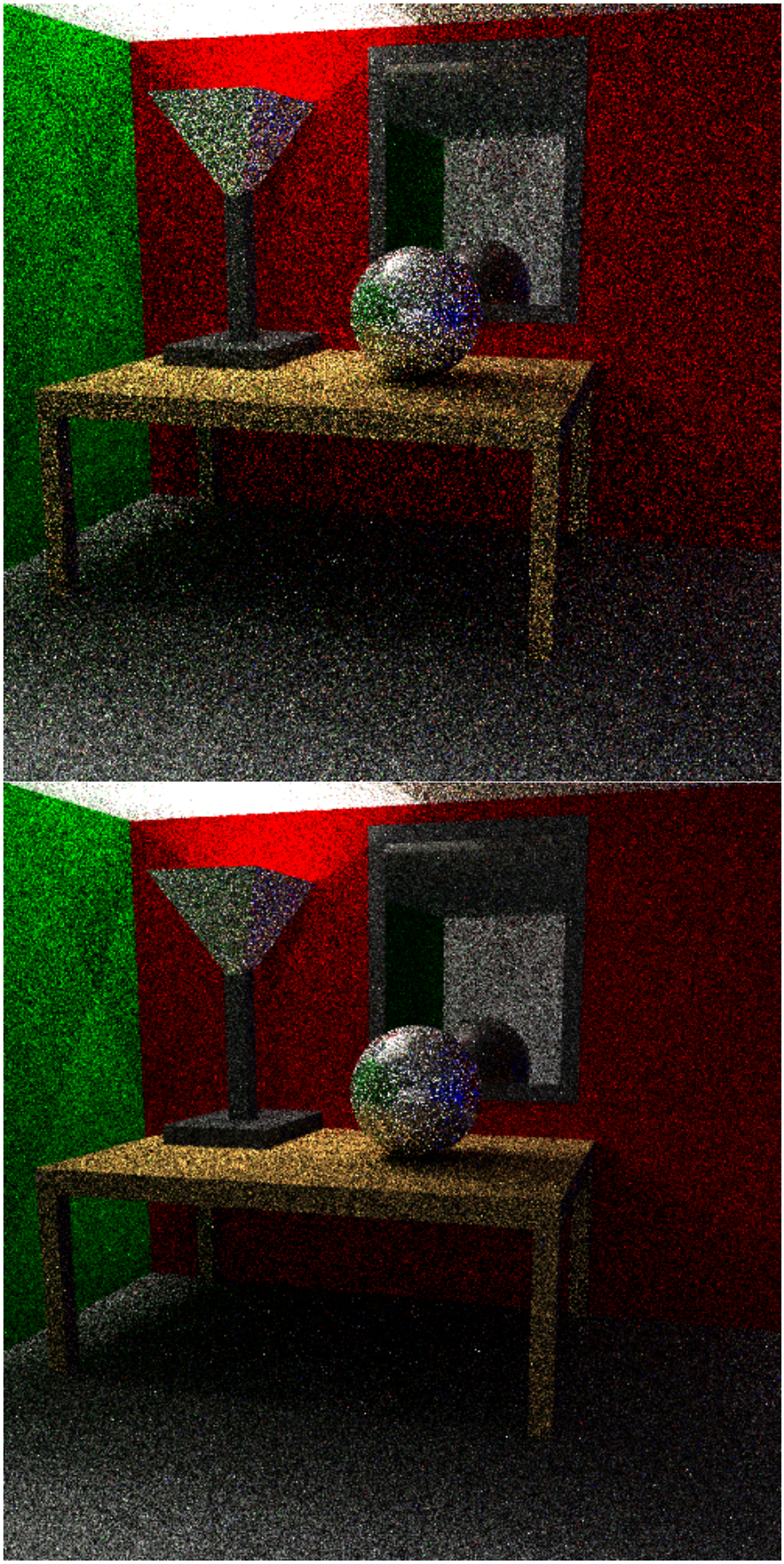

Figure 3: Top: 4 samples/pixel without importance sampling. Bottom: 4 samples/pixel with importance sampling

