Ray Tracing

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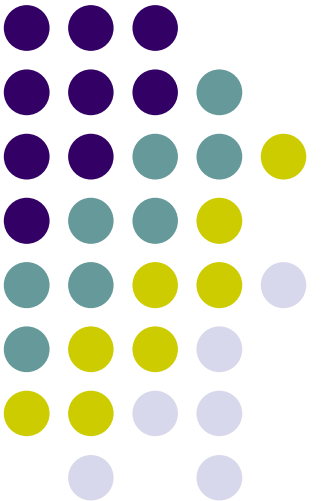
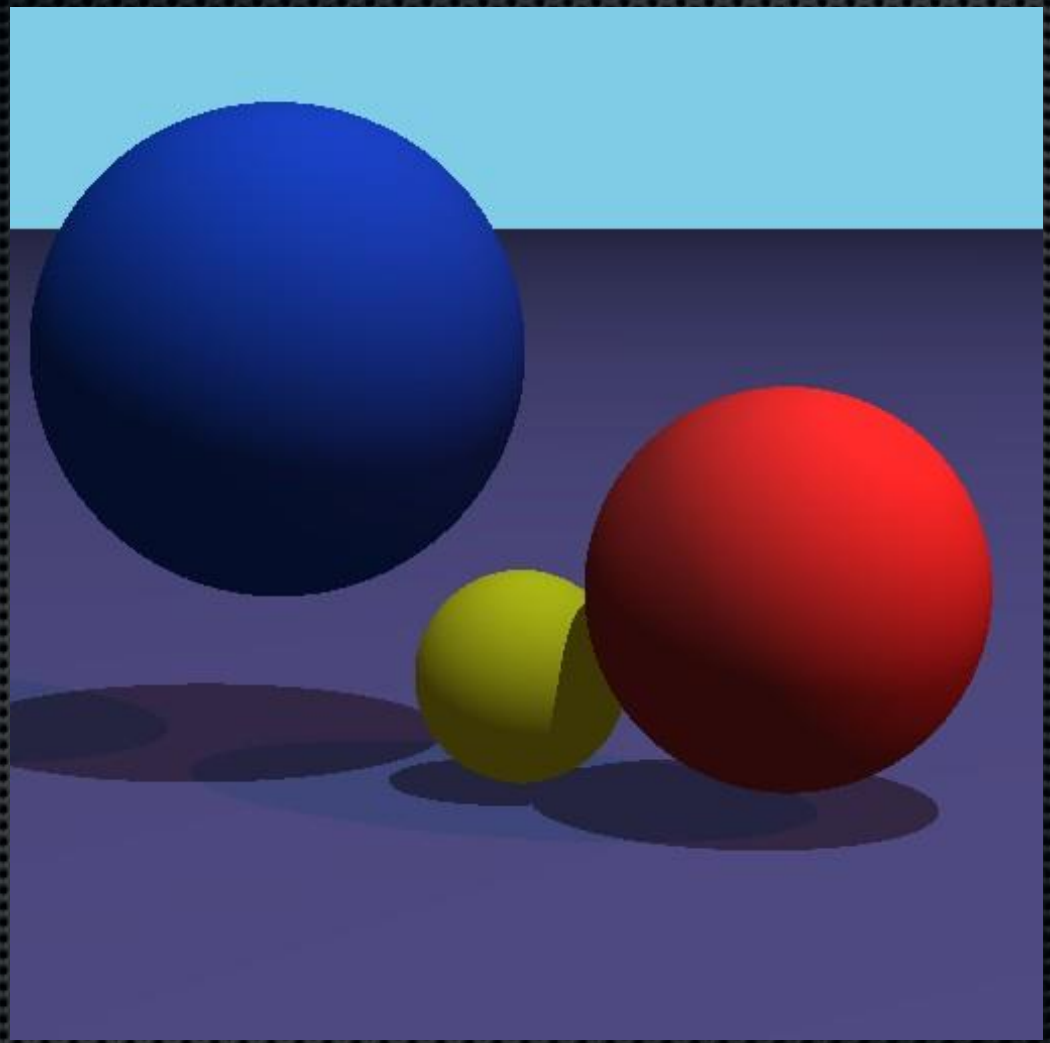
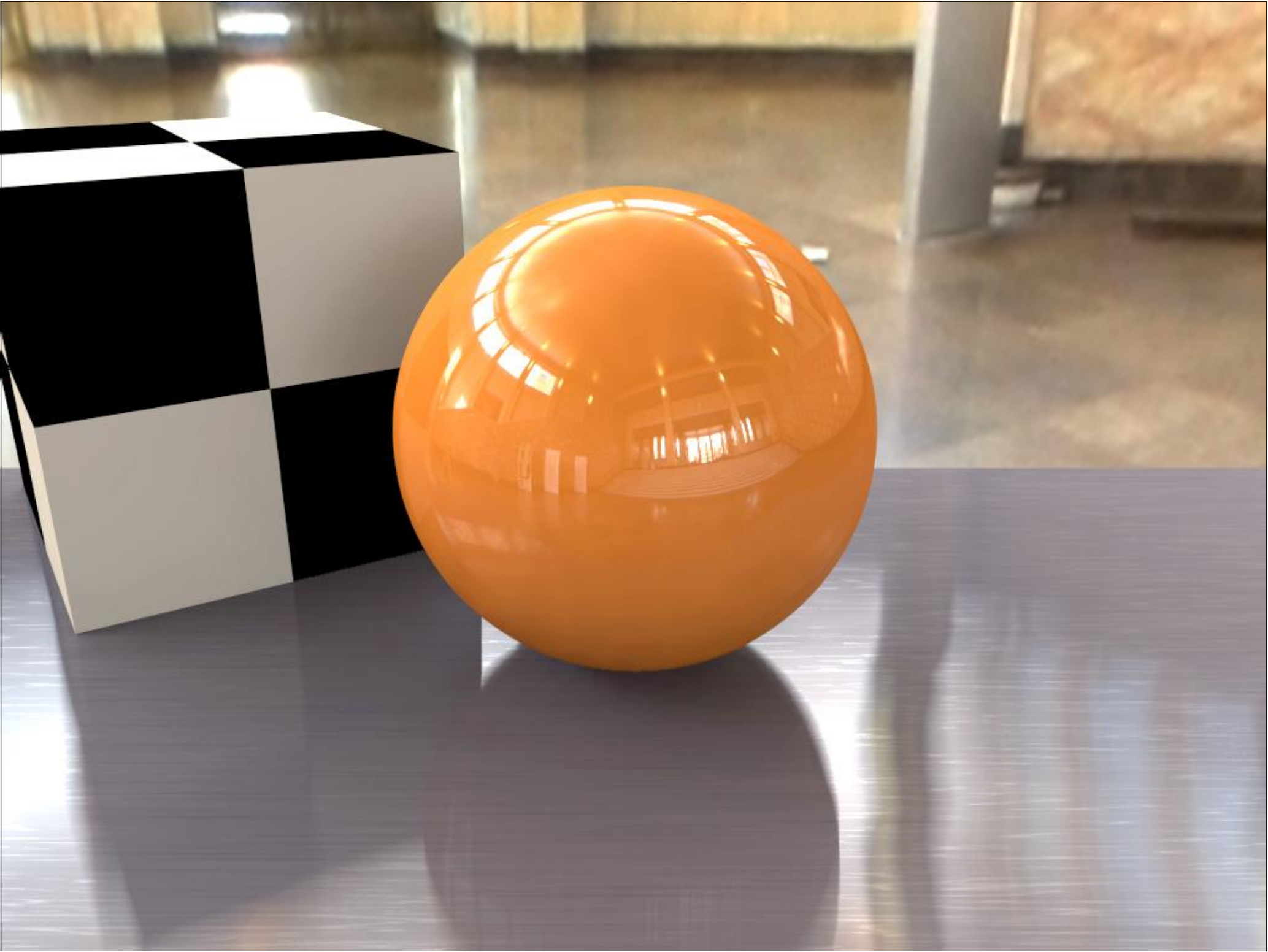
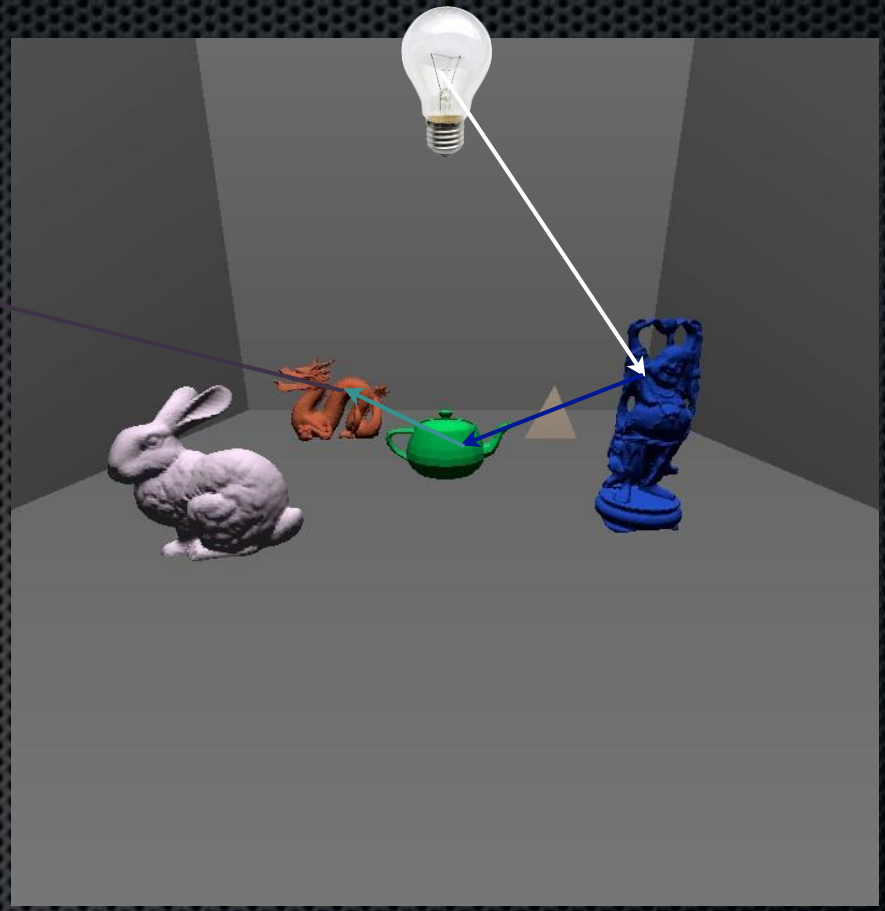


Some Slides Courtesy of Matt Stoker (Utah)



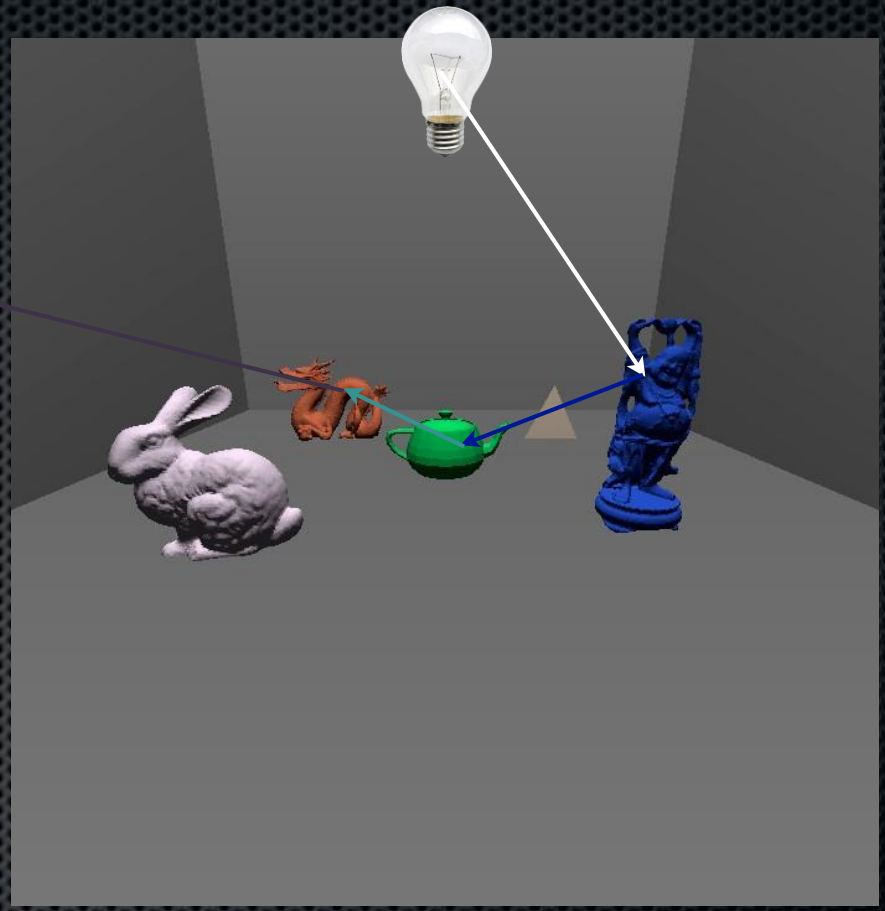


Ray Tracing



- For each light in scene
  - Emit 1,000,000,000 photons
  - For each photon
    - Find what geometry photon hits
    - Color photon
    - Scatter photon
    - Find what photon hits next
    - ...
    - Pray photon hits camera CCD
    - Light pixel that CCD micro-square represents

