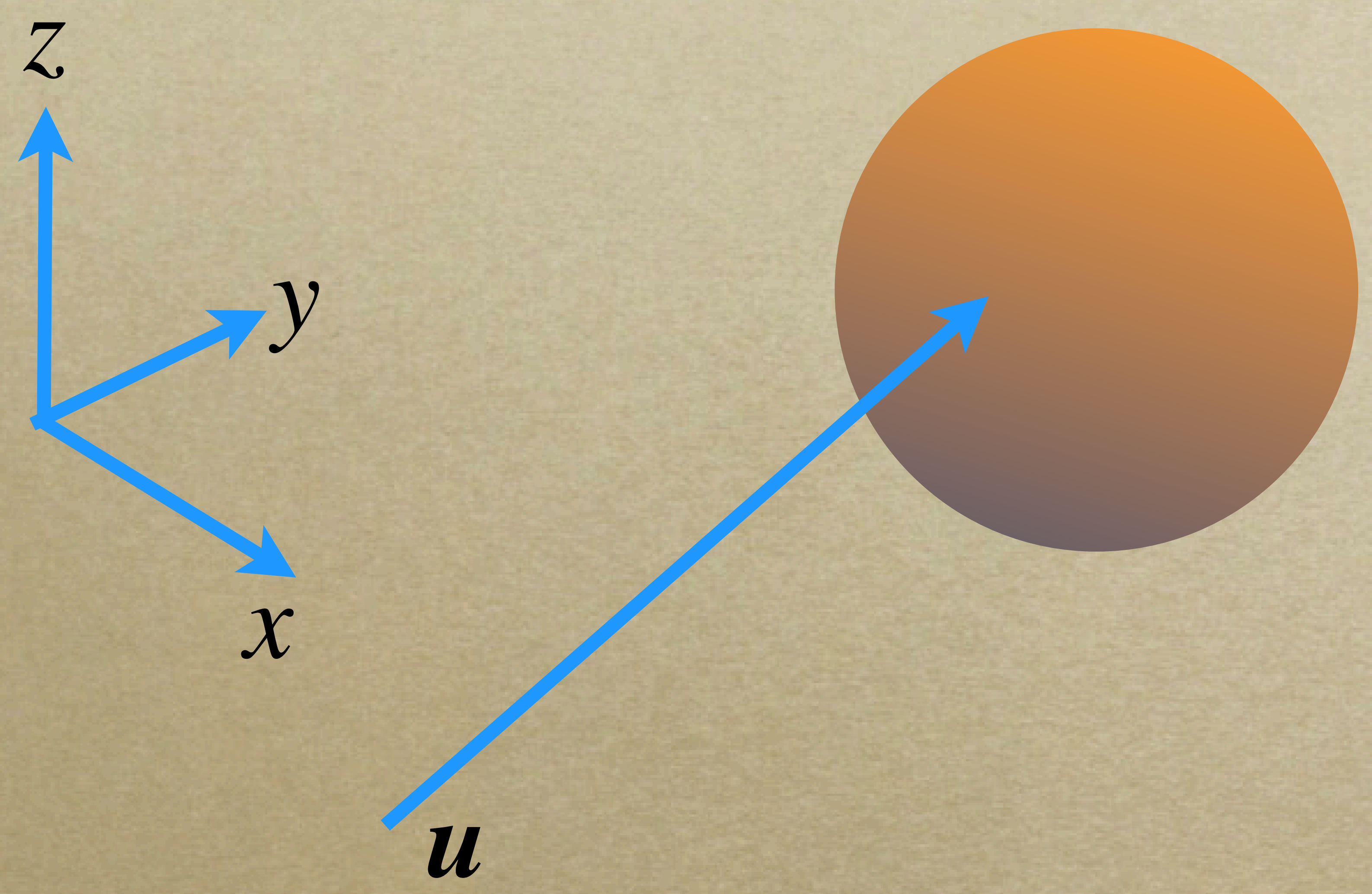
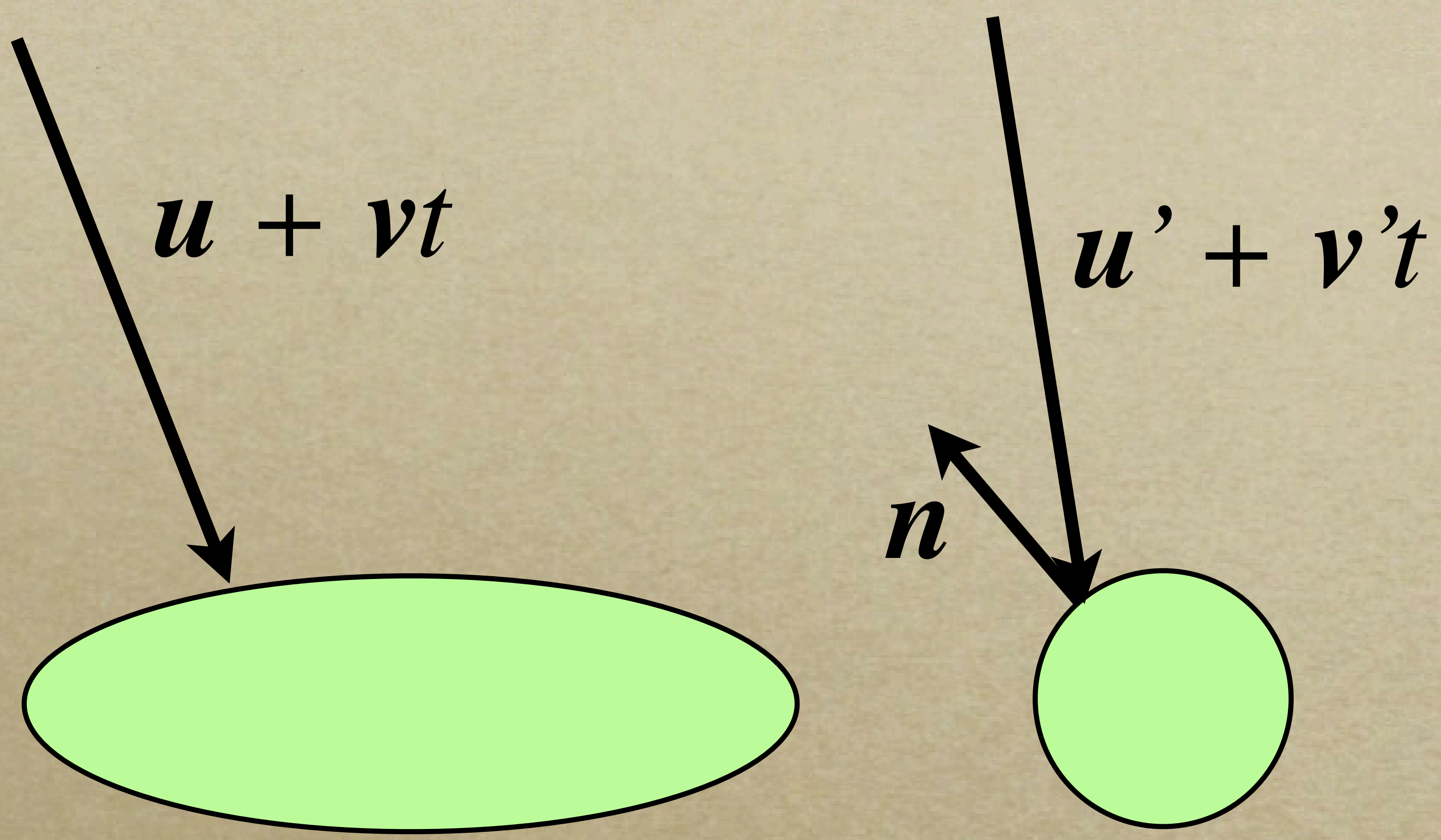
Efficient illumination of transformed objects and some global illumination