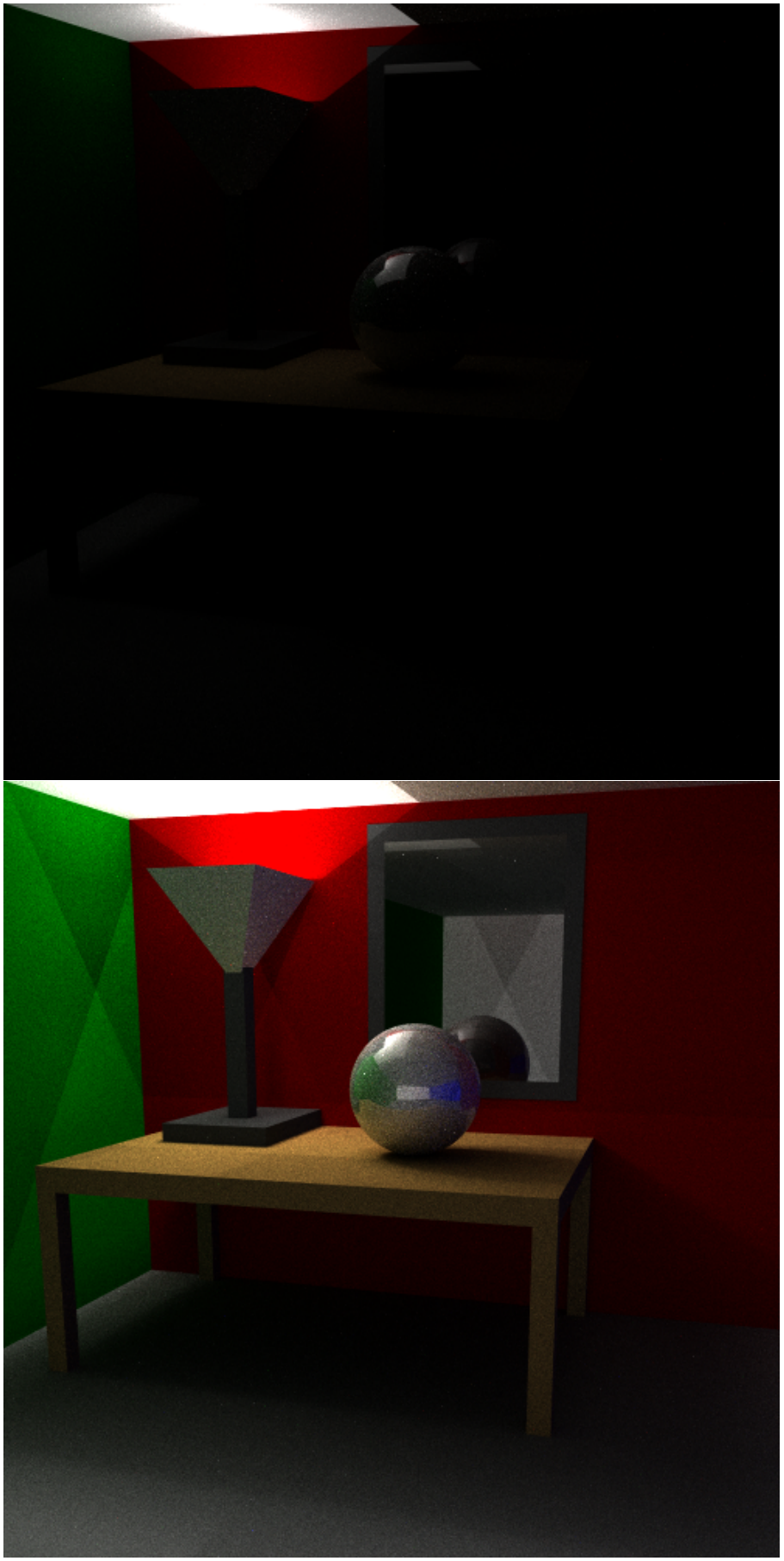

Figure 4: Top: 256 samples/pixel with regular path tracing, 4m 22s render time. Bottom: 256 samples/pixel with bidirectional path tracing, 12m 0s render time.

