

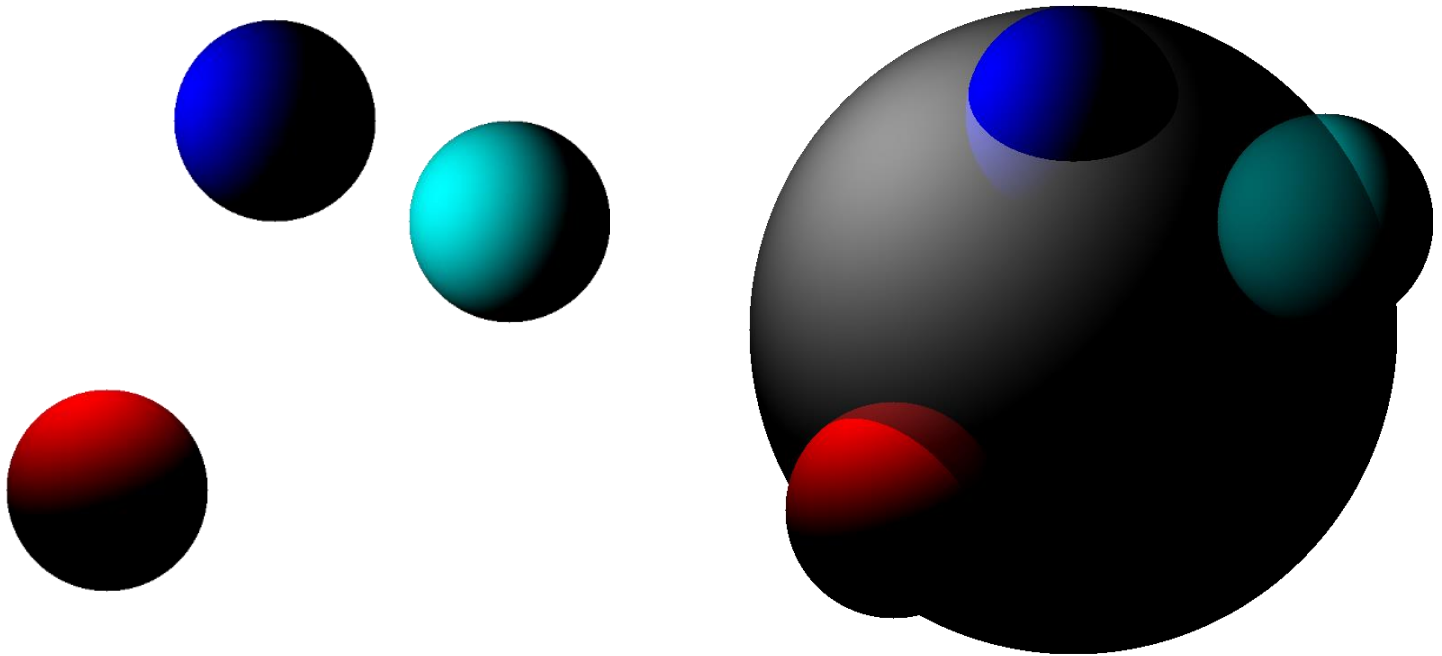
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### Task 1:

I rendered 3 different colored spheres in orthographic projection (Figure 1). To better see their positions in space, I then added a big, semi-transparent sphere as reference (Figure 2). The added sphere has an alpha of 0.5, and intersects with both the red and blue sphere; the cyan sphere is behind the transparent reference sphere.