Transformed objects

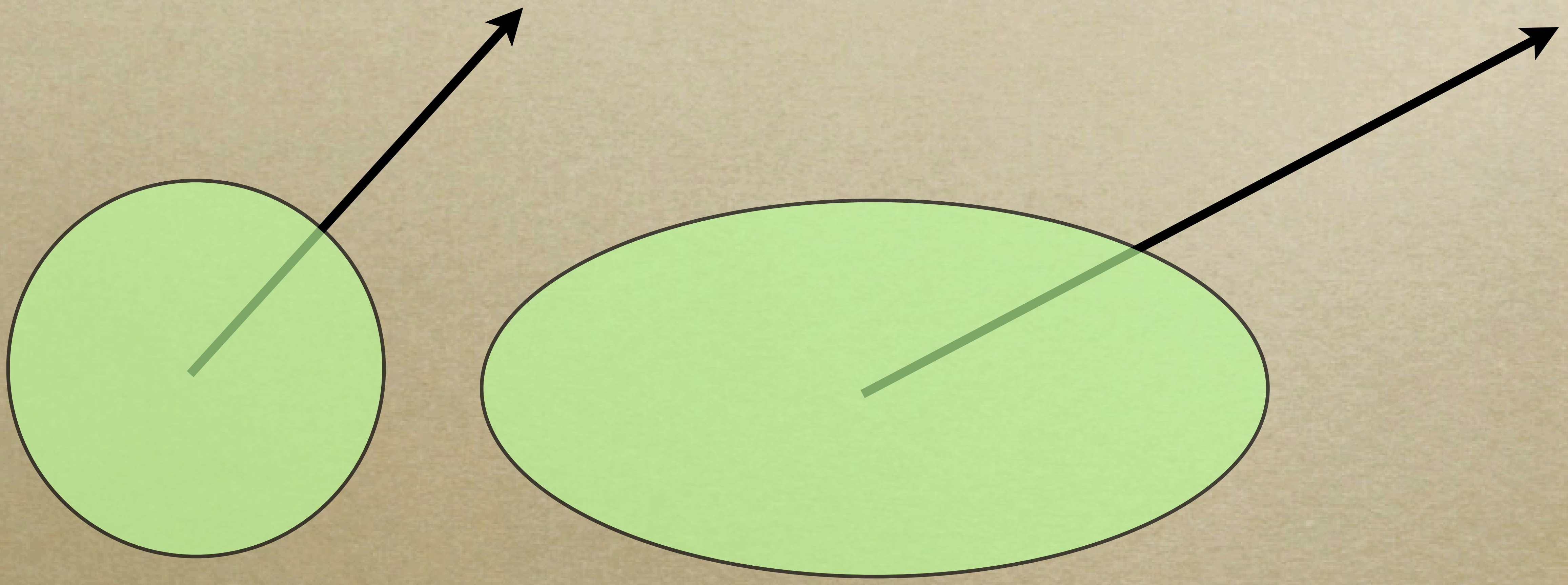


Transform the ray but ...



How do you get the surface normal back into world space?