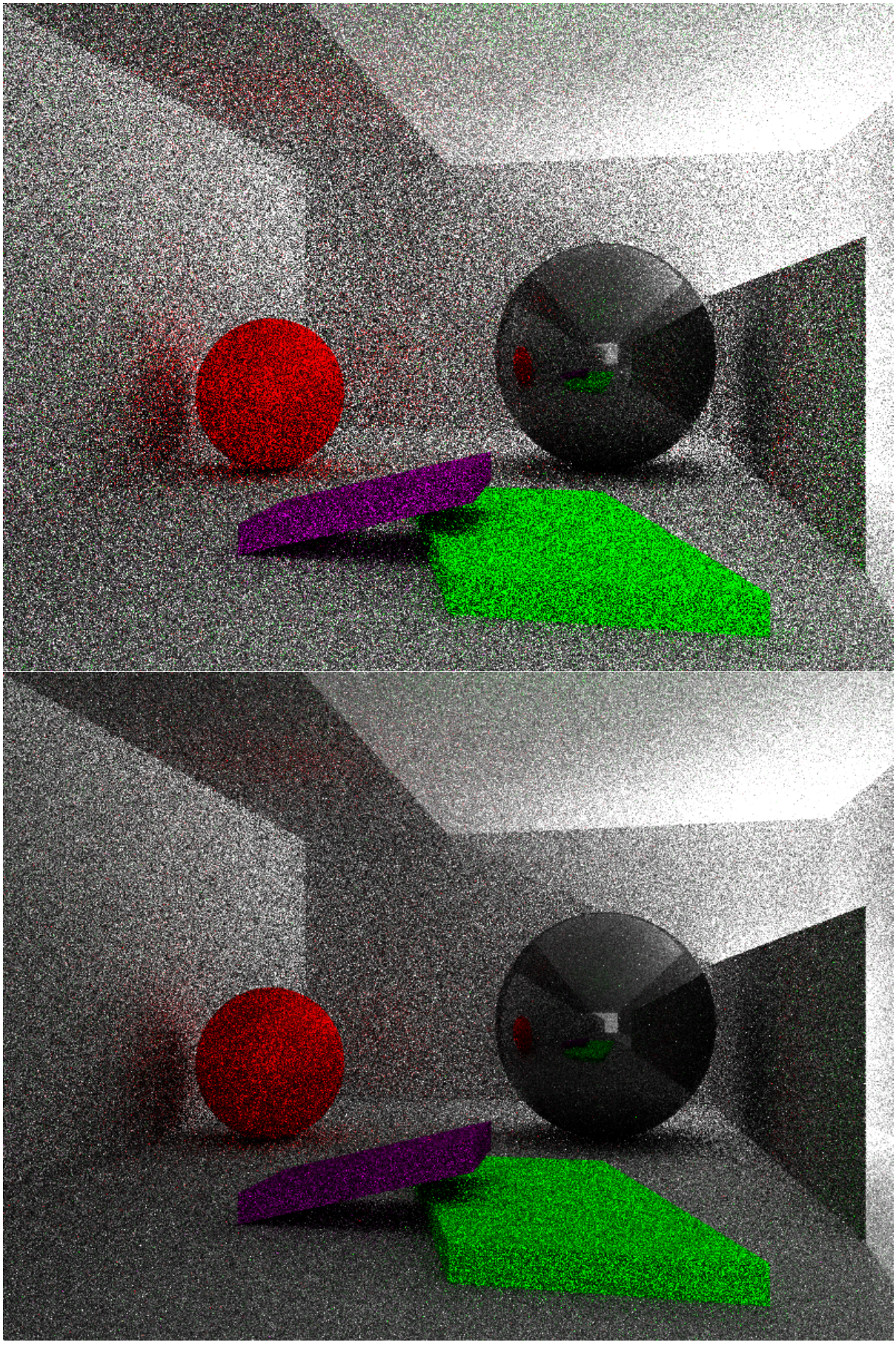

Figure 5: Top: 4 samples/pixel without importance sampling. Bottom: 4 samples/pixel with importance sampling