Ray Tracing



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  - Emit 1,000,000,000 photons
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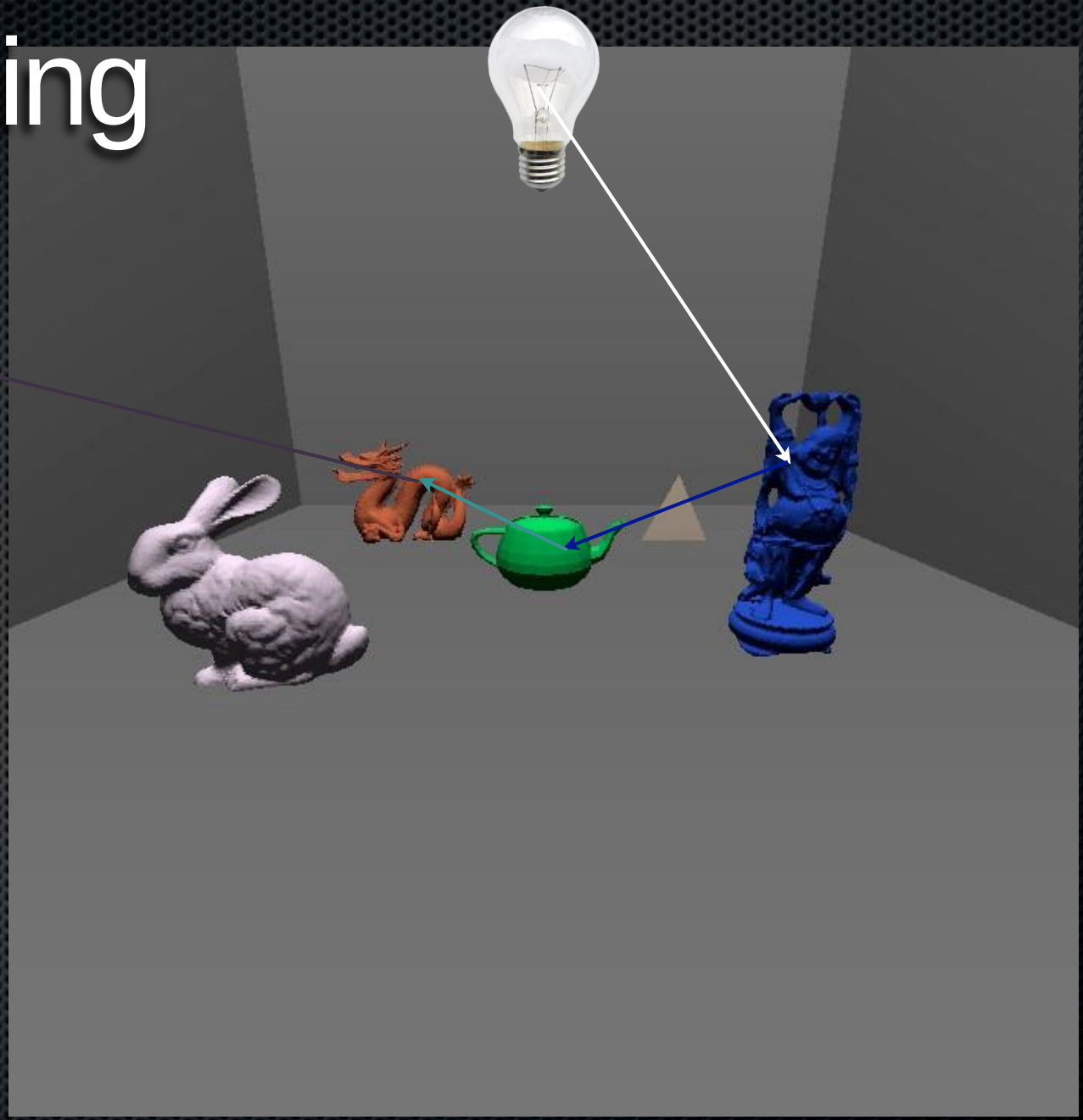
Ray Tracing



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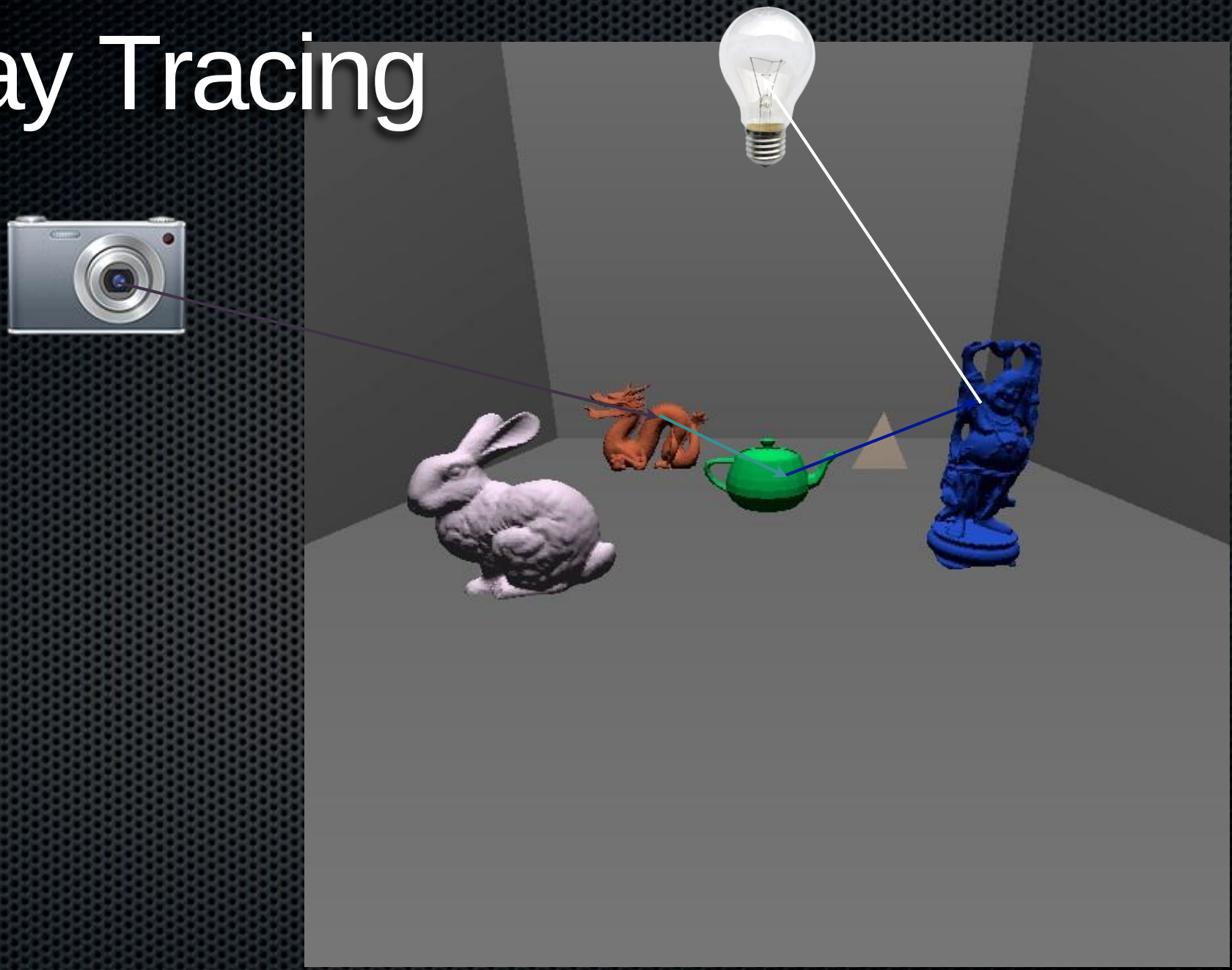

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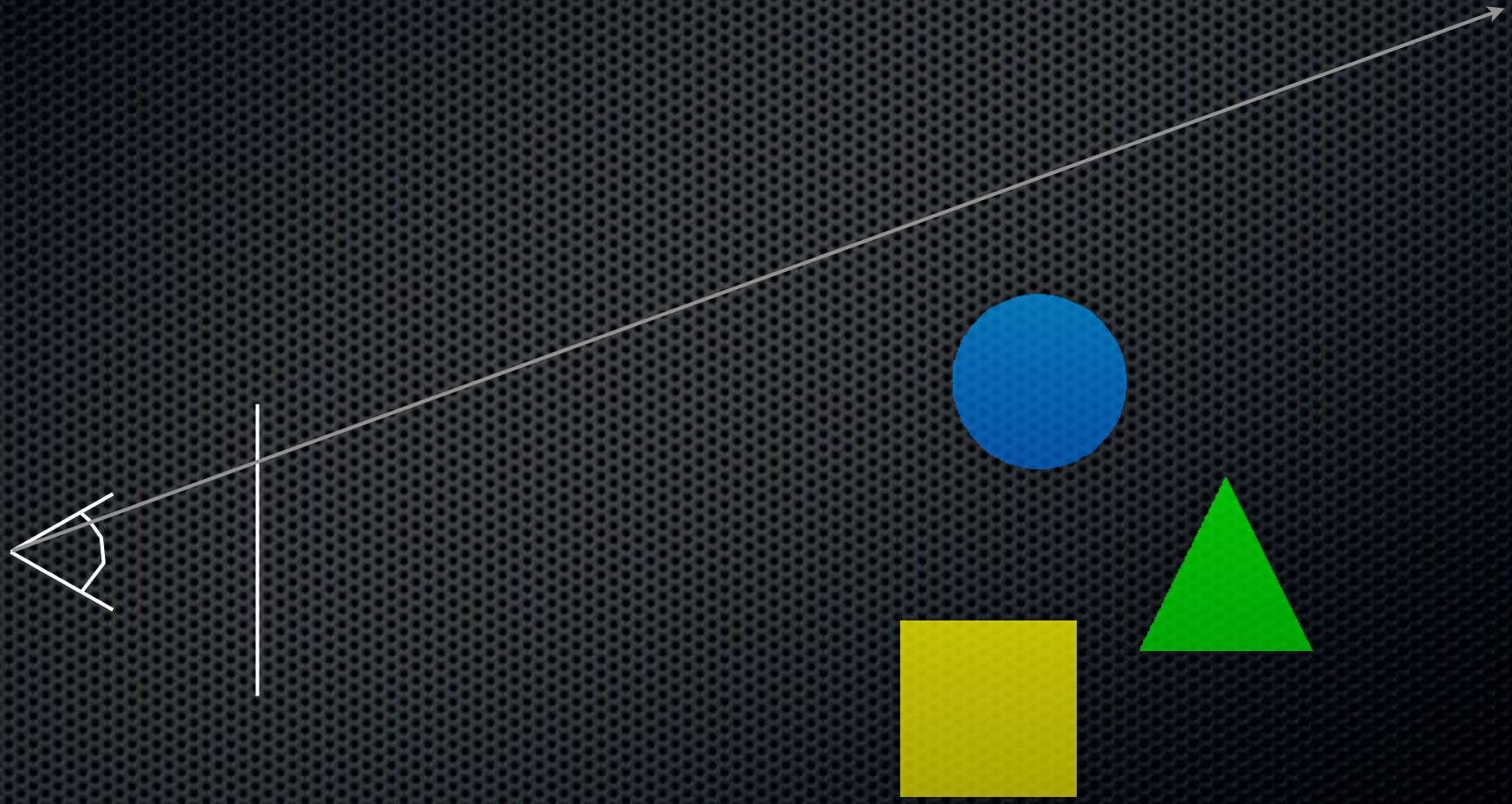
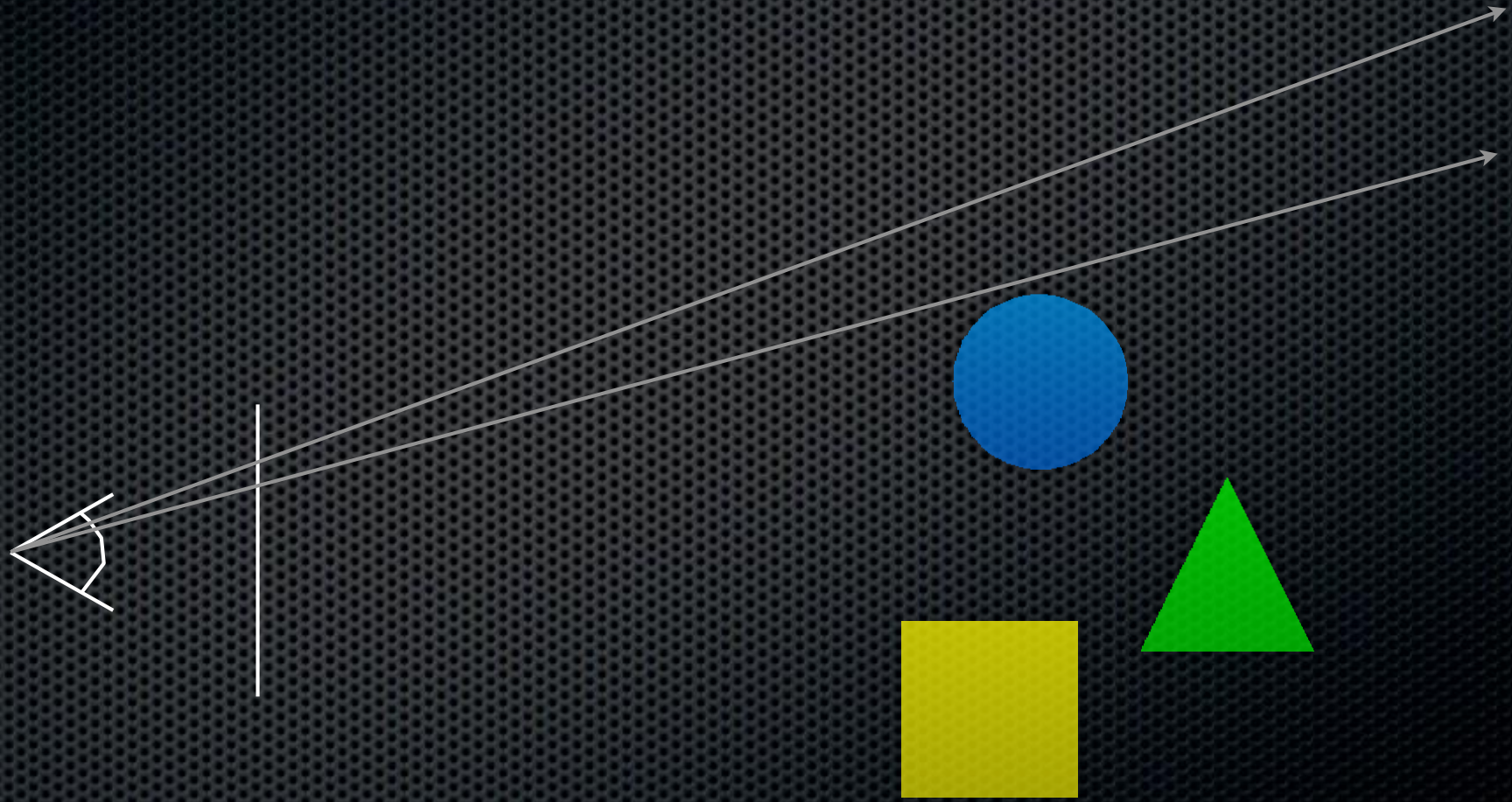
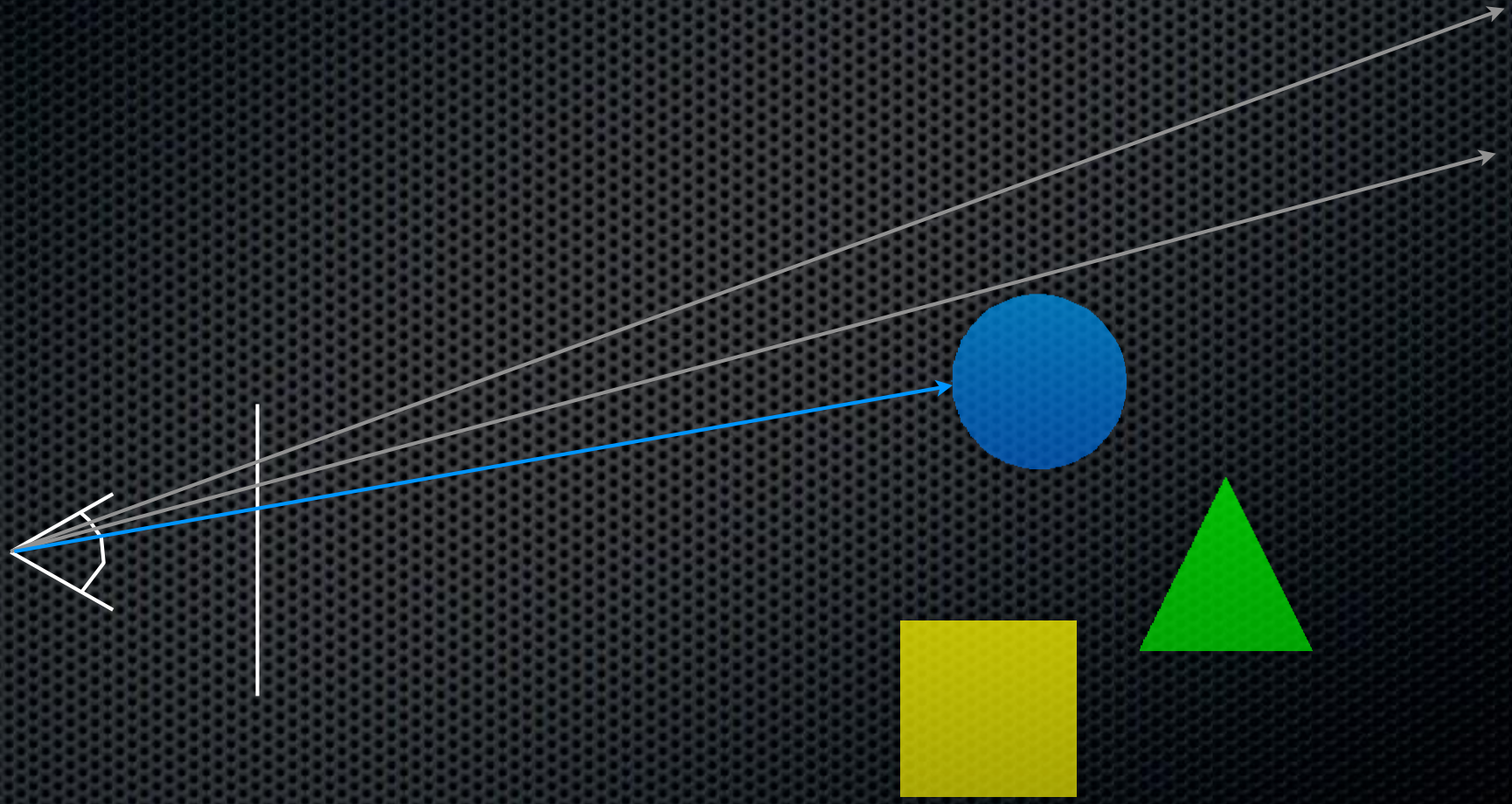