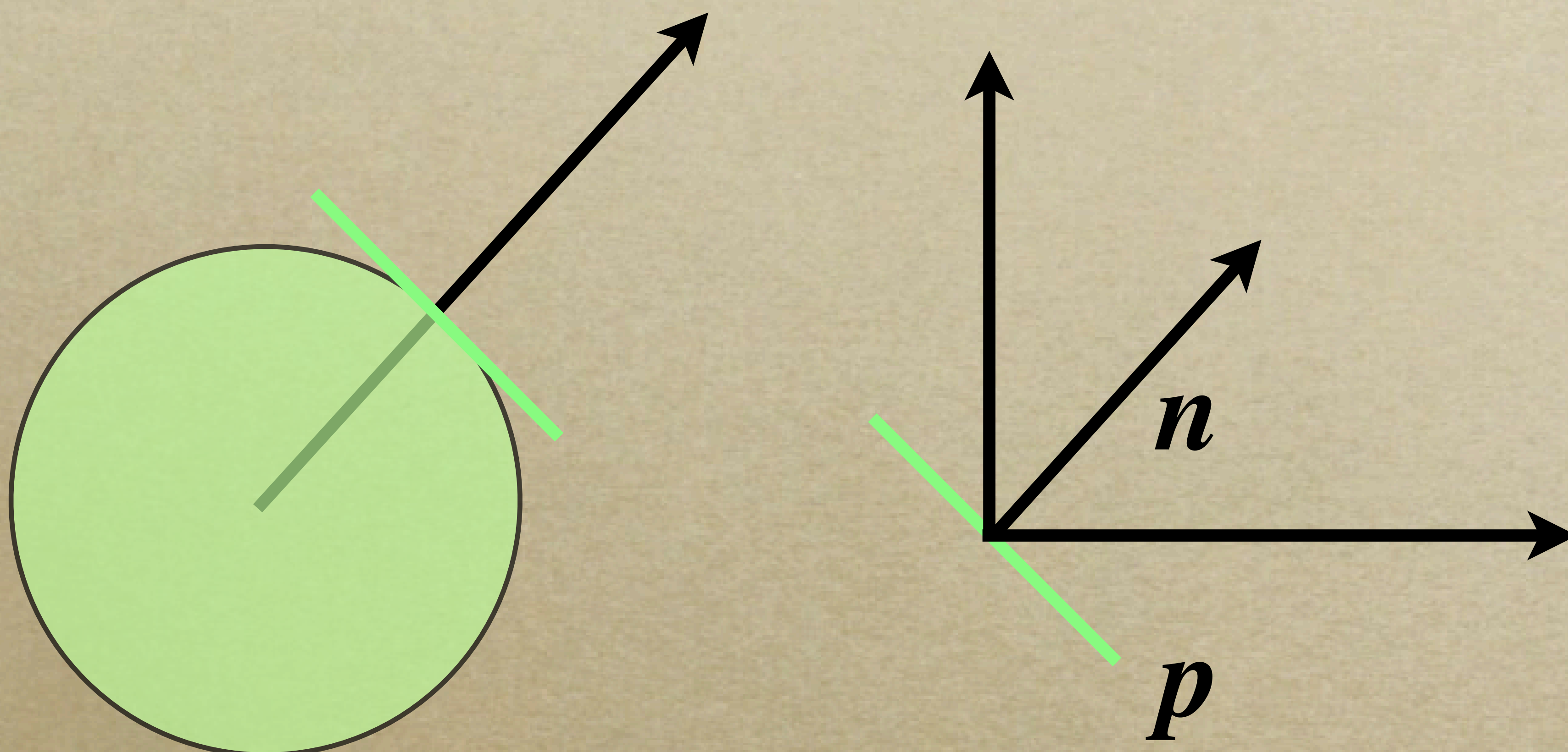
Transformed ***n*** is not normal



So what do we do?

- *When we apply a transformation matrix lines and planes are preserved but not angles.*
- *The normal defines a plane and the plane transforms to a plane.*

Which Plane?



$\mathbf{p}.\mathbf{n} = 0$ *is a plane through the origin.*

Suppose $\mathbf{p}' = T\mathbf{p}$

Dot product as matrix multiplication

$$\boldsymbol{p} = \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \qquad \boldsymbol{v} = \begin{bmatrix} a \\ b \\ c \\ 0 \end{bmatrix}$$

$$\boldsymbol{p}^T\boldsymbol{v} = [\, x \;\; y \;\; z \;\; 1 \,] \begin{bmatrix} a \\ b \\ c \\ 0 \end{bmatrix} = \boldsymbol{p.v}$$

Now we can do the maths

$\mathbf{p}.\mathbf{n} = 0$ *is a plane through the origin.*

or in matrix terms $\mathbf{p}^{\mathrm{T}}\mathbf{n} = 0$

Suppose $\mathbf{p}' = T\mathbf{p}$, *(T is any transformation)*

$\mathbf{p} = T^{-1}\mathbf{p}'$ *and* $T^{-1}\mathbf{p}'.\mathbf{n} = 0$

So… $T^{-1}\mathbf{p}'.\mathbf{n} = 0$ *or* $(T^{-1}\mathbf{p}')^{\mathrm{T}}\mathbf{n} = 0$

Now $(AB)^{\mathrm{T}} = B^{\mathrm{T}}A^{\mathrm{T}}$ *(prove that yourself)*

$(\mathbf{p}'^{\mathrm{T}}T^{-1\mathrm{T}})\,\mathbf{n} = 0$ $\mathbf{p}'^{\mathrm{T}}\,(T^{-1\mathrm{T}}\,\mathbf{n}) = 0$

i.e.: $\mathbf{p}'.T^{-1\mathrm{T}}\mathbf{n} = 0$

Beyond maths: see what it means

$$\boldsymbol{p}.\boldsymbol{n} = 0 \quad \text{and} \quad \boldsymbol{p}' = T\boldsymbol{p}$$

p *is a point on a plane with normal* ***n****.*

p′ *is a point on a transformed plane.*

And we have shown that $\boldsymbol{p}'.(T^{-1})^{\mathrm{T}}\boldsymbol{n} = 0$

So ***p′*** *is a point on a plane with normal*

$$T^{-1\mathrm{T}}\boldsymbol{n}$$

And the application...

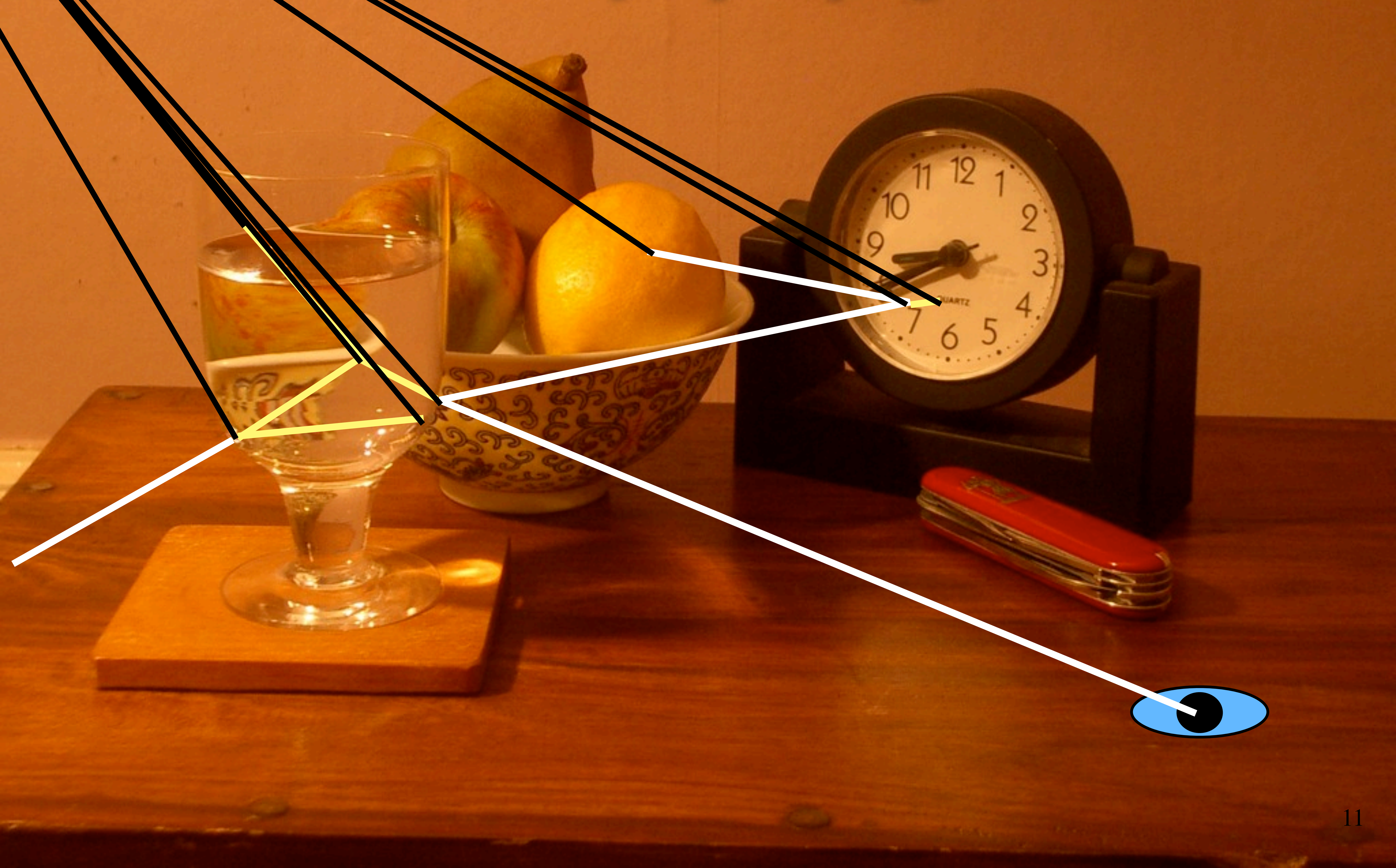
Suppose we have an object that has been transformed by a matrix T.

We transform $\mathbf{u} + \mathbf{v}t$ *by* T^{-1} *and find* t *at the hit point, and a normal,* $\mathbf{n}$.

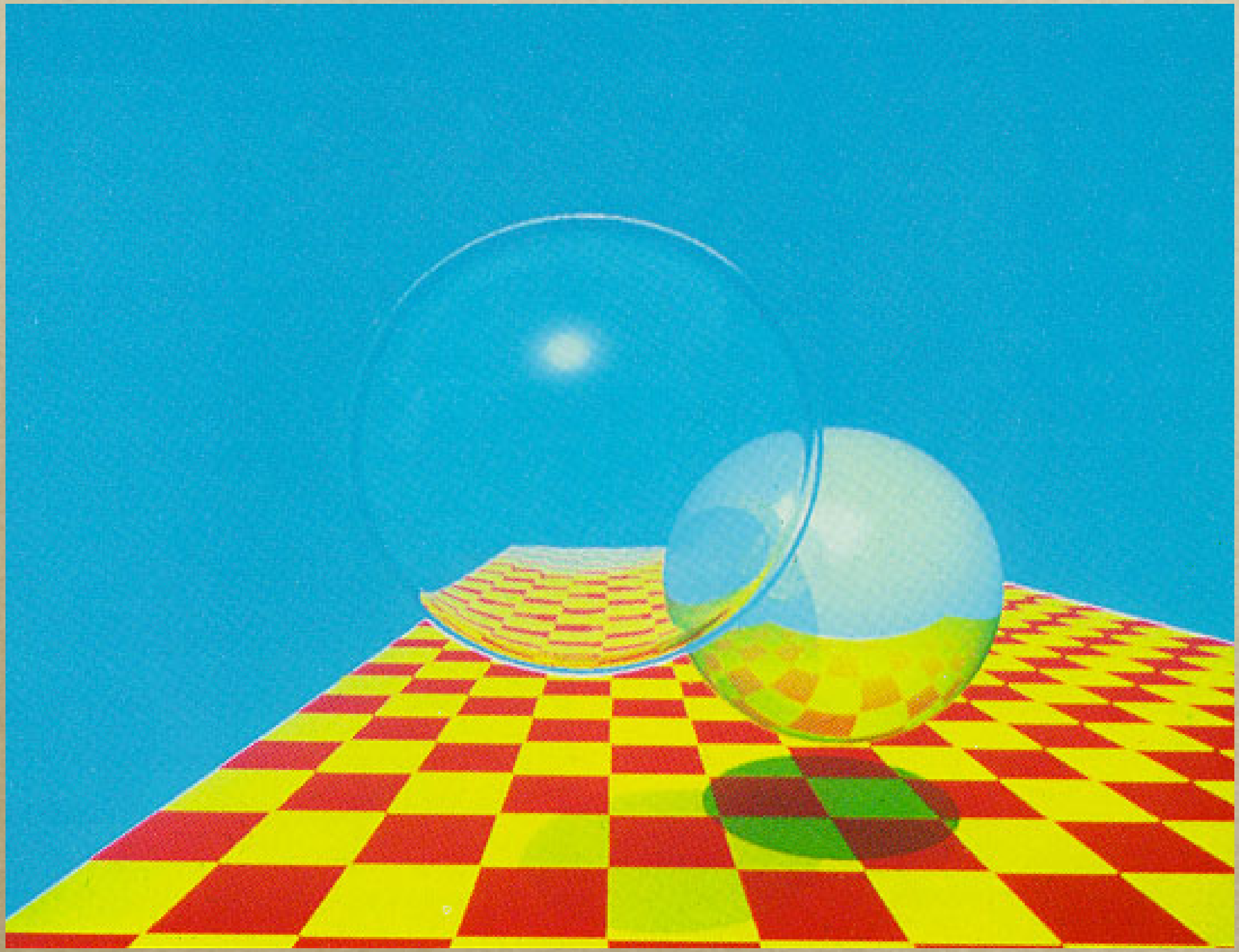
The hit point in world space is $\mathbf{u} + \mathbf{v}t$

and the normal in world space is $T^{-1\mathrm{T}}\mathbf{n}$.

How rays propagate



Whitted 1980



Ambient, Lambert, Phong, reflection, refraction, point light sources.

Just the beginning...

- *Aliasing artefacts*
- *No surface/surface illumination*
- *No caustics*
- *Real shadows are soft*
- *Colour problems*
- *Very slow*

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