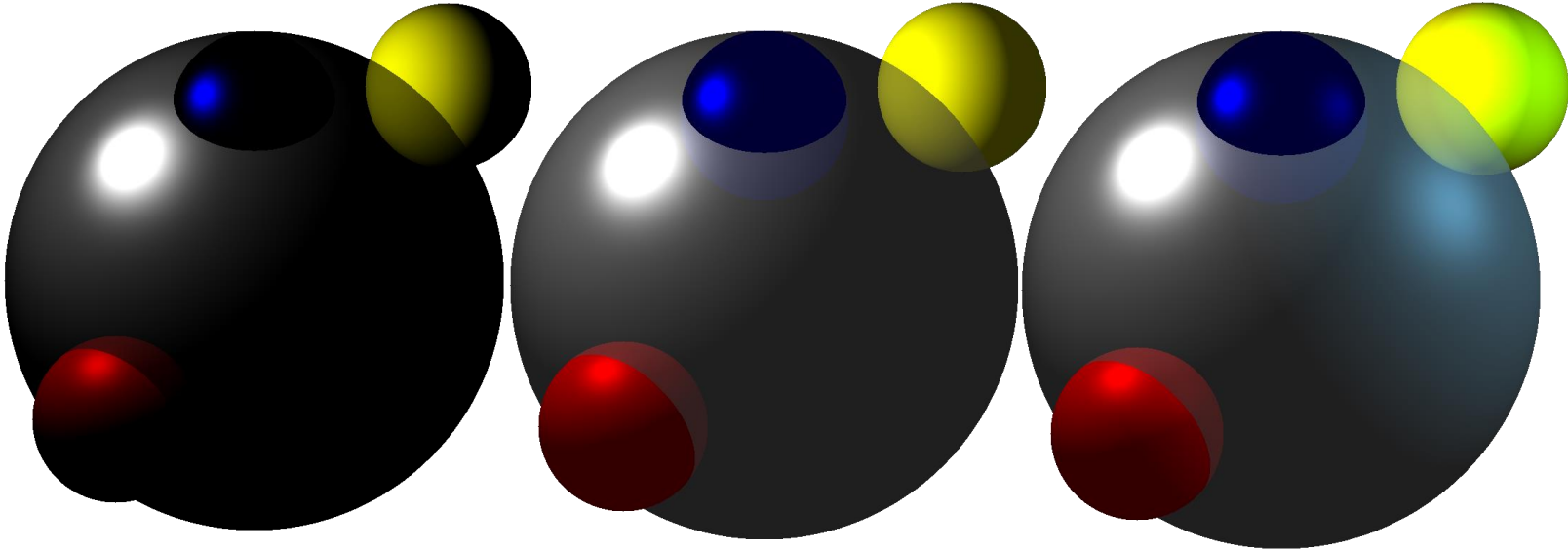
Since I tried to implement an alpha channel, I soon found rendering transparent object is not so easy with the simple z-buffer method; it's hard to calculate alpha-blending when the spheres are not rendered in sorted order. I spent a lot of time trying to figure out a solution, and found some papers on the so-called "Depth Peeling" method, but it's pretty complex to implement. So I fall back to a simpler implementation, adding the restriction that all transparent spheres (alpha > 0.99) must be rendered after all other objects has already been rendered; they also must be sorted in a strictly accending order on z-axis (non-transparent spheres could still be rendered in any order). Since I read the spheres directly from a data file, this is also the requirement for the data file if there is any transparent sphere in it.



### Task 2:

First picture is Diffuse + Specular. Second Picture is Diffuse + Specular + Ambient. Third picture adds a second light source on the right. (Yellow ball is pure diffuse. Blue ball is pure specular. Red ball has both. Gray ball has all + semi-transparent.)

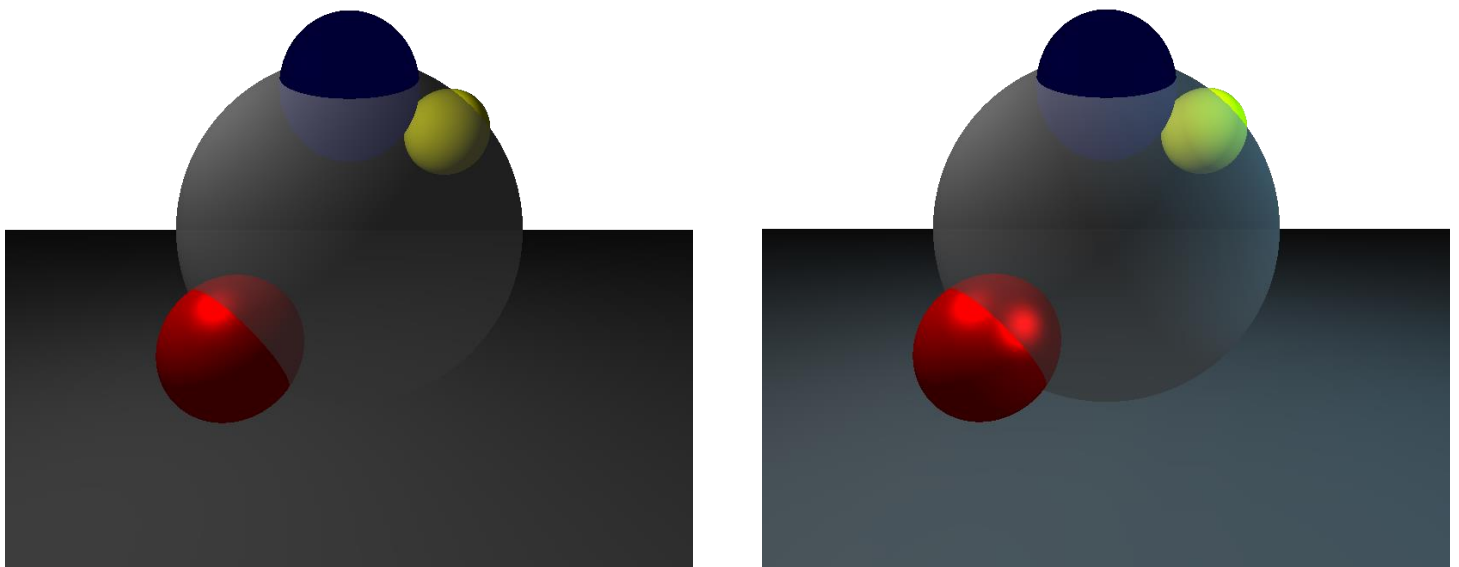
All parameter details can be seen in the file "data/spheres\_1.dat" by opening it with a text editor.



### Task 3:

The second and third pictures in Task 2 re-rendered in perspective projection (1 and 2 light sources respectively).

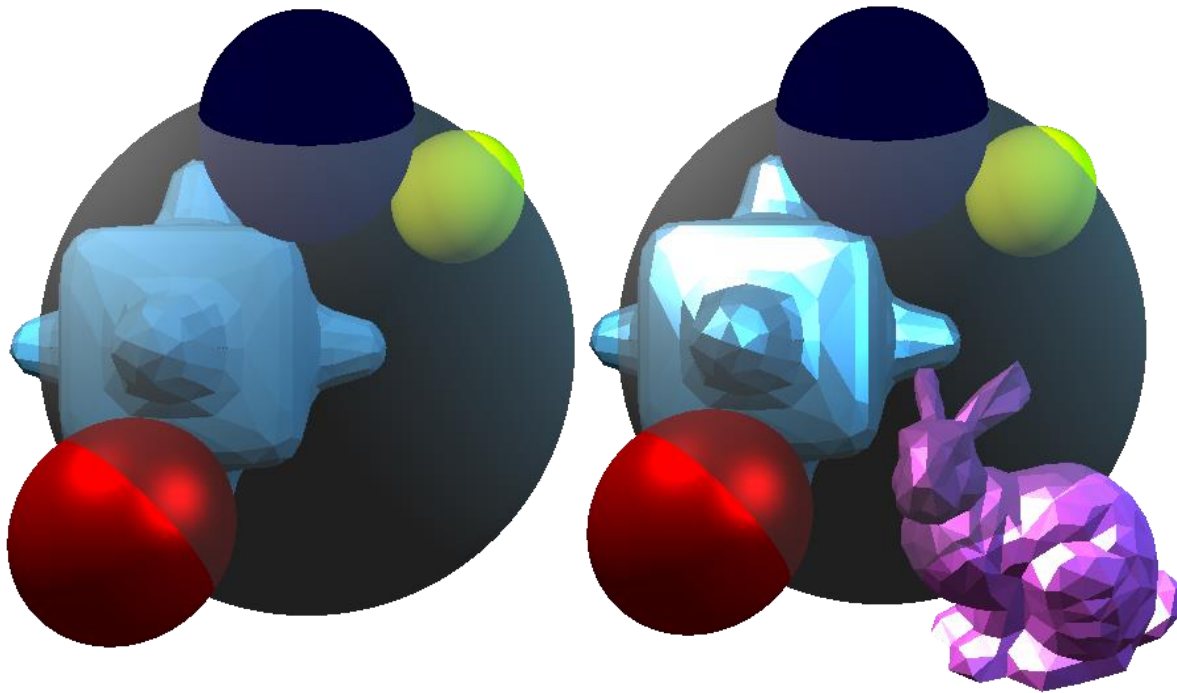
We can now see the floor (which is rendered with diffuse only). Note the blue ball seems very dim, that's because it's specular only, and from this angle we happen to not be able to see the highlight on its edge (I chose a pretty drastic perspective angle to show the difference from orthographic projection).



#### Task 4:

Loaded meshes into the same scene. Both are scaled and translated for better display.

First picture renders the meshes with diffuse only; second picture renders meshes with both diffuse and specular.

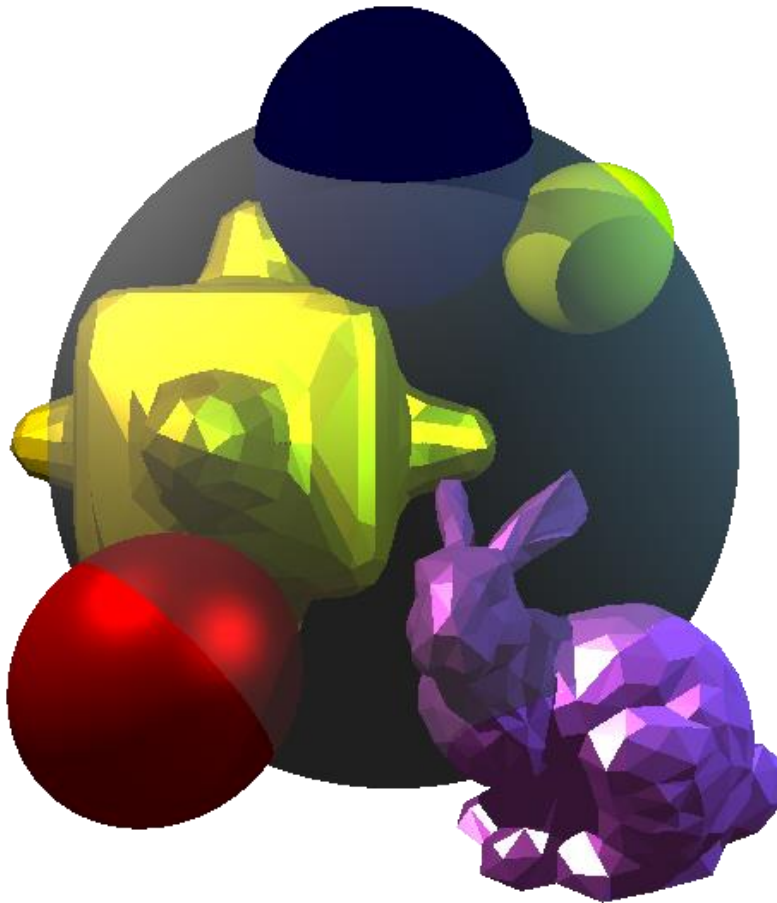


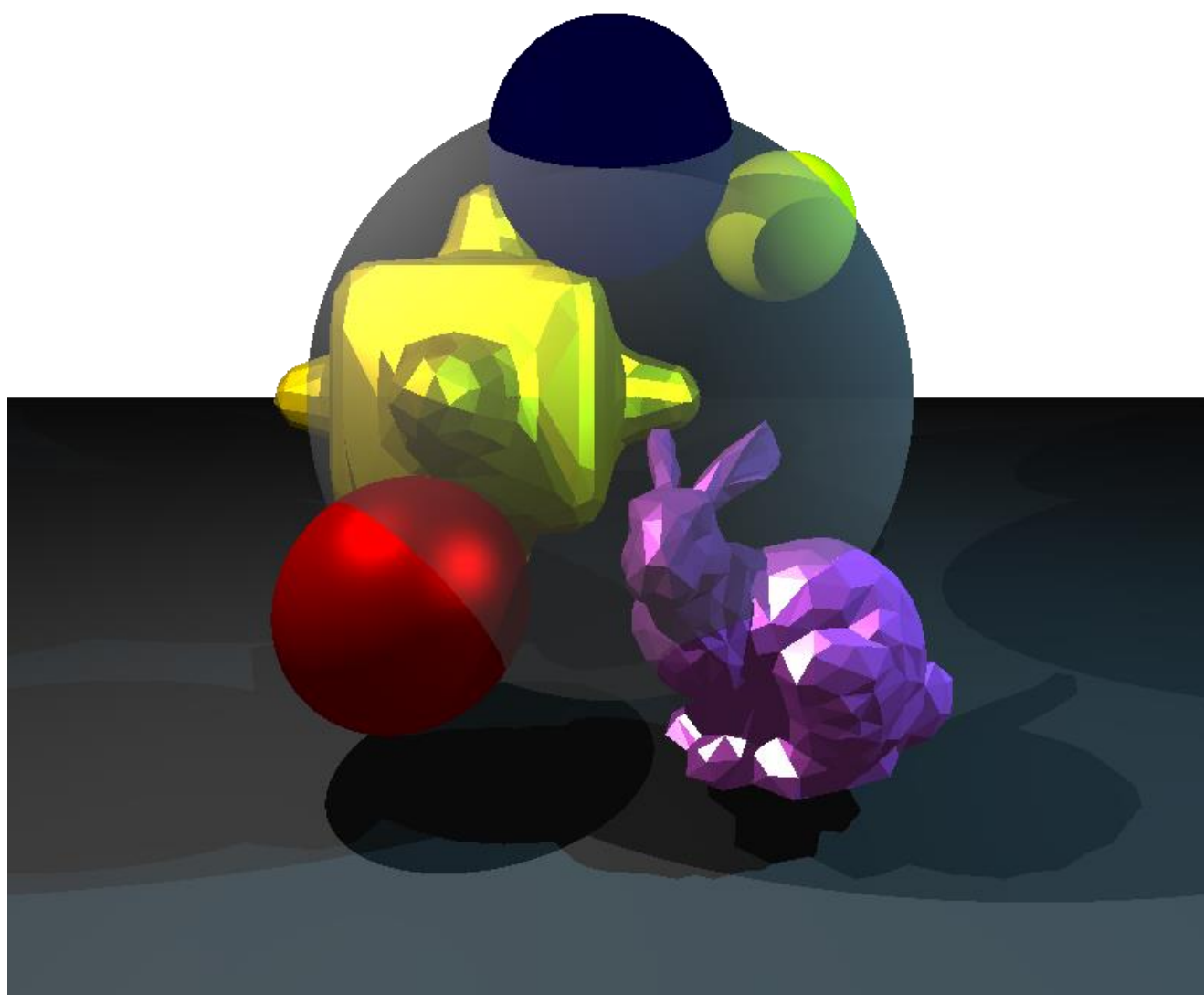
### Task 5:

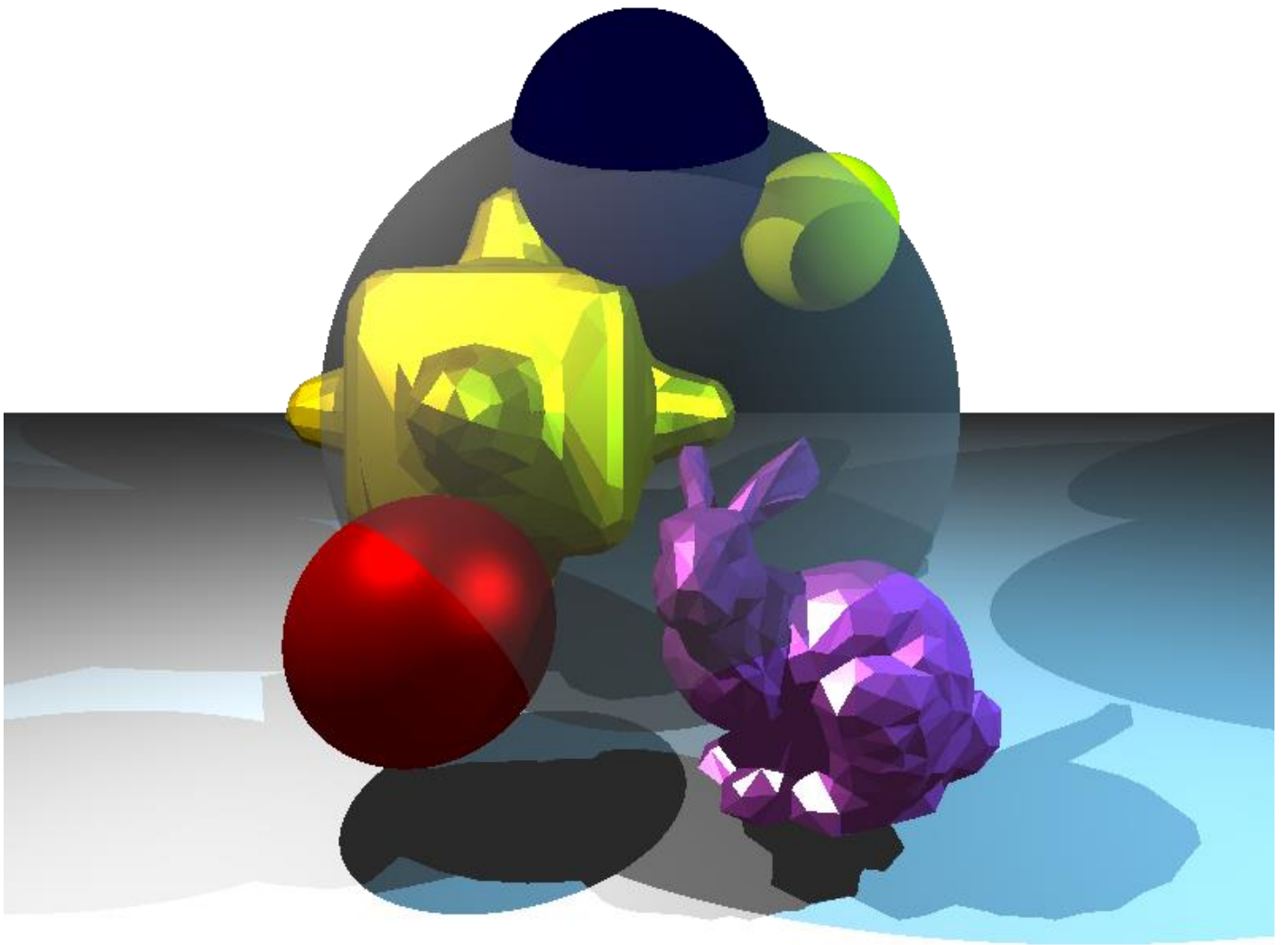
Added shadows. The first picture is without floor. Second is with floor added. In the third picture, I changed the floor color to white to make the shadows easier to see. (For the first picture, the most obvious shadows are on the yellow sphere in the back. There are two light sources in the scene.)

I made semi-transparent objects to dim the light source in proportion to its alpha value instead of casting a full shadow.

(I also changed color of the bumped cube to gold because I'm a little color blind and it's hard for me to distinguish blue and purple. )

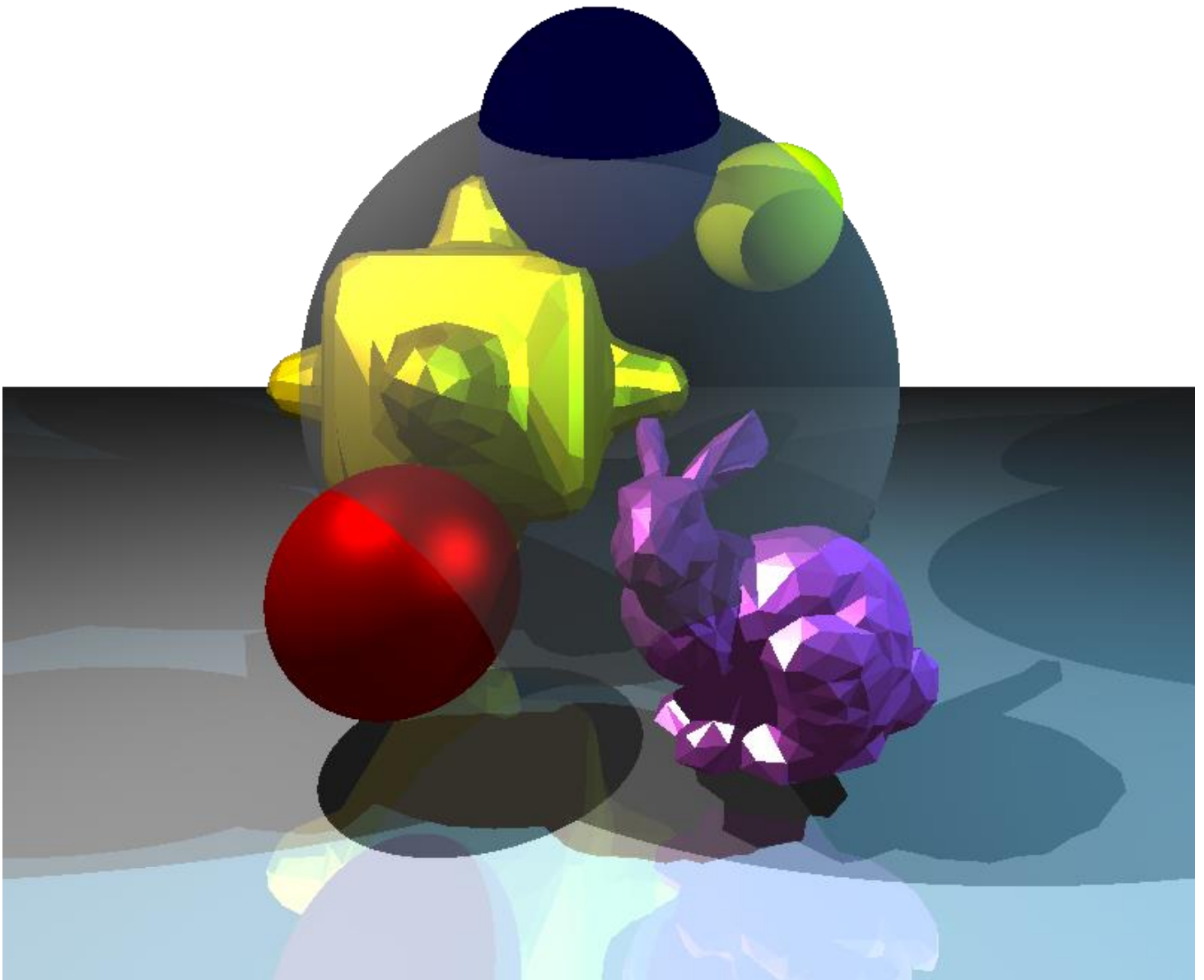


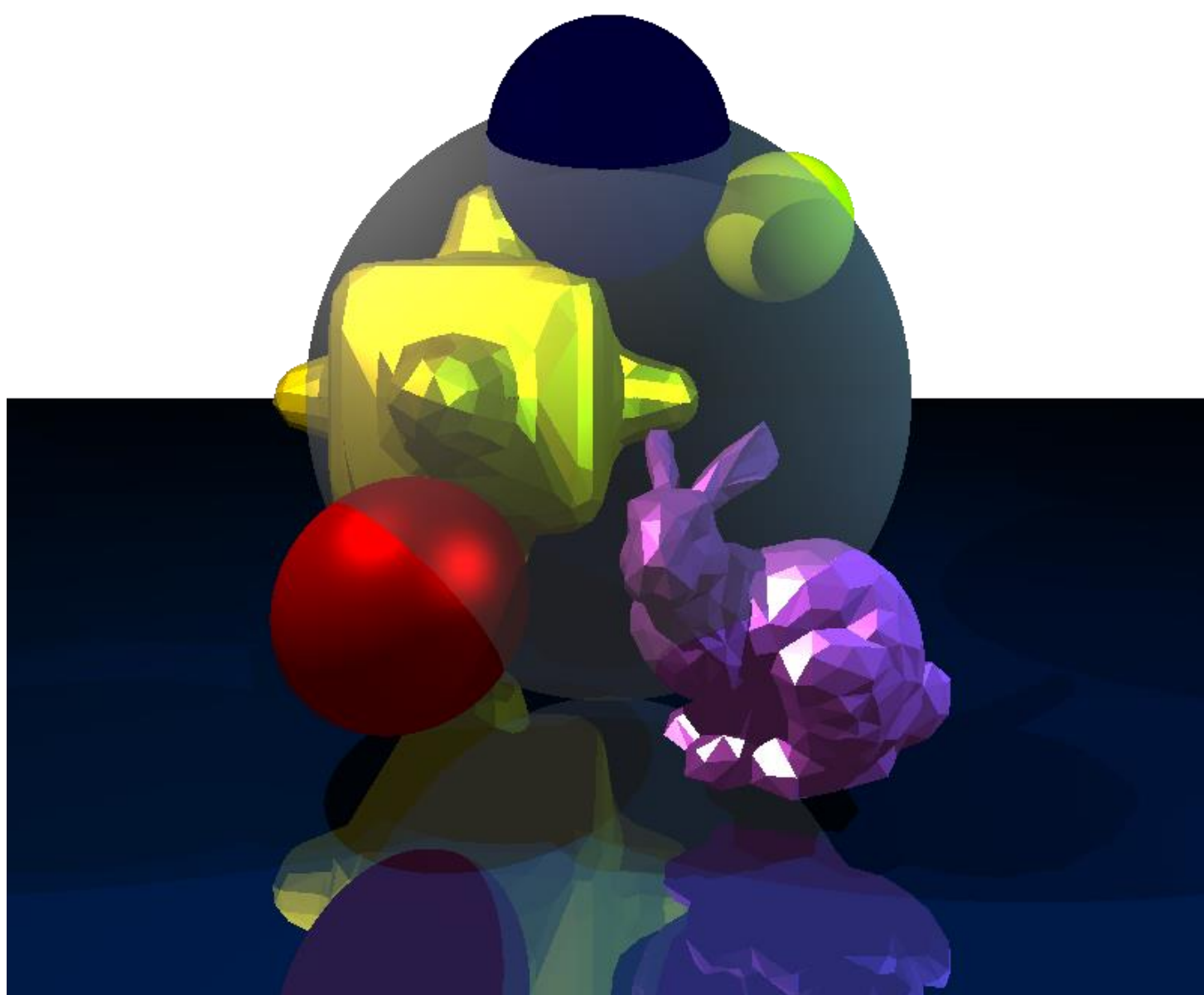




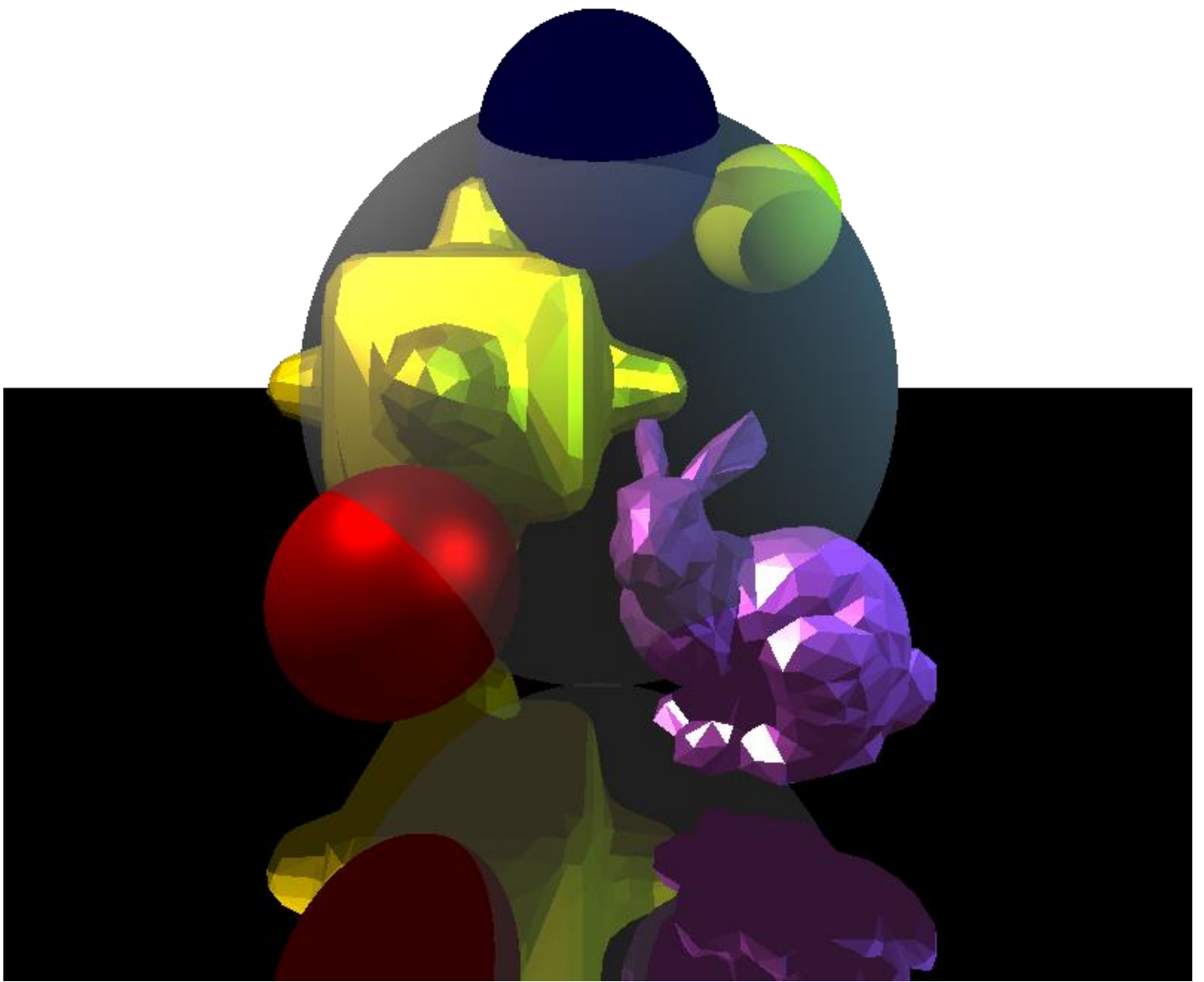
Task 6:

Added floor reflection. First picture is white floor with reflection coefficient set to 0.5. Second picture is blue floor with reflection coefficient set to 0.8. Third picture is blue floor with reflection coefficient set to 1.0 (the floor looks black because it's pure reflection without any diffuse).









#### Additional task 1:

Added an option (a compilation flag in the form of a macro define) to use `tbb::parallel_for()` function for looping through each ray. The submitted version has the flag turned off.

To enable parallel computation, uncomment `"#define TBB_PARALLEL"` in the source file then compile.

#### Additional task 2:

An animation of a scene with a grid of 1000 spheres. During the animation the camera perspective angle continuously changes, as well as two moving light sources (one along z-axis, the other along x-axis). The spheres data file is generated with a simple script (`"generate_spheres_grid_file.cpp"`) in the `"data"` folder. Below are some frames of the animation (the full output can be seen in the `"output"` folder).