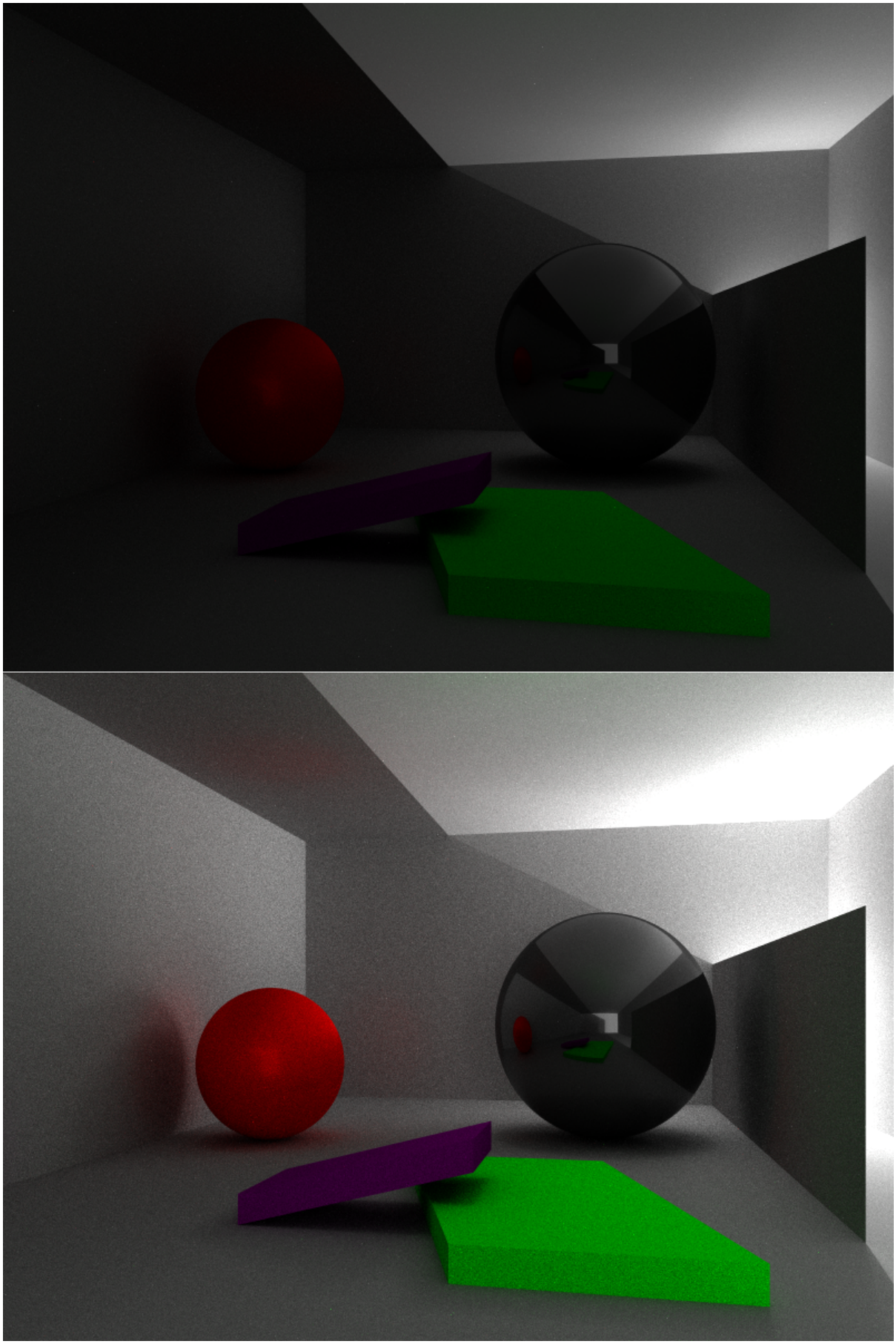

Figure 6: Top: 256 samples/pixel with regular path tracing, 5m 22s render time. Bottom: 256 samples/pixel with bidirectional path tracing, 14m 27s render time.

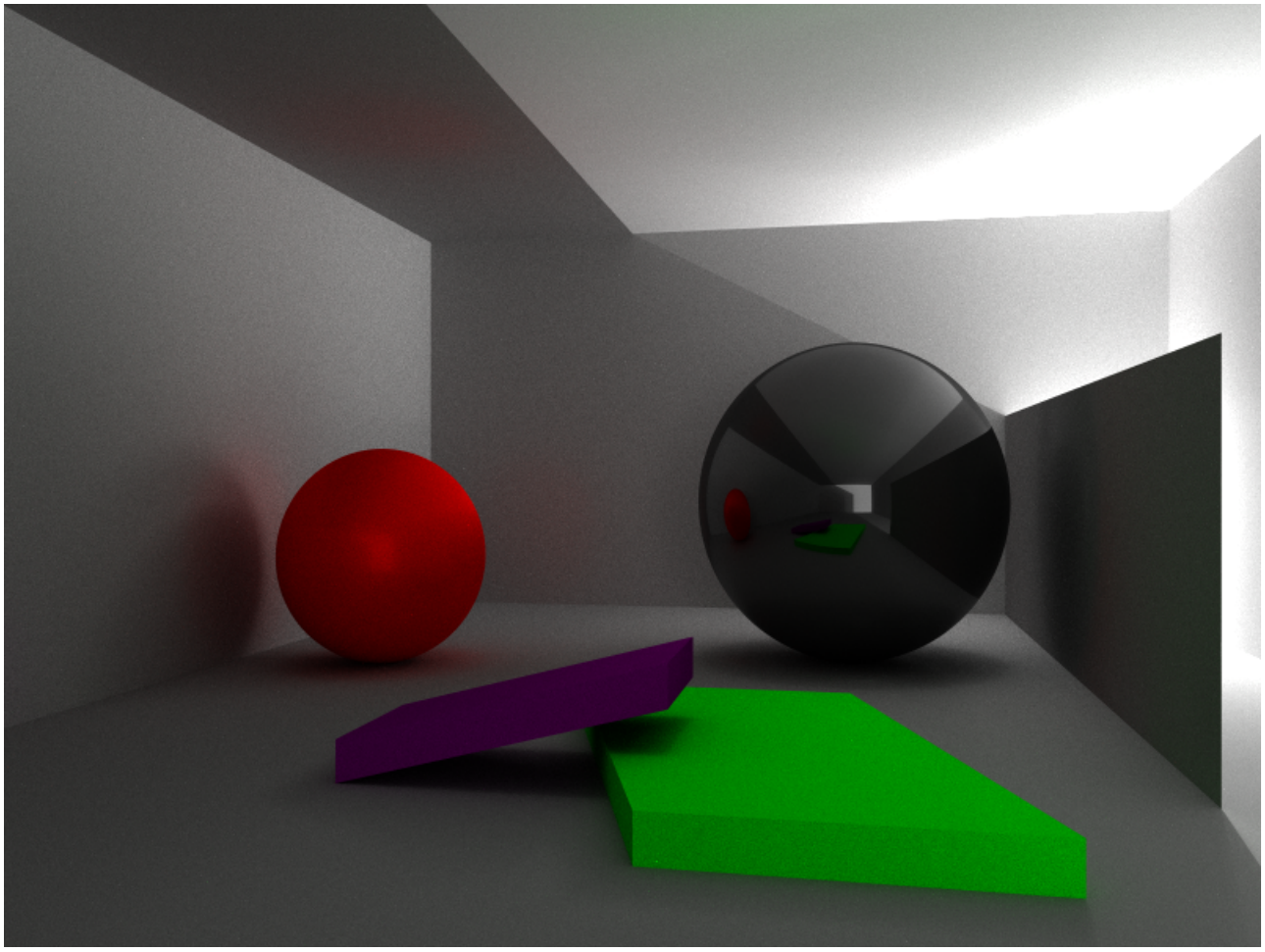

Figure 7: 1024 samples/pixel with bidirectional path tracing, 56m 38s render time

The reduction in variance from importance sampling is slight but noticeable. The difference in global illumination quality between regular path tracing and bidirectional path tracing is not very noticeable in the first scene because a majority of the lighting is direct. However, in the second and third scenes the difference is very apparent. The difference is particularly striking in the second scene, where most of the scene is very dark when regular path tracing is used, but with bidirectional path tracing the room is well lit. The downside to using bidirectional path tracing is that it takes about 3x longer to render the same scene as opposed to regular path tracing.