CSC 471

# Ray Tracing in a Weekend

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# Rays, Camera, Viewport

**Rays** - P is a 3D position along a line. o is the origin and d is the ray direction.

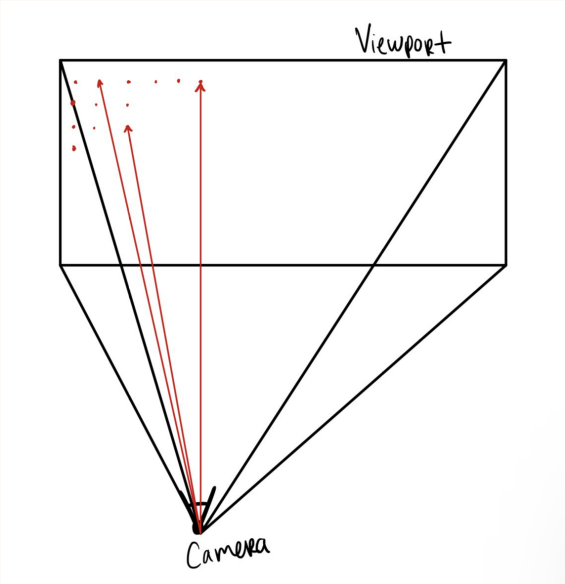
$$P(t) = \vec{o} + t\bar{d}$$

**Camera** - A point in 3D space from which we cast rays. Rays are shot from the camera through the viewport to determine what is visible.

**Viewport** - A virtual 2D display.

For every pixel, a ray is cast from the camera through the respective pixel on the viewport, then traced to see what object it intersects. The color is determined by lighting, textures, and material properties at the intersection point.

# Rays, Camera, Viewport



# Geometry

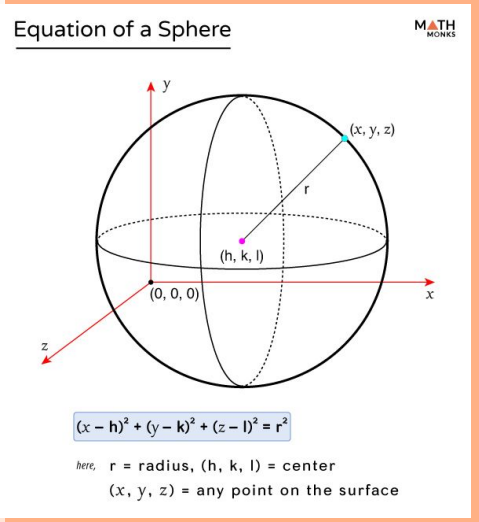
## Sphere

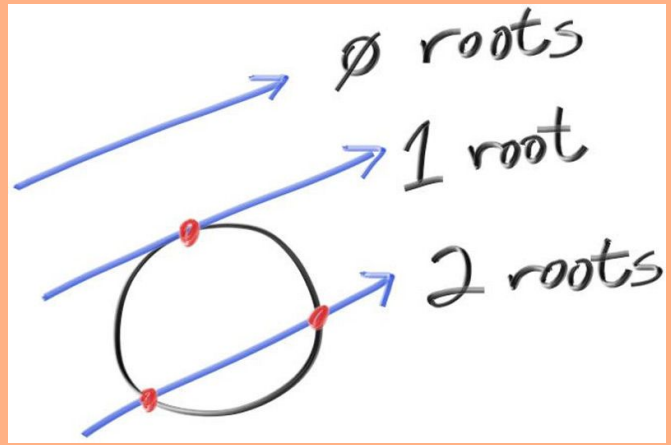
$$x^2 + y^2 + z^2 = r^2$$

$$(C_x - x)^2 + (C_y - y)^2 + (C_z - z)^2 = r^2$$

$$t^2\vec{d} \cdot \vec{d} - 2t\vec{d} \cdot (\vec{C} - \vec{o}) + (\vec{C} - \vec{o}) \cdot (\vec{C} - \vec{o}) - r^2$$

## Intersection Points



# Materials

## Lambertians (Diffuse) -

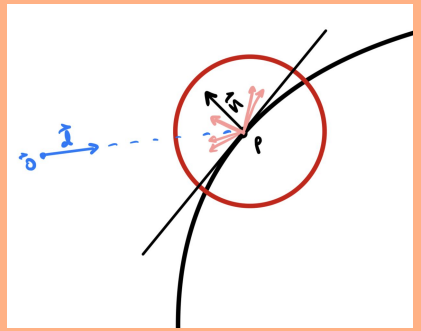
- Scatter light in all directions, creating a soft, non-shiny look
- The surface color depends on how much light is absorbed and reflected

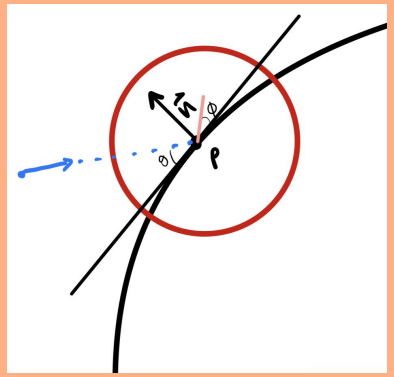
## Metals (Reflective) -

- Reflections depending on how smooth the surface is
- Rough metals create blurry reflections, while polished metals have sharp reflections.

## Dielectrics (Transparent) -

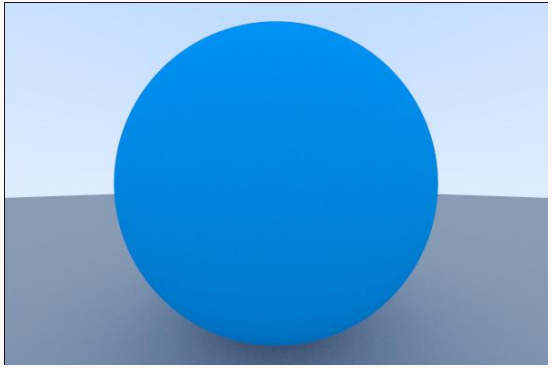
- Allow light to pass through while bending it based on their refractive index.



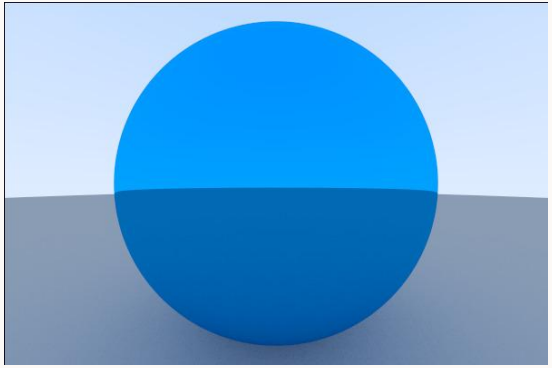



# Materials

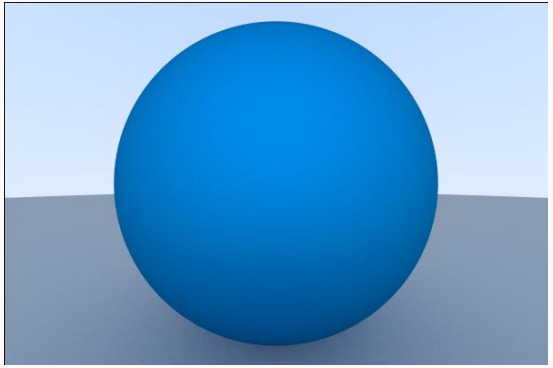
Lambertian



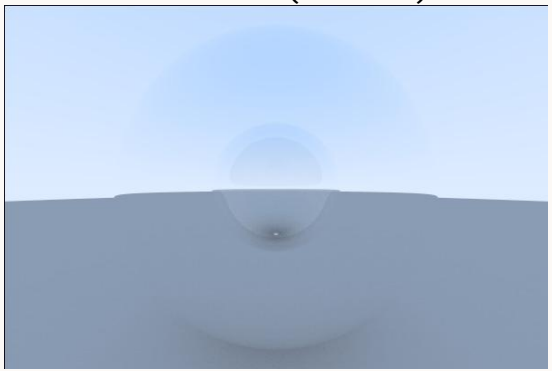
Metal (0 fuzz)