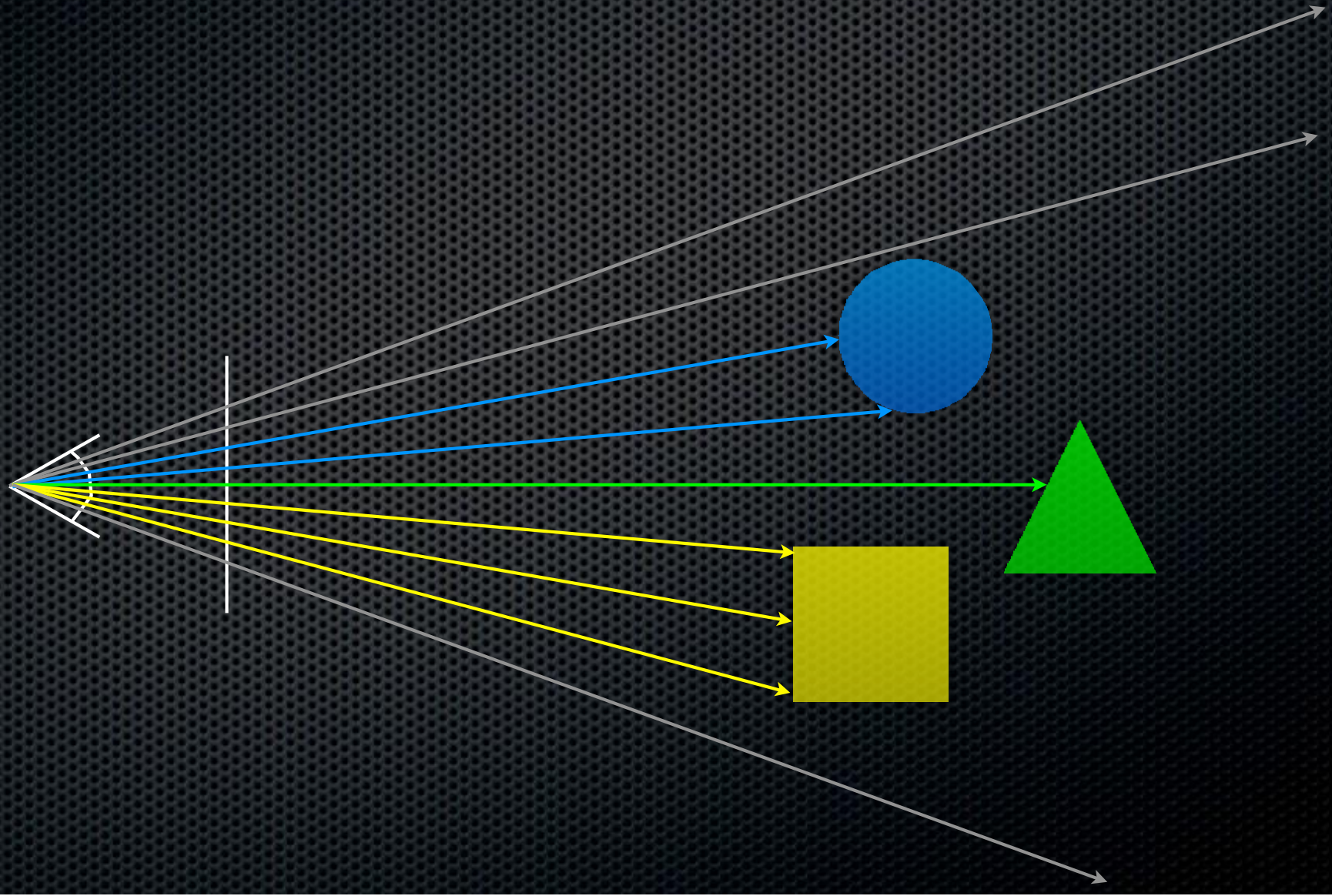
Ray Tracing



Ray Tracing



Ray Tracing



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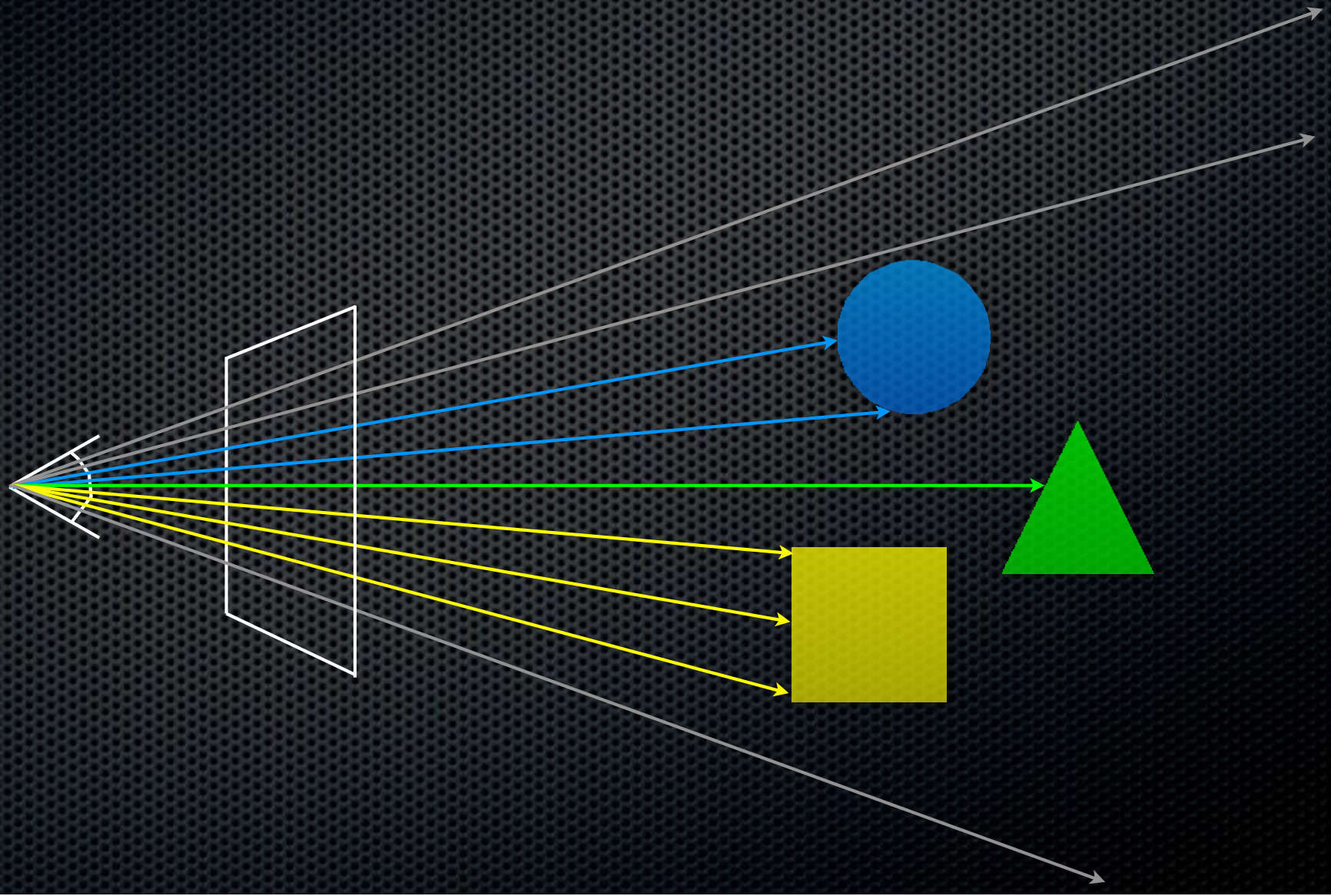

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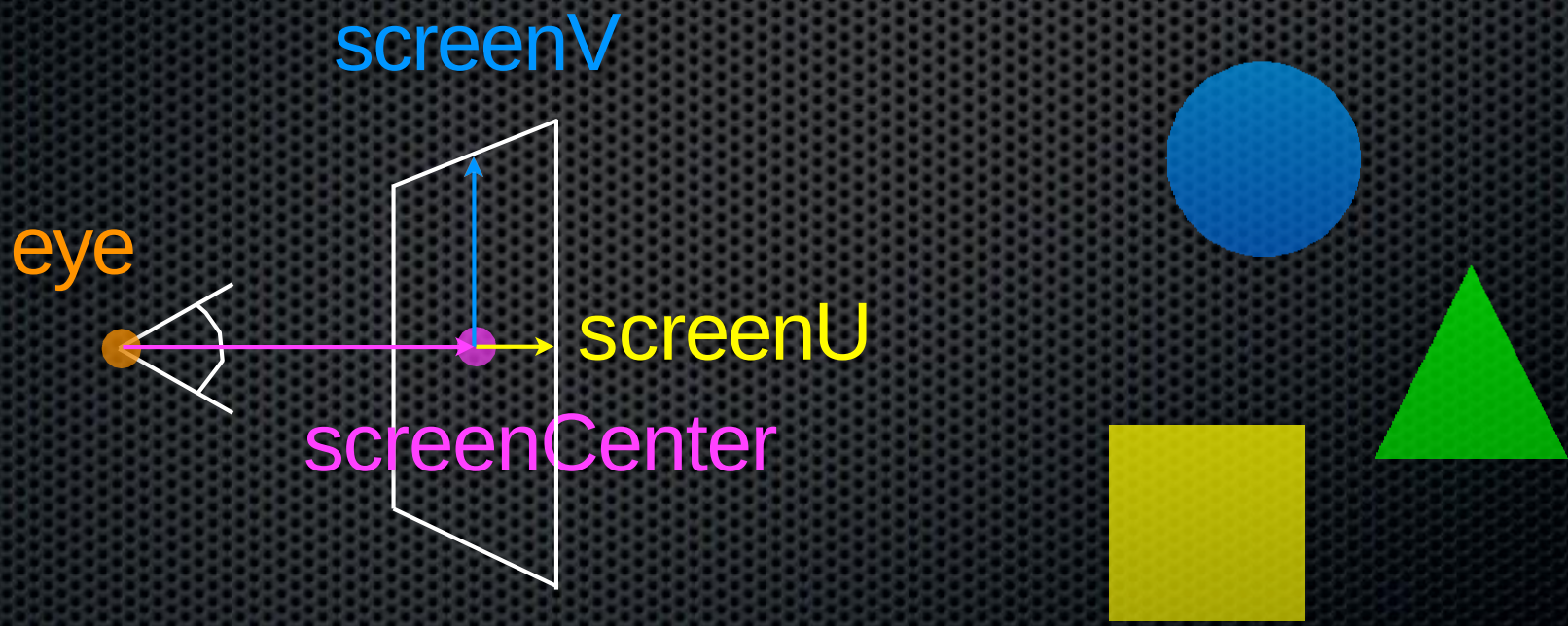

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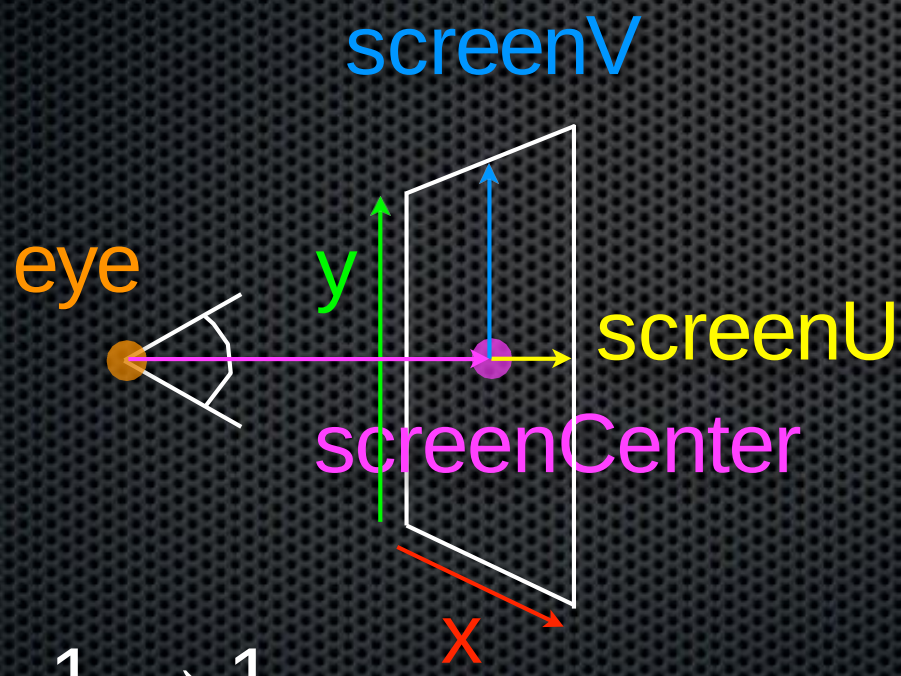
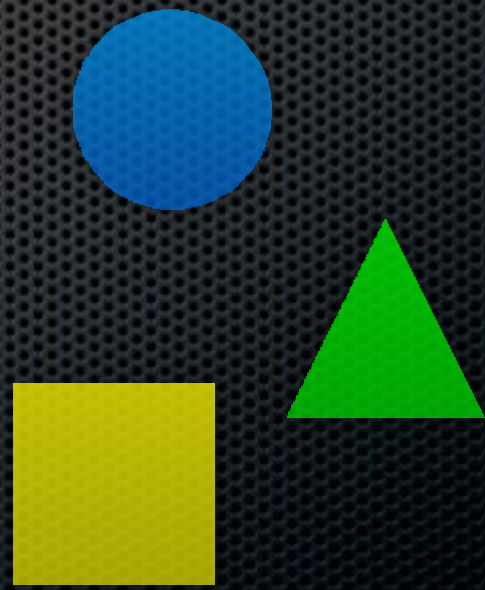




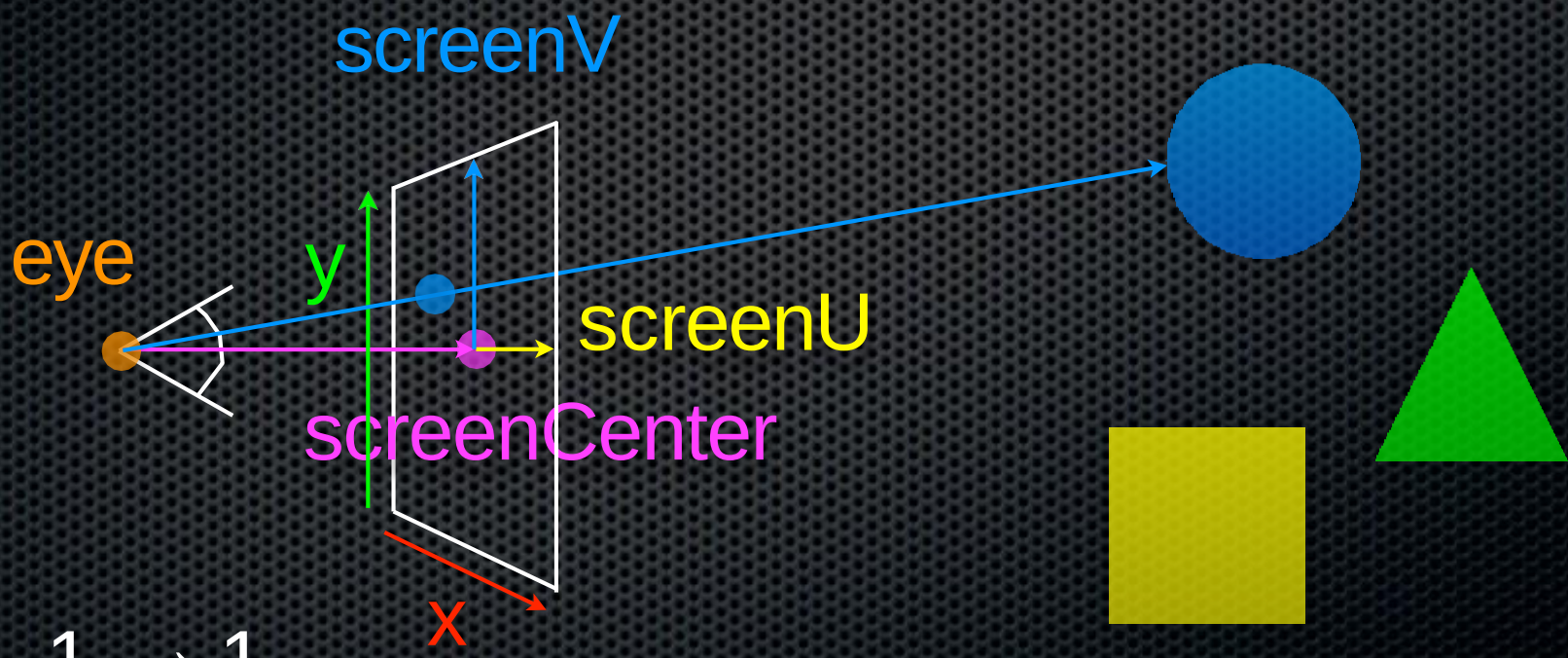
x: -1 → 1

y: -1 → 1

Ray Tracing

ray origin: eye

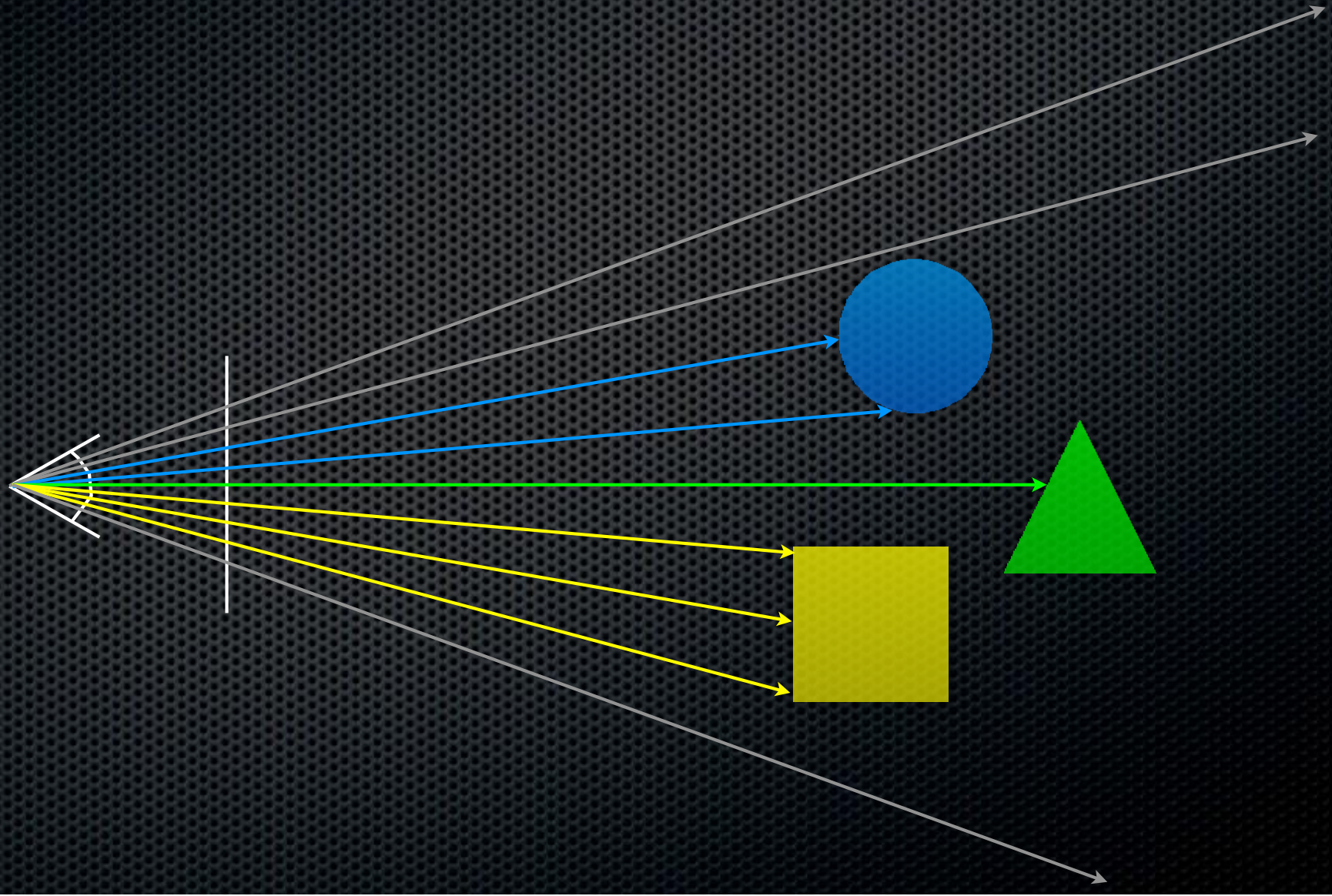
ray direction: screenCenter + x•screenU + y•screenV



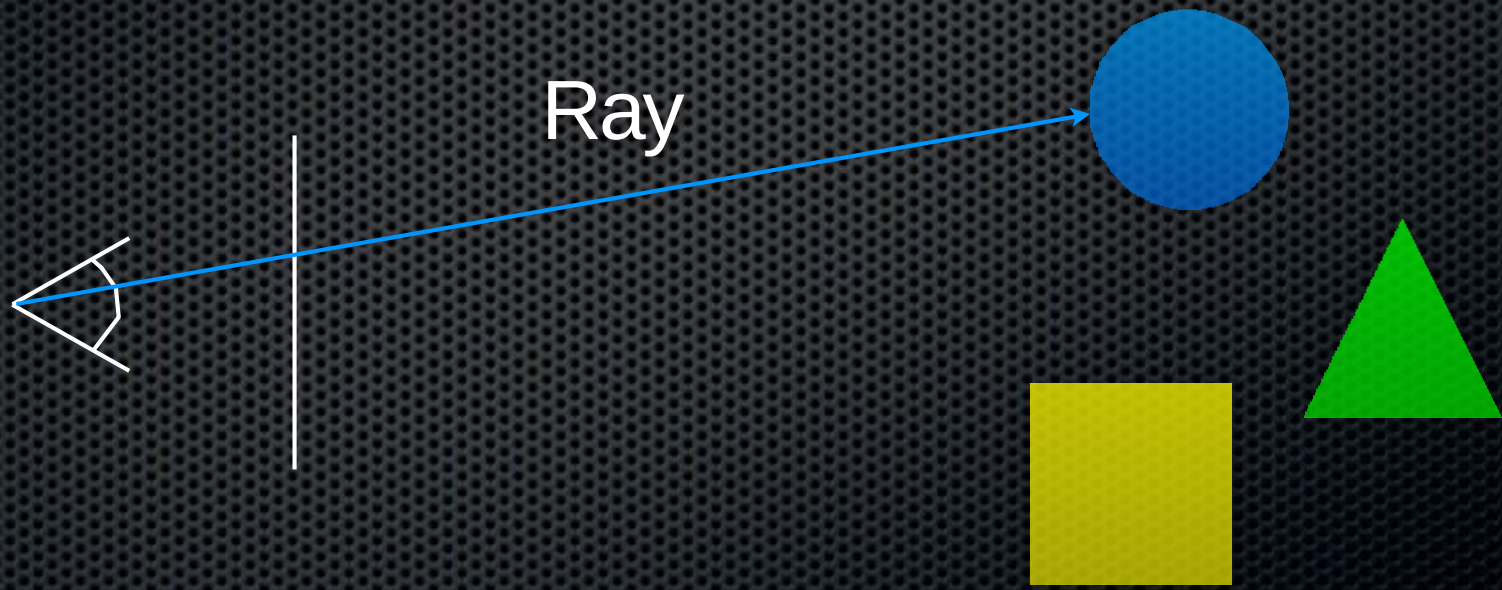
x: -1 → 1

y: -1 → 1

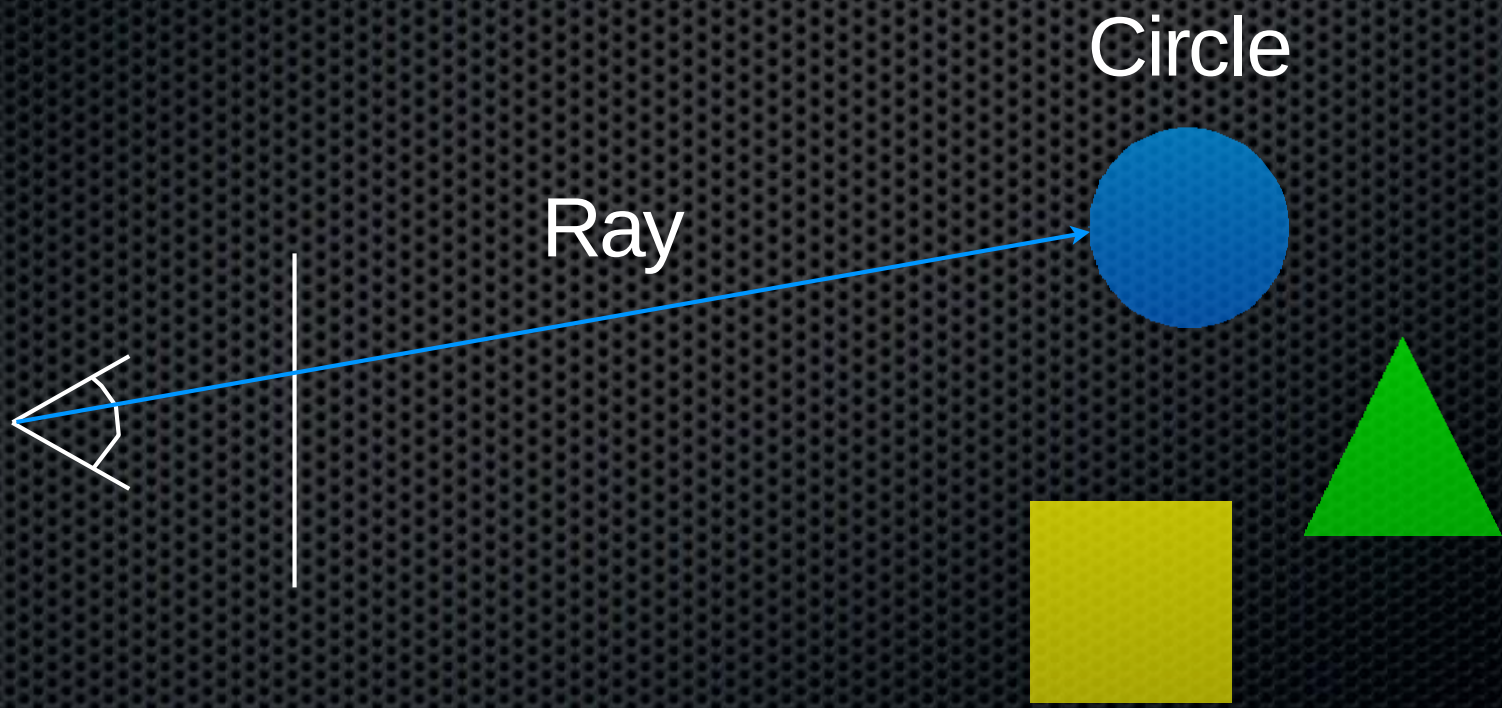
Ray Tracing



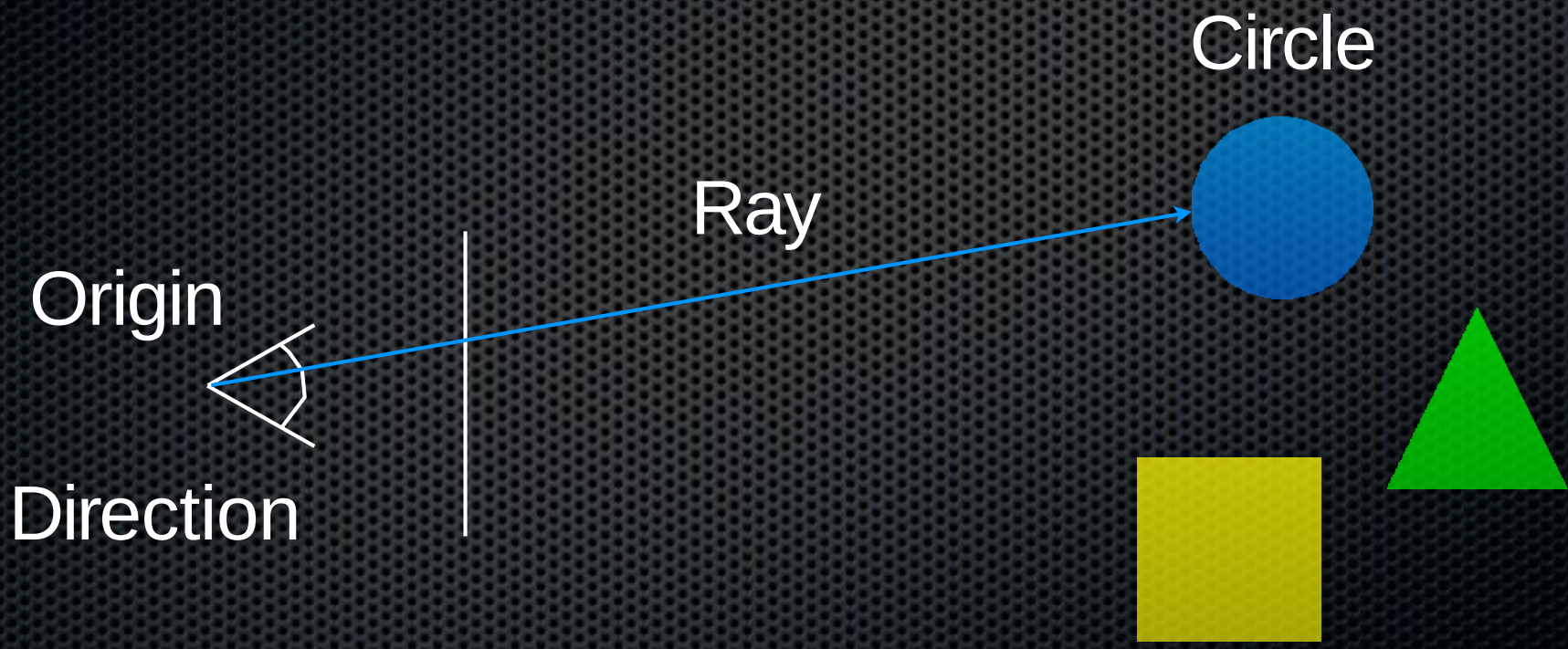
Ray Tracing



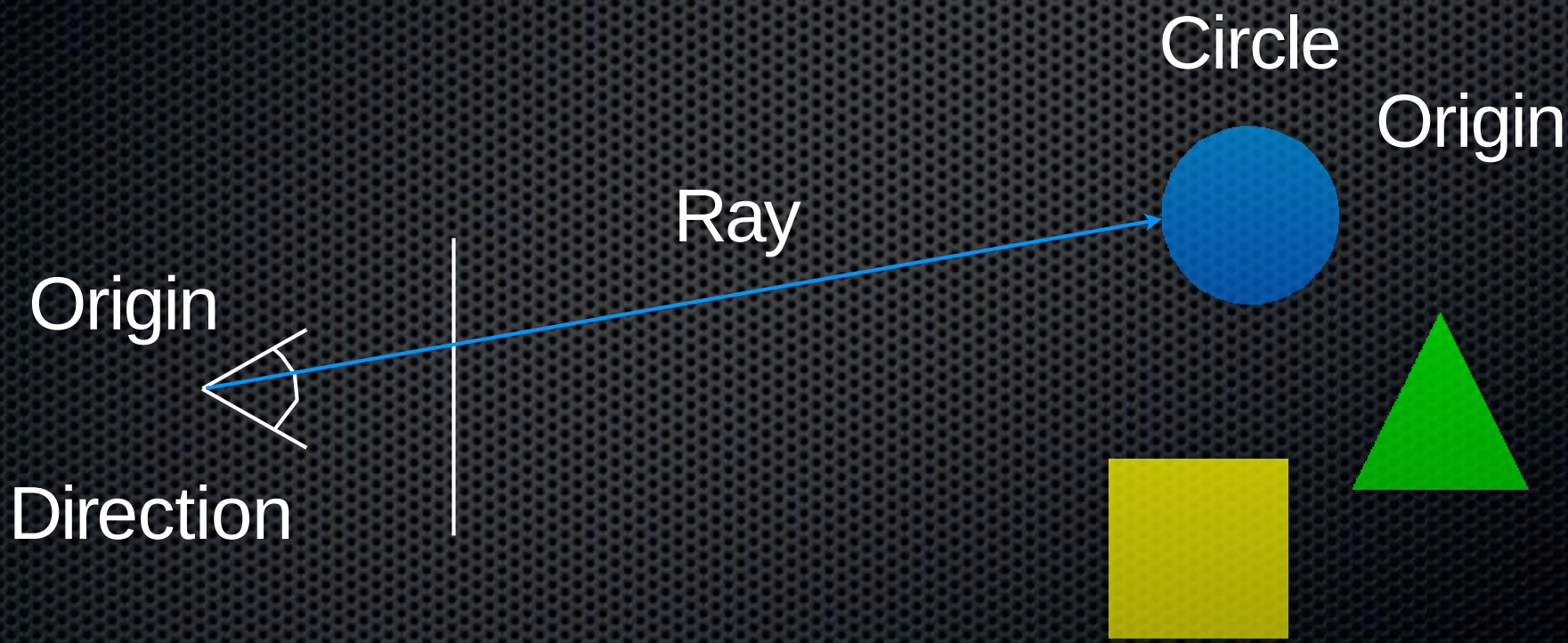
Ray Tracing



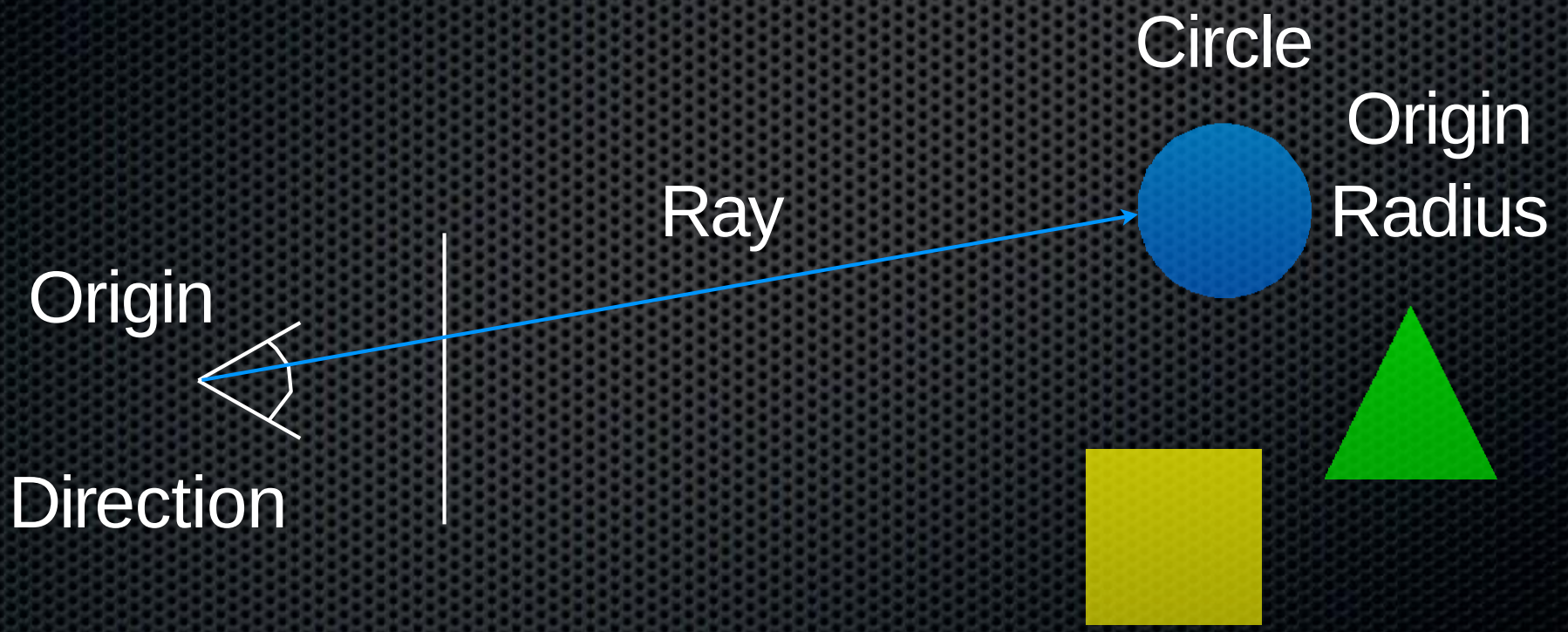
Ray Tracing



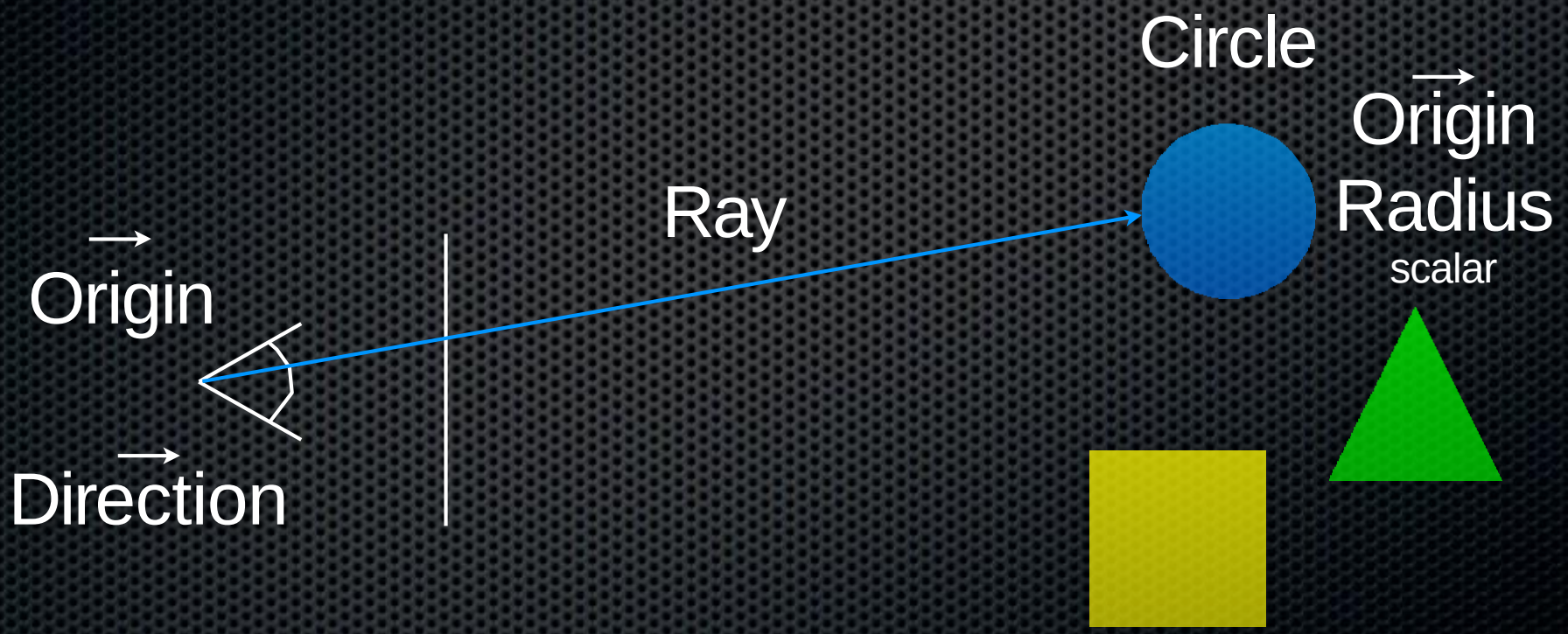
Ray Tracing



Ray Tracing

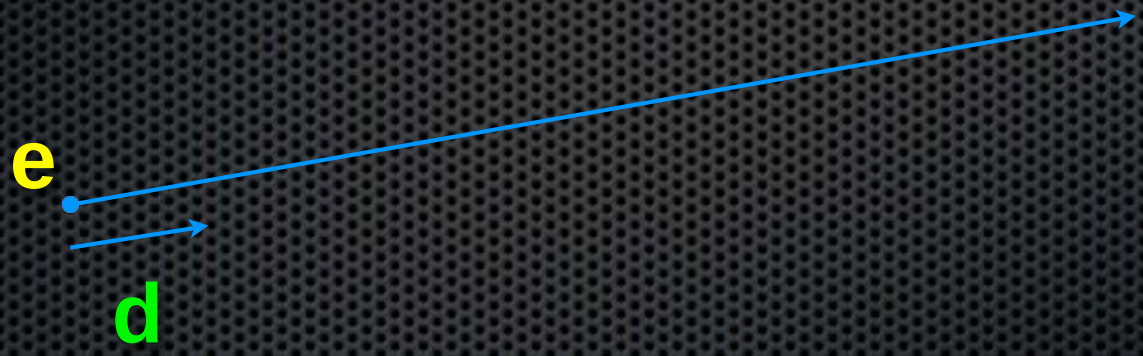


Ray Tracing



Ray Tracing

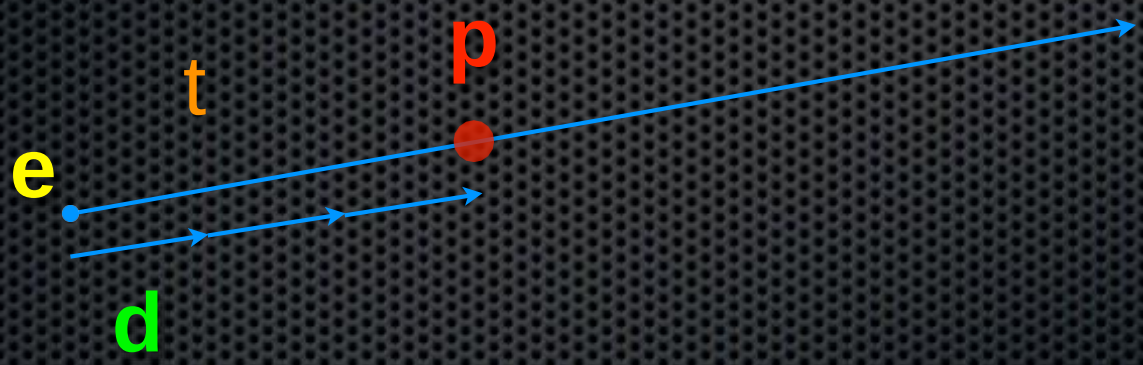
Ray: emission point (**e**) and direction (**d**)



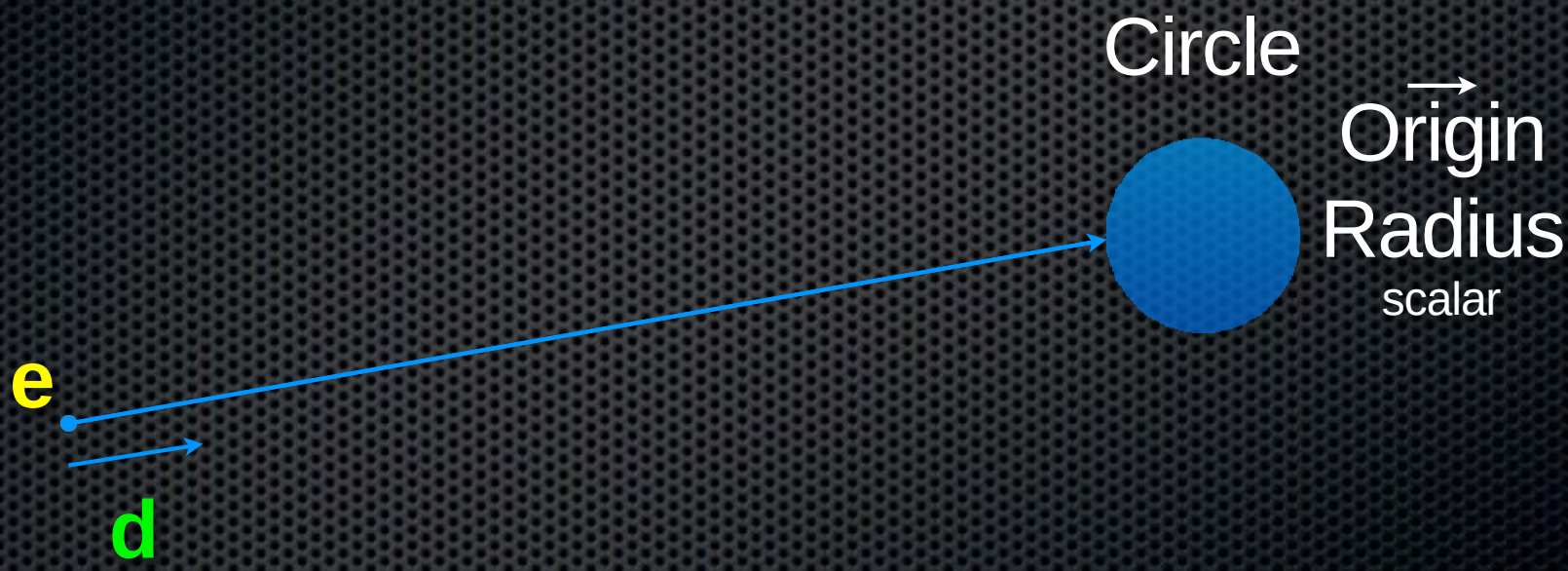
Ray Tracing

Ray: emission point (**e**) and direction (**d**)

Point on Ray: **p**(t) = **e** + t**d**

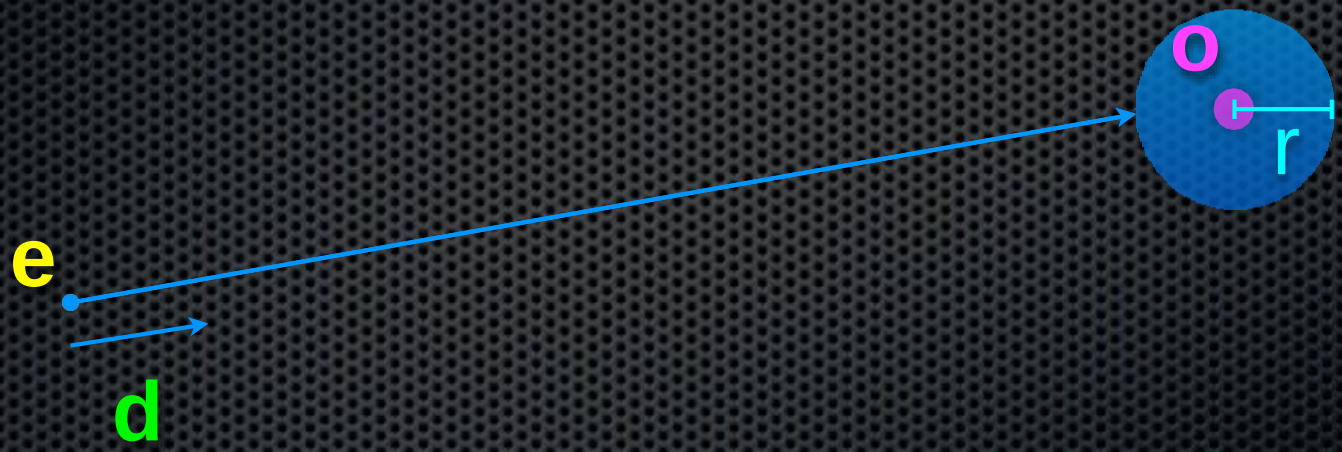


Ray Tracing



Ray Tracing

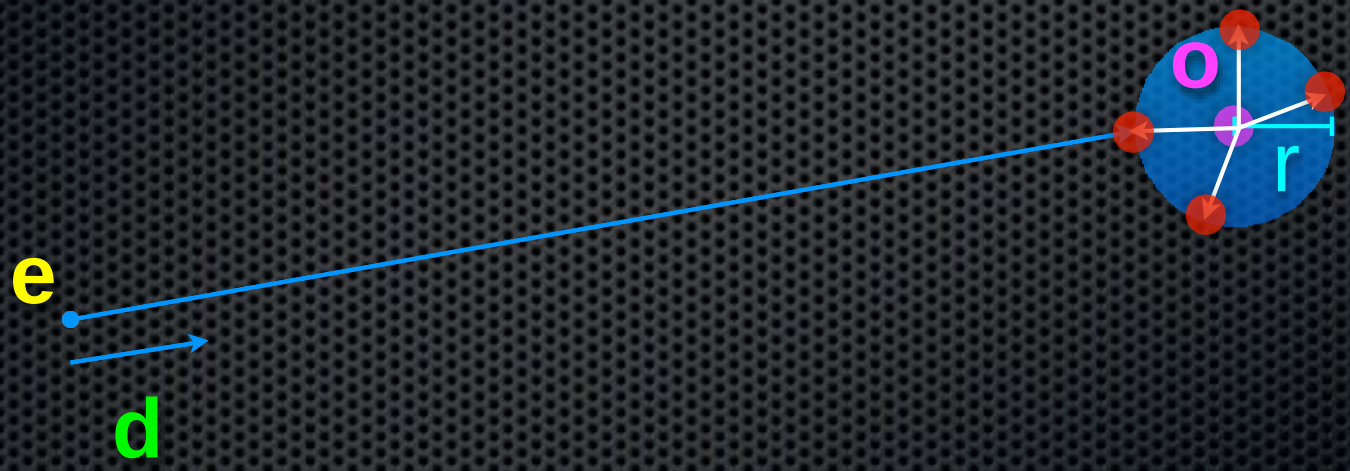
Circle: center point (**o**) and radius (**r**)



Ray Tracing

Circle: center point (**o**) and radius (**r**)

Point on circle: $(\mathbf{p} - \mathbf{o}) \cdot (\mathbf{p} - \mathbf{o}) - r^2 = 0$

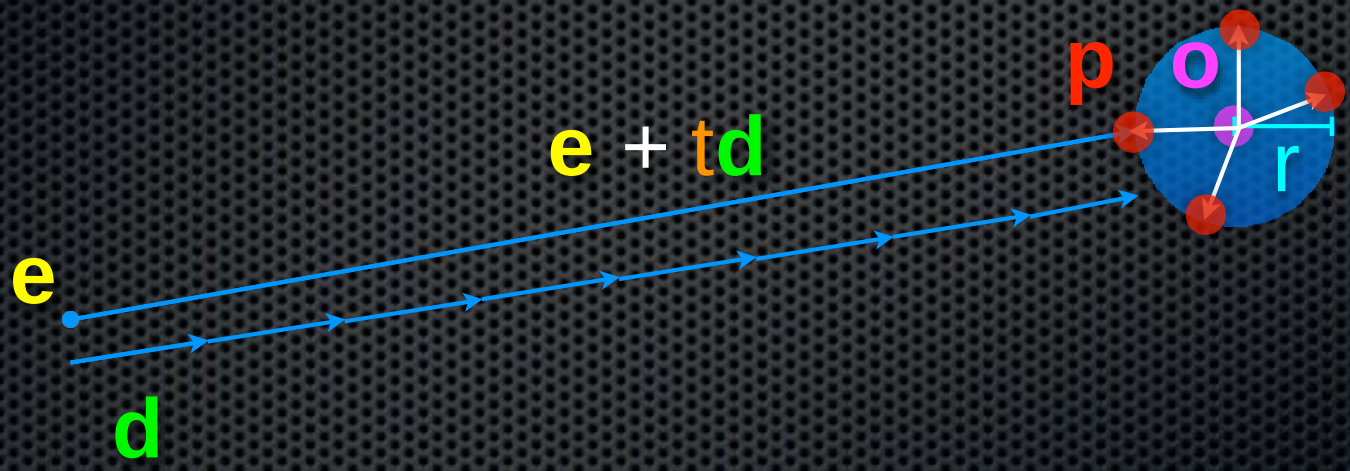


Ray Tracing

Circle: center point (**o**) and radius (**r**)

Point on circle: (**p** - **o**)•(**p** - **o**) - $r^2 = 0$

Point on Ray: **p**(t) = **e** + t**d**

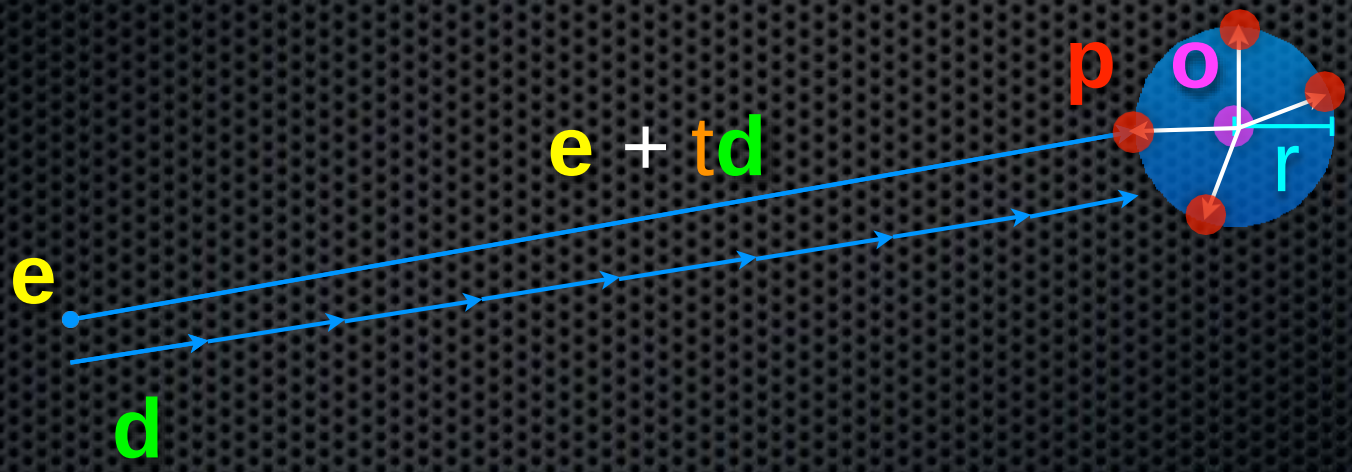


Ray Tracing

Circle: center point (**o**) and radius (**r**)

Point on circle: $(\mathbf{p} - \mathbf{o}) \cdot (\mathbf{p} - \mathbf{o}) - r^2 = 0$

Point on Ray: $\mathbf{p}(t) = \mathbf{e} + t\mathbf{d}$



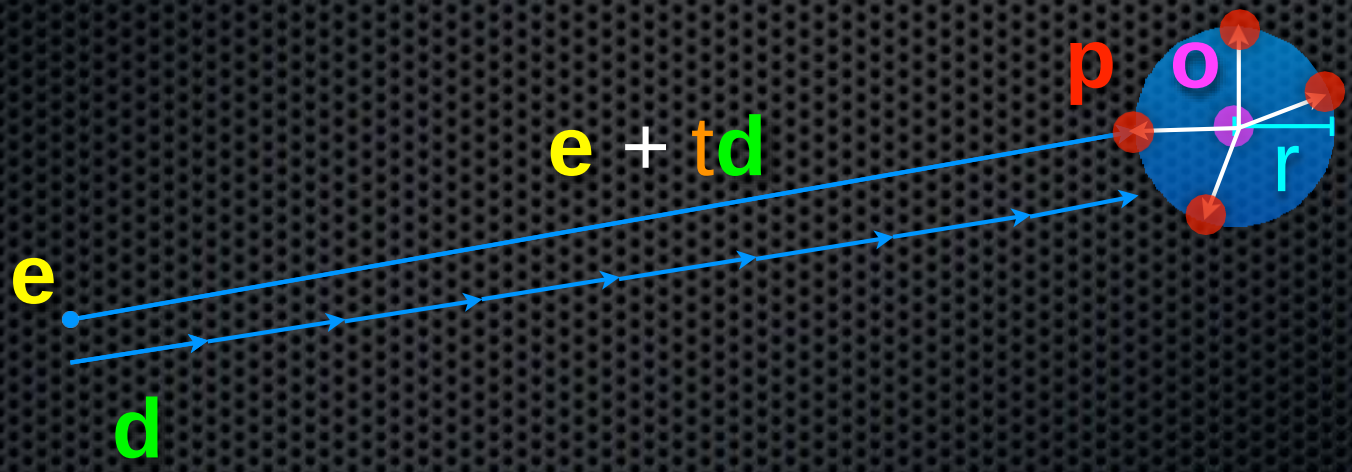
$$(\mathbf{e} + t\mathbf{d} - \mathbf{o}) \cdot (\mathbf{e} + t\mathbf{d} - \mathbf{o}) - r^2 = 0$$

Ray Tracing

Circle: center point (**o**) and radius (**r**)

Point on circle: $(\mathbf{p} - \mathbf{o}) \cdot (\mathbf{p} - \mathbf{o}) - r^2 = 0$

Point on Ray: $\mathbf{p}(t) = \mathbf{e} + t\mathbf{d}$



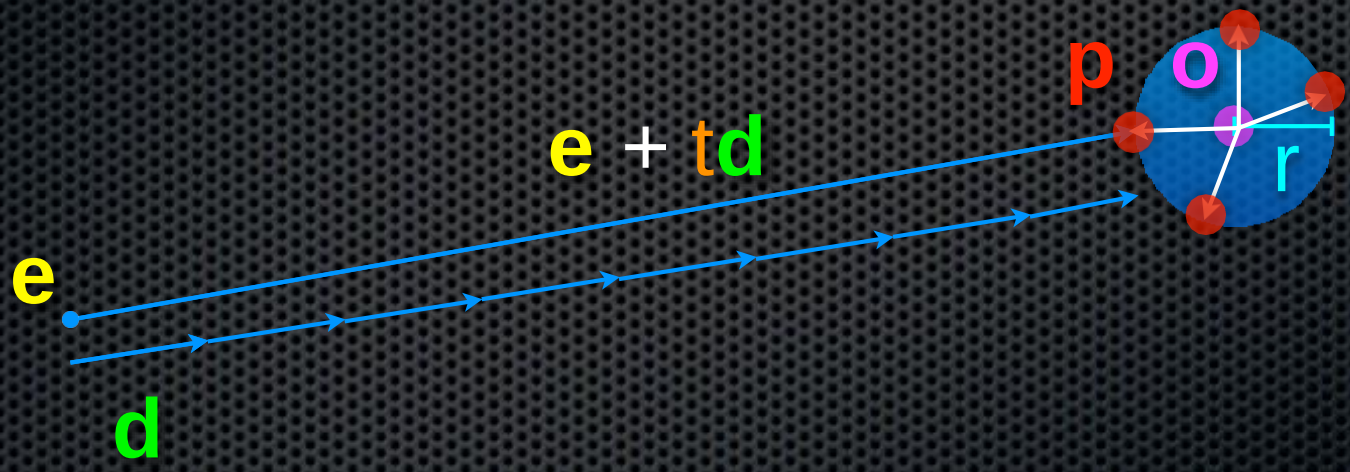
$$(t\mathbf{d} + \mathbf{e} - \mathbf{o}) \cdot (t\mathbf{d} + \mathbf{e} - \mathbf{o}) - r^2 = 0$$

Ray Tracing

Circle: center point (**o**) and radius (**r**)

Point on circle: $(\mathbf{p} - \mathbf{o}) \cdot (\mathbf{p} - \mathbf{o}) - r^2 = 0$

Point on Ray: $\mathbf{p}(t) = \mathbf{e} + t\mathbf{d}$



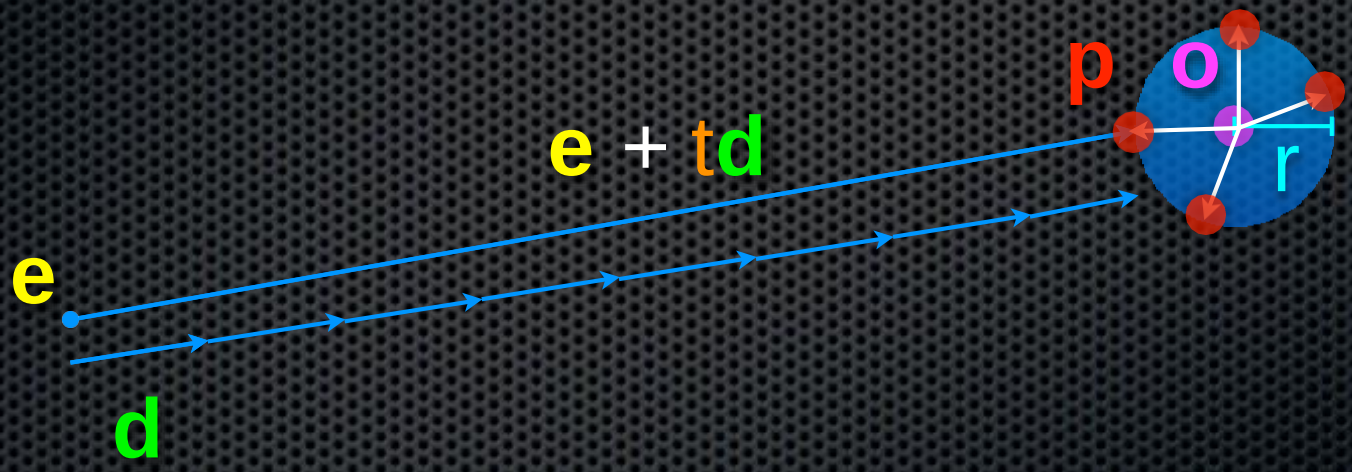
$$(t\mathbf{d} + (\mathbf{e} - \mathbf{o})) \cdot (t\mathbf{d} + (\mathbf{e} - \mathbf{o})) - r^2 = 0$$

Ray Tracing

Circle: center point (**o**) and radius (**r**)

Point on circle: $(\mathbf{p} - \mathbf{o})\bullet(\mathbf{p} - \mathbf{o}) - r^2 = 0$

Point on Ray: $\mathbf{p}(t) = \mathbf{e} + t\mathbf{d}$



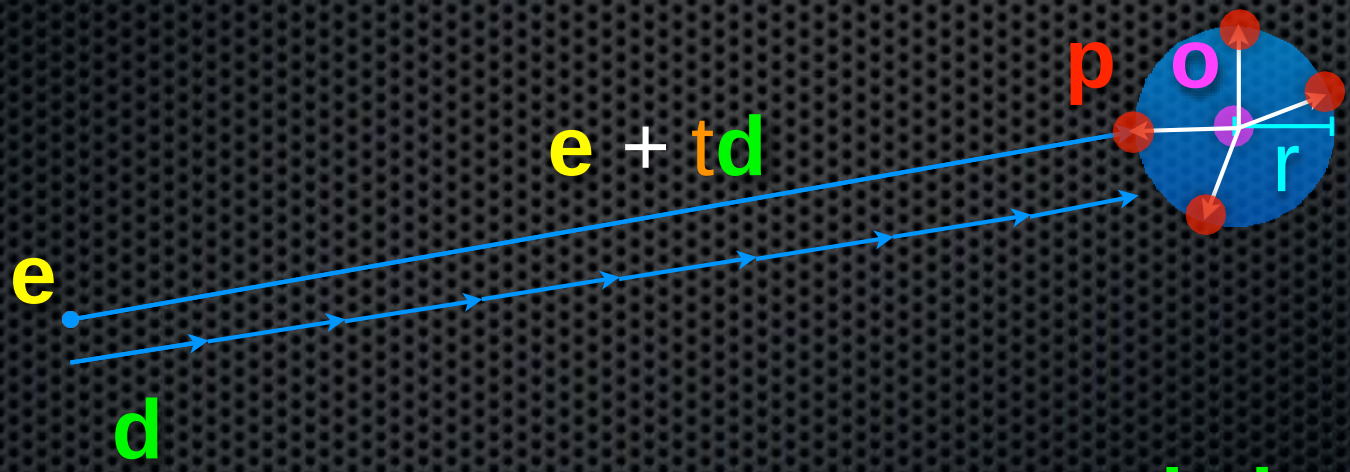
$t^2(\mathbf{d}\bullet\mathbf{d}) + 2t\mathbf{d}\bullet(\mathbf{e} - \mathbf{o}) + (\mathbf{e} - \mathbf{o})\bullet(\mathbf{e} - \mathbf{o}) - r^2 = 0$

Ray Tracing

Circle: center point (**o**) and radius (r)

Point on circle: $(\mathbf{p} - \mathbf{o}) \cdot (\mathbf{p} - \mathbf{o}) - r^2 = 0$

Point on Ray: $\mathbf{p}(t) = \mathbf{e} + t\mathbf{d}$



$at^2 + bt + c = 0$

$a = \mathbf{d} \cdot \mathbf{d}$

$b = 2\mathbf{d} \cdot (\mathbf{e} - \mathbf{o})$

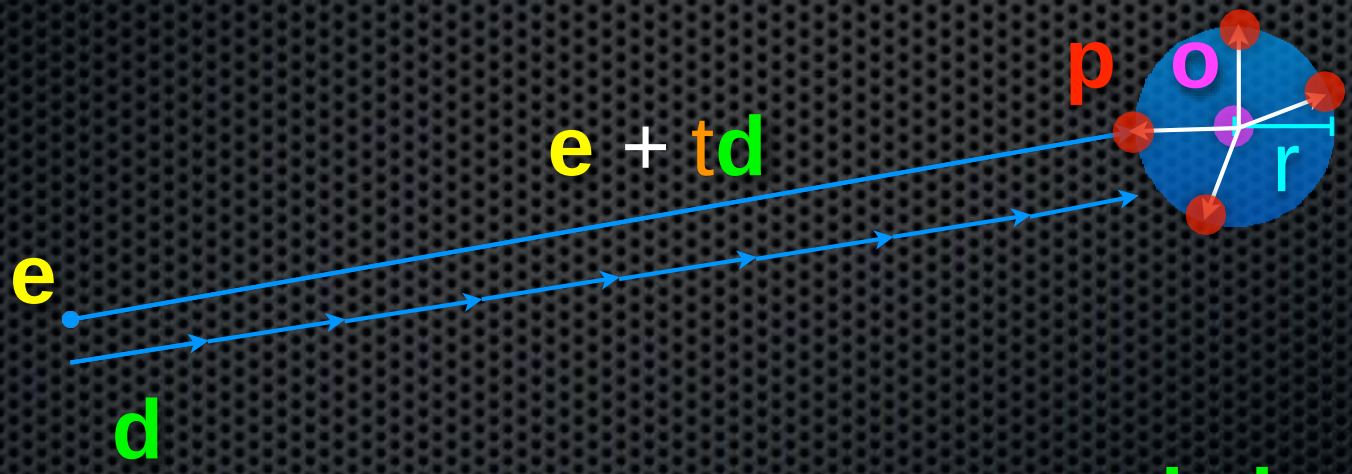
$c = (\mathbf{e} - \mathbf{o}) \cdot (\mathbf{e} - \mathbf{o}) - r^2$

Ray Tracing

Circle: center point (**o**) and radius (**r**)

Point on circle: $(\mathbf{p} - \mathbf{o}) \cdot (\mathbf{p} - \mathbf{o}) - r^2 = 0$

Point on Ray: $\mathbf{p}(t) = \mathbf{e} + t\mathbf{d}$



$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$a = \mathbf{d} \cdot \mathbf{d}$

$b = 2\mathbf{d} \cdot (\mathbf{e} - \mathbf{o})$

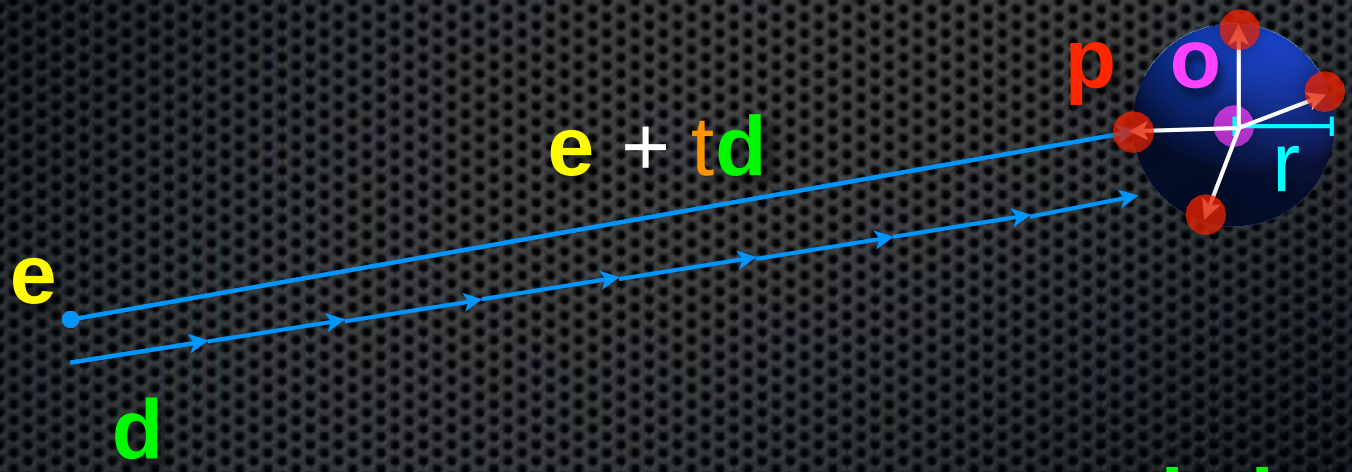
$c = (\mathbf{e} - \mathbf{o}) \cdot (\mathbf{e} - \mathbf{o}) - r^2$

Ray Tracing

Circle: center point (**o**) and radius (**r**)

Point on **sphere**: $(\mathbf{p} - \mathbf{o})\bullet(\mathbf{p} - \mathbf{o}) - r^2 = 0$

Point on Ray: $\mathbf{p}(t) = \mathbf{e} + t\mathbf{d}$



$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$a = \mathbf{d}\bullet\mathbf{d}$

$b = 2\mathbf{d}\bullet(\mathbf{e} - \mathbf{o})$

$c = (\mathbf{e} - \mathbf{o})\bullet(\mathbf{e} - \mathbf{o}) - r^2$

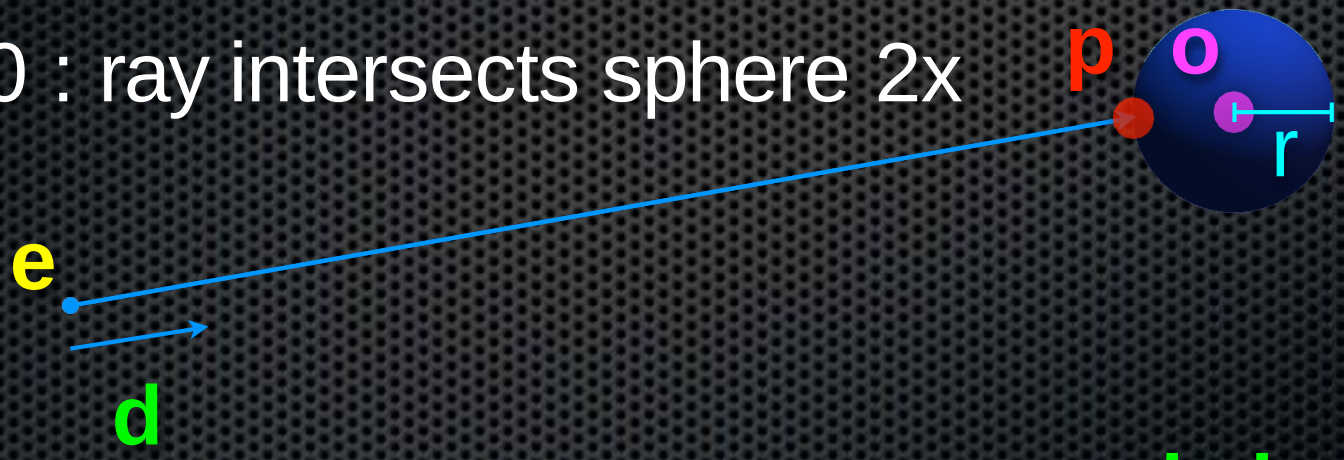
Ray Tracing

$h = b^2 - 4ac$

$h < 0$: ray misses sphere

$h = 0$: ray tangent to sphere

$h > 0$: ray intersects sphere 2x



$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$a = \mathbf{d} \cdot \mathbf{d}$

$b = 2\mathbf{d} \cdot (\mathbf{e} - \mathbf{o})$

$c = (\mathbf{e} - \mathbf{o}) \cdot (\mathbf{e} - \mathbf{o}) - r^2$

Ray Tracing

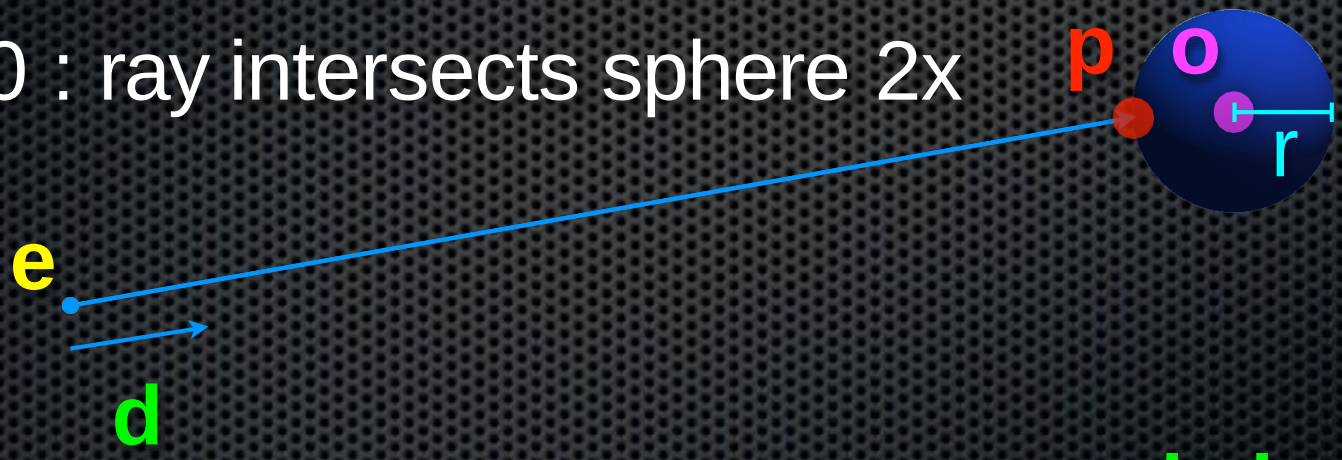
$h = b^2 - 4ac$

$h < 0$: ray misses sphere

$h = 0$: ray tangent to sphere

$h > 0$: ray intersects sphere 2x

Which intersection should be used?



$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$a = \mathbf{d} \cdot \mathbf{d}$

$b = 2\mathbf{d} \cdot (\mathbf{e} - \mathbf{o})$

$c = (\mathbf{e} - \mathbf{o}) \cdot (\mathbf{e} - \mathbf{o}) - r^2$