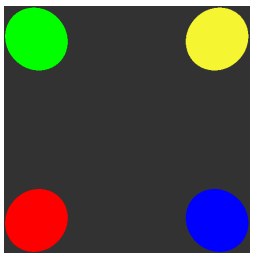
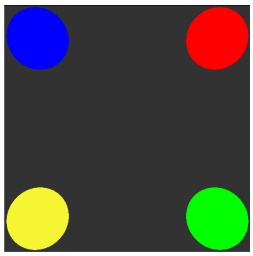
1. How does the direction of the ‘up’ vector affect the rendered view of a scene? You should specifically consider tipping the ‘up’ vector from side to side and forward to back. You will want to define scenes with multiple objects, asymmetrically arranged, to explore this question.

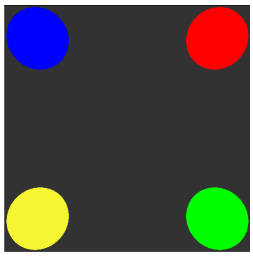
The up vector affects the rendered view by rotating the scene around the viewing direction. For example, a scene with a viewing direction of <0, 0, -1> (looking directly down the z axis) and an up direction of <0, 1, 0> renders 4 spheres like this:



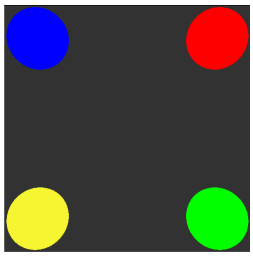
The same scene, same viewing direction, with an up direction of <0, -1, 0> renders 4 spheres like this, an exact 180 degree rotation (just as the vectors <0,1,0> and <0,-1,0> are rotated 180 degrees from one another):



If the specified up direction is not exactly orthogonal to the viewing direction, the vector that is used by the raytracer is the projection of the specified up direction onto the plane orthogonal to the viewing direction. Thus the up direction does not change the viewing direction. The contents of the same scene, same viewing direction, with an up direction of <0, -1, -1>, renders 4 spheres like this, the exact same as with an up direction of <0, -1, 0> (since the projection of <0, -1, -1> onto the plane perpendicular to the viewing direction <0, 0, -1> is <0, -1, 0>):



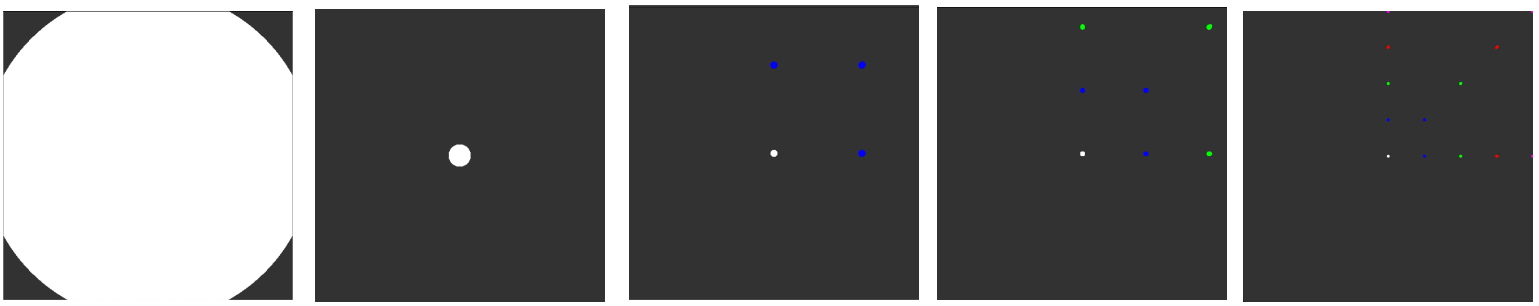
Lastly, the length of the up direction does not affect the rendered scene. This is the contents of the same scene, same viewing direction, with an up direction of <0, -2, -2>>:



2. How do changes in the FOV settings affect the contents of your rendered images? Please explicitly consider images with a range of different aspect ratios.

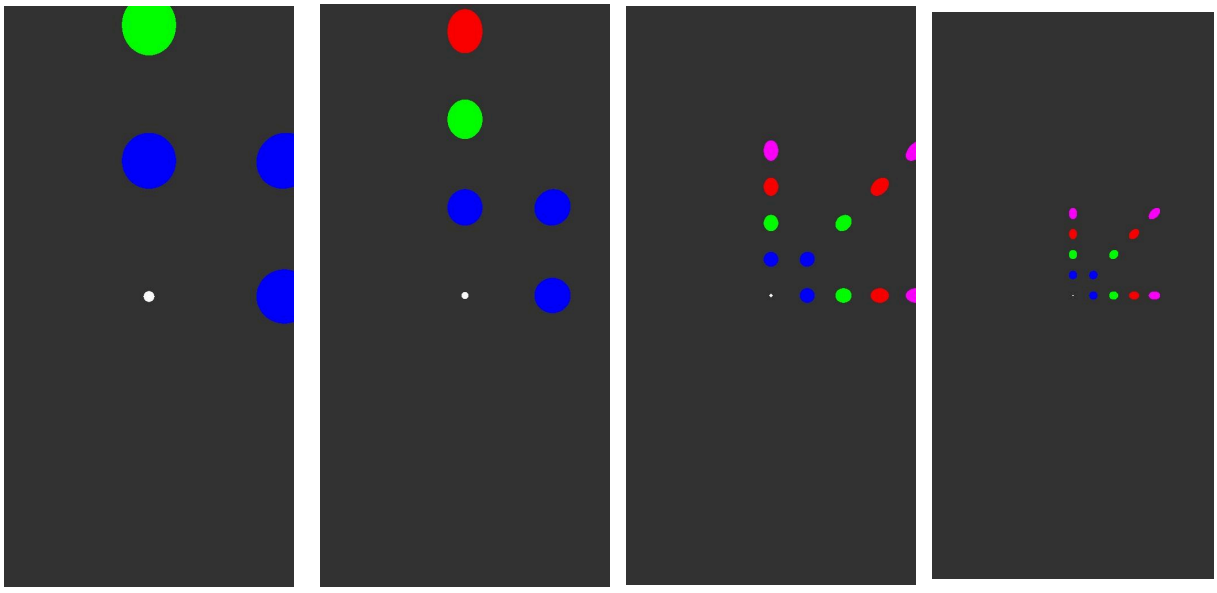
Changes in the FOV settings affect the amount of the scene that is visible. However, the amount of distortion is radially symmetrical: it grows with distance from the center of the scene, unaffected by the aspect ratio. Thus a tighter FOV causes less distortion towards the edges of the screen because the things it's displaying are closer to the center of the scene, while a larger FOV causes greater distortion because it shows objects farther from the center.

1:1 aspect ratio: distortion is equal in all directions, stretching objects away from the center



1° 15° 30° 45° 60°

2:1 aspect ratio: distortion again equal in all directions (objects enlarged to show this)



15° 30° 45° 60°

3. How do various modifications of the viewing parameters affect the amount of perspective distortion apparent in your image?

The greater the angle between the ray that passes through the center of the viewing window from the eye and the ray that passes through the object to the eye, the greater the perspective distortion. Thus objects that are visible and yet near the edges of renderings of scenes with a wide FOV are always the most distorted:

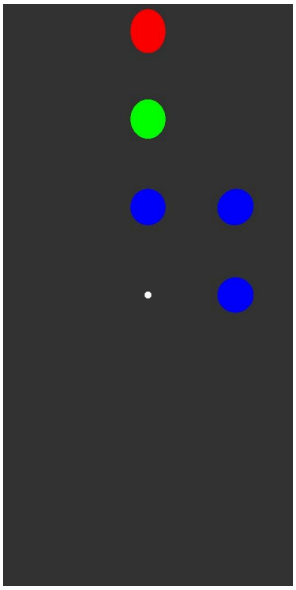


Image size can also distort the perspective; a 5x5 “grainy” image with a sphere in the center may appear like a “+” sign at the right size and distance, as shown here:

The eye’s position, the view direction, and the up direction will never affect the amount of perspective distortion as they only affect what objects will be shown (although objects’ distance and angle to the view direction can affect perspective).

The viewing parameters that affect the amount of perspective distortion are the image size, and the FOV, but they cannot act alone; the most important part of a distorted image is placing objects in the correct locations.