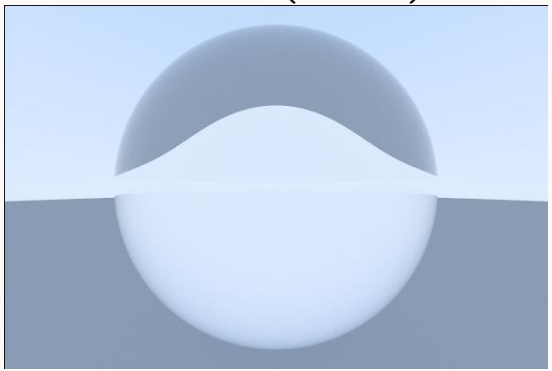
Metal (1 fuzz)



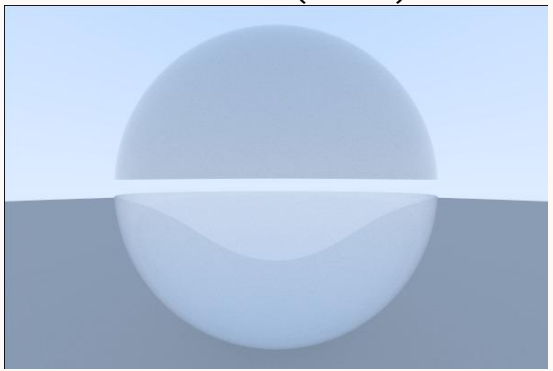
Dielectric (RI = 0.5)



Dielectric (RI = 1.5)

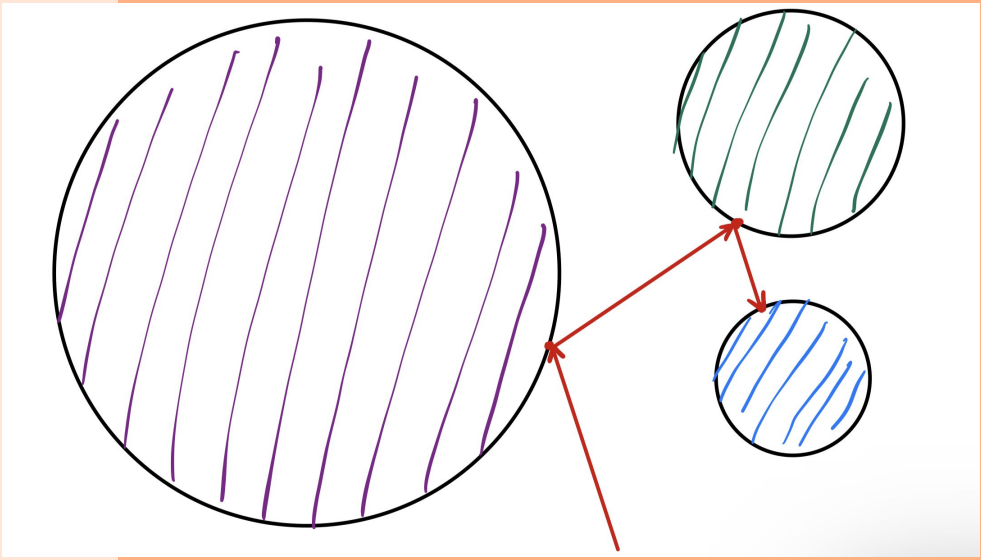


Dielectric (RI = 3)

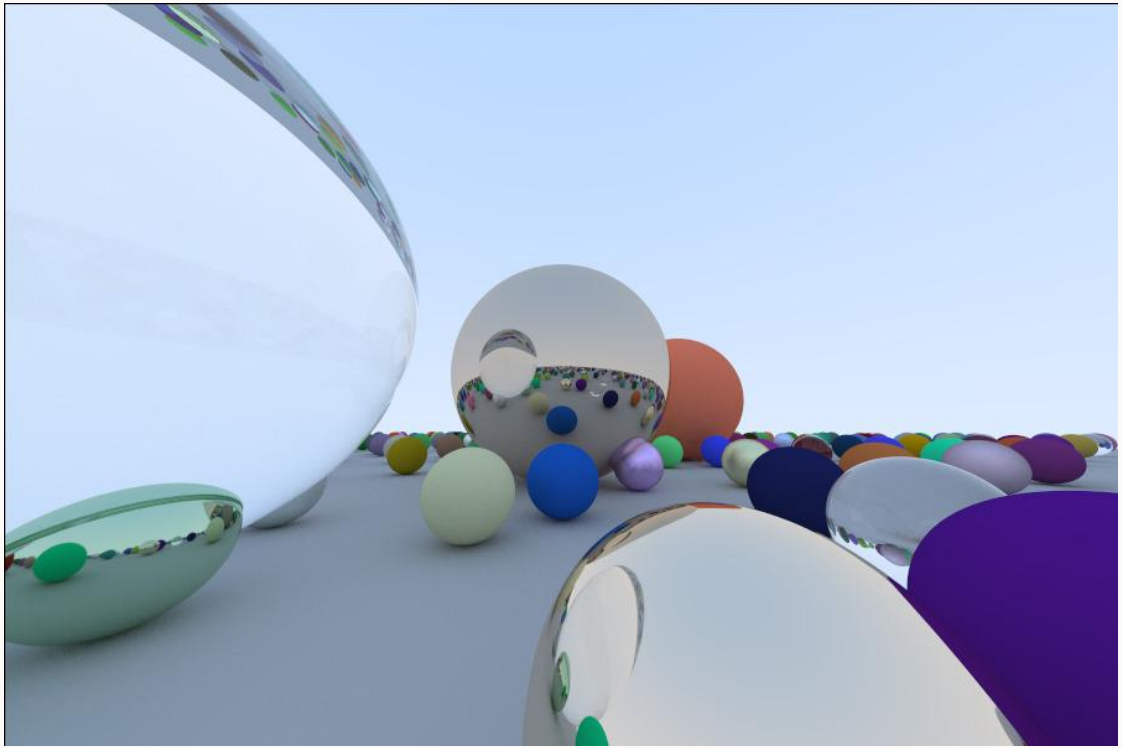


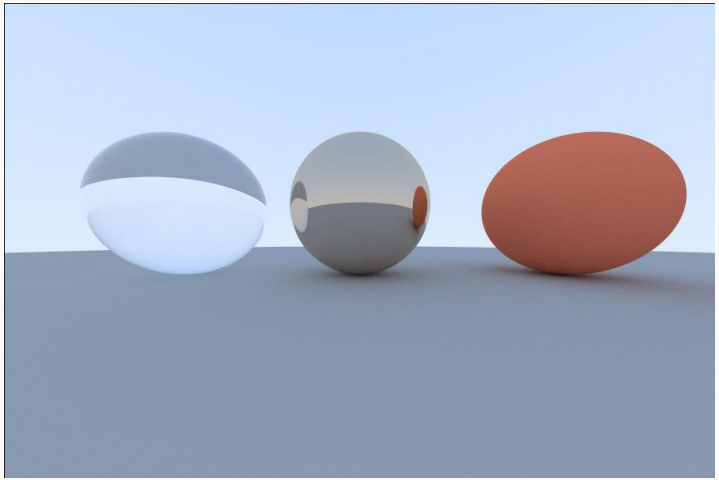
# Child Rays

- Generated when a primary ray interacts with a surface. They handle effects like reflections, refractions, and shadows by tracing additional rays from the intersection point

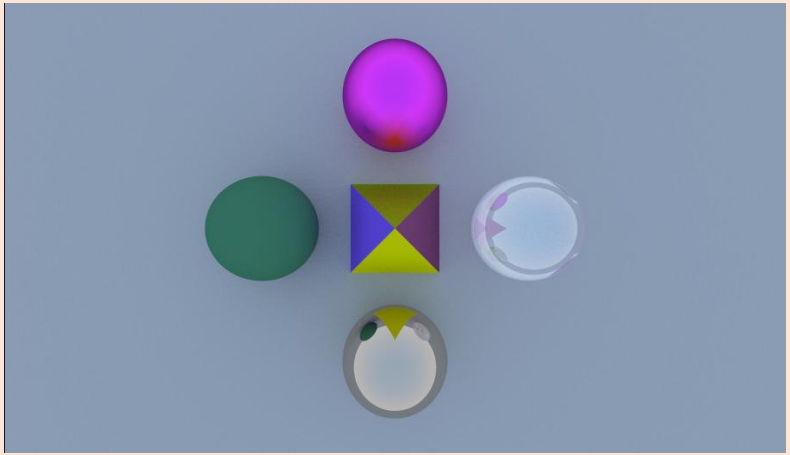


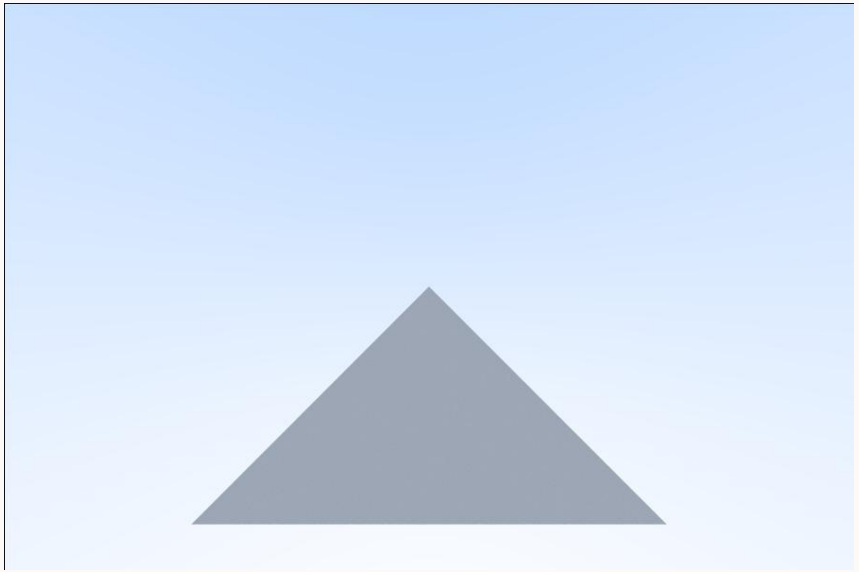
# Results (no blur)





# Triangle and Meshes

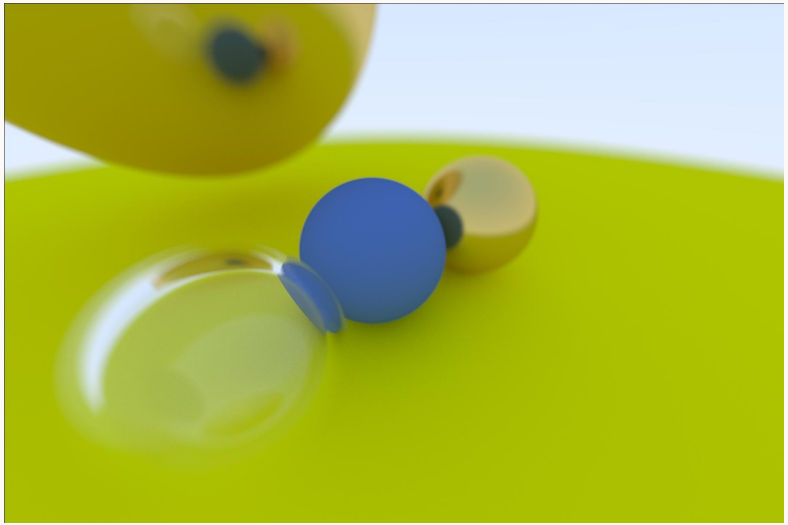


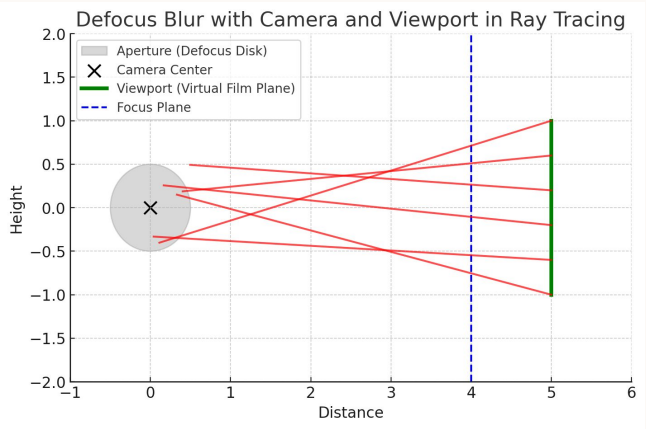


# Camera

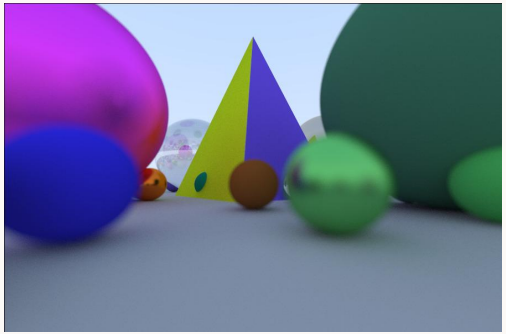
## Defocus blur (Depth of field)

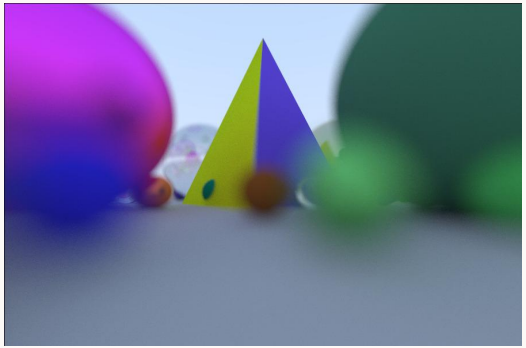
- Simulates the way real cameras focus on objects at a specific distance while blurring others
- Instead of tracing rays from a single point (camera), randomly sample rays from a thin lens (a small disk around the camera center), passing through a focus plane where objects appear sharp
- The larger the defocus disk, the more blur is applied to objects outside the focus distance. Rays from different points on the lens create slight variations in pixel colors, producing the blur effect. This technique mimics real-world depth of field, making the rendered image more realistic.

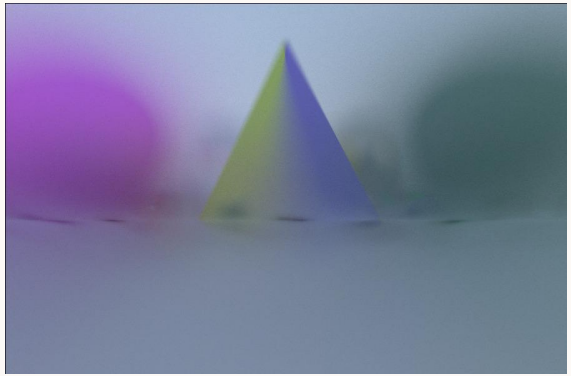


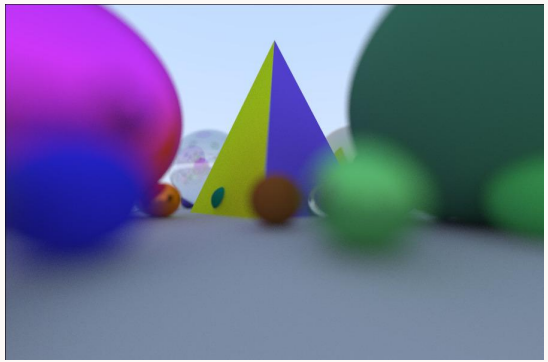


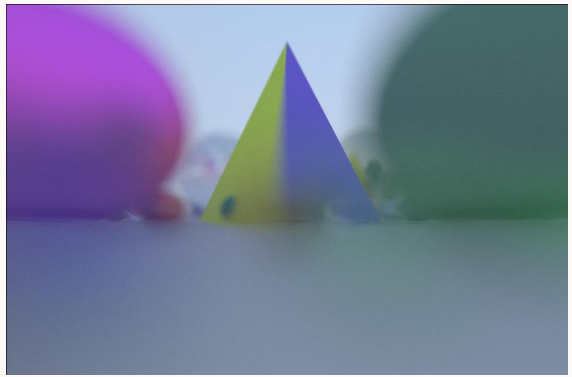
# Final Results (blur)



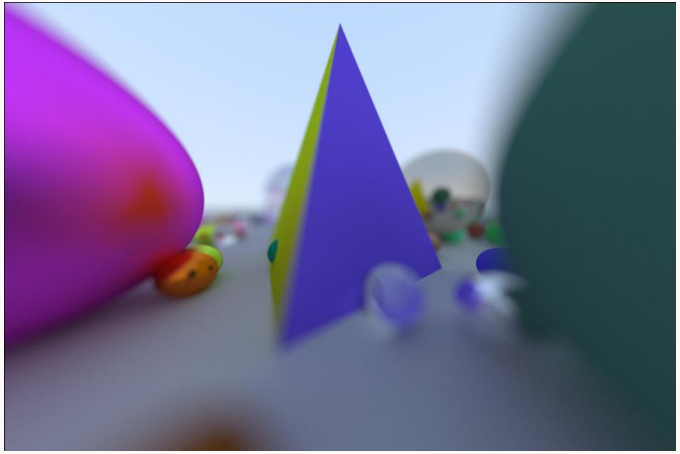


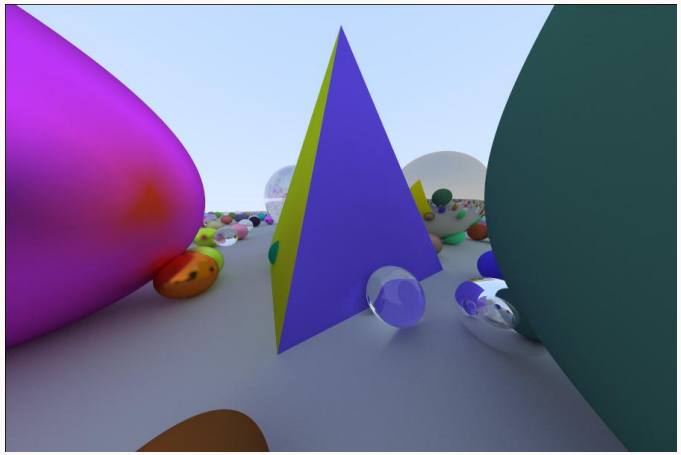


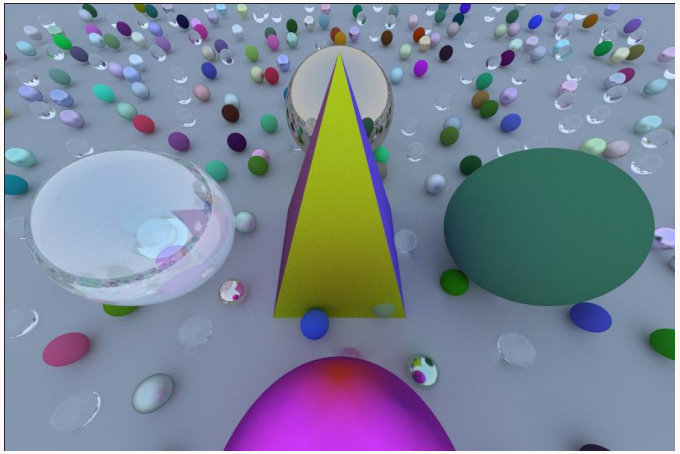


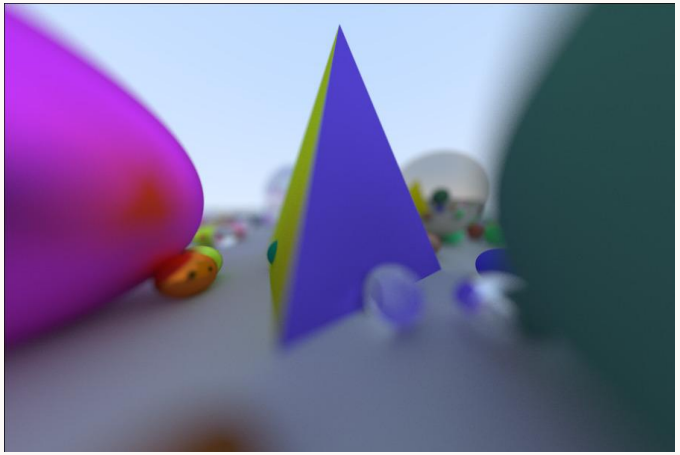


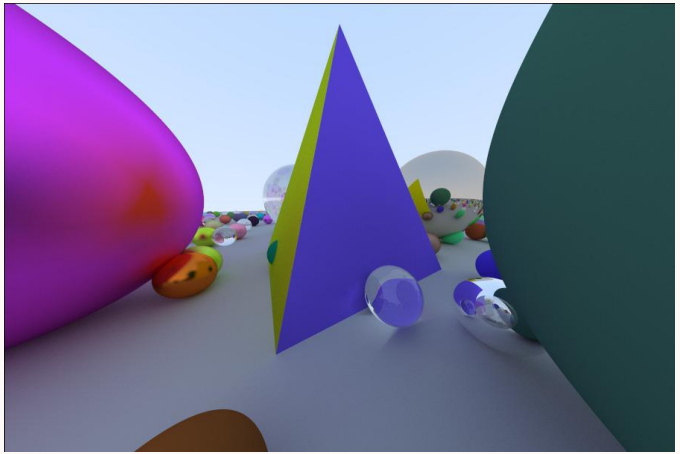
# More Results

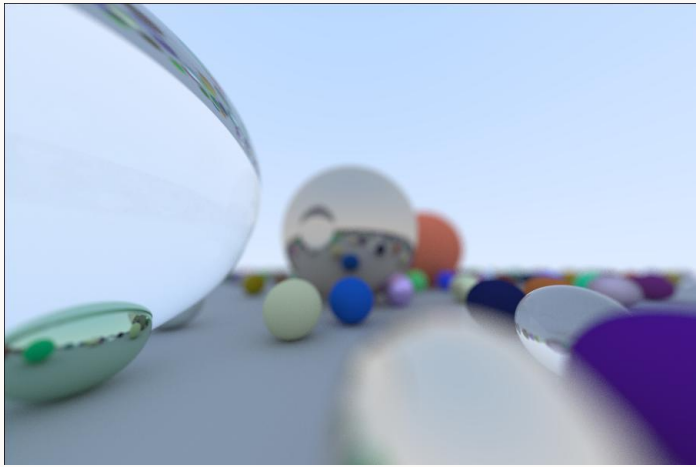


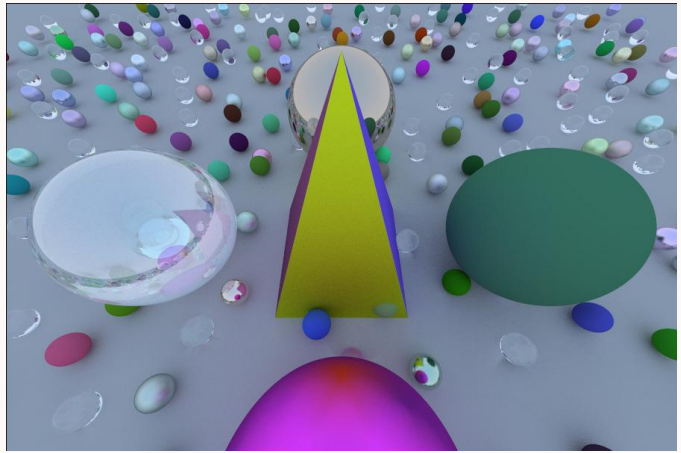












# References:

https://raytracing.github.io/books/RayTracingInOneWeekend.html

https://www.scratchapixel.com/lessons/3d-basic-rendering/ray-tracing-rendering-a-triangle/moller-trumbore-ray-triangle-intersection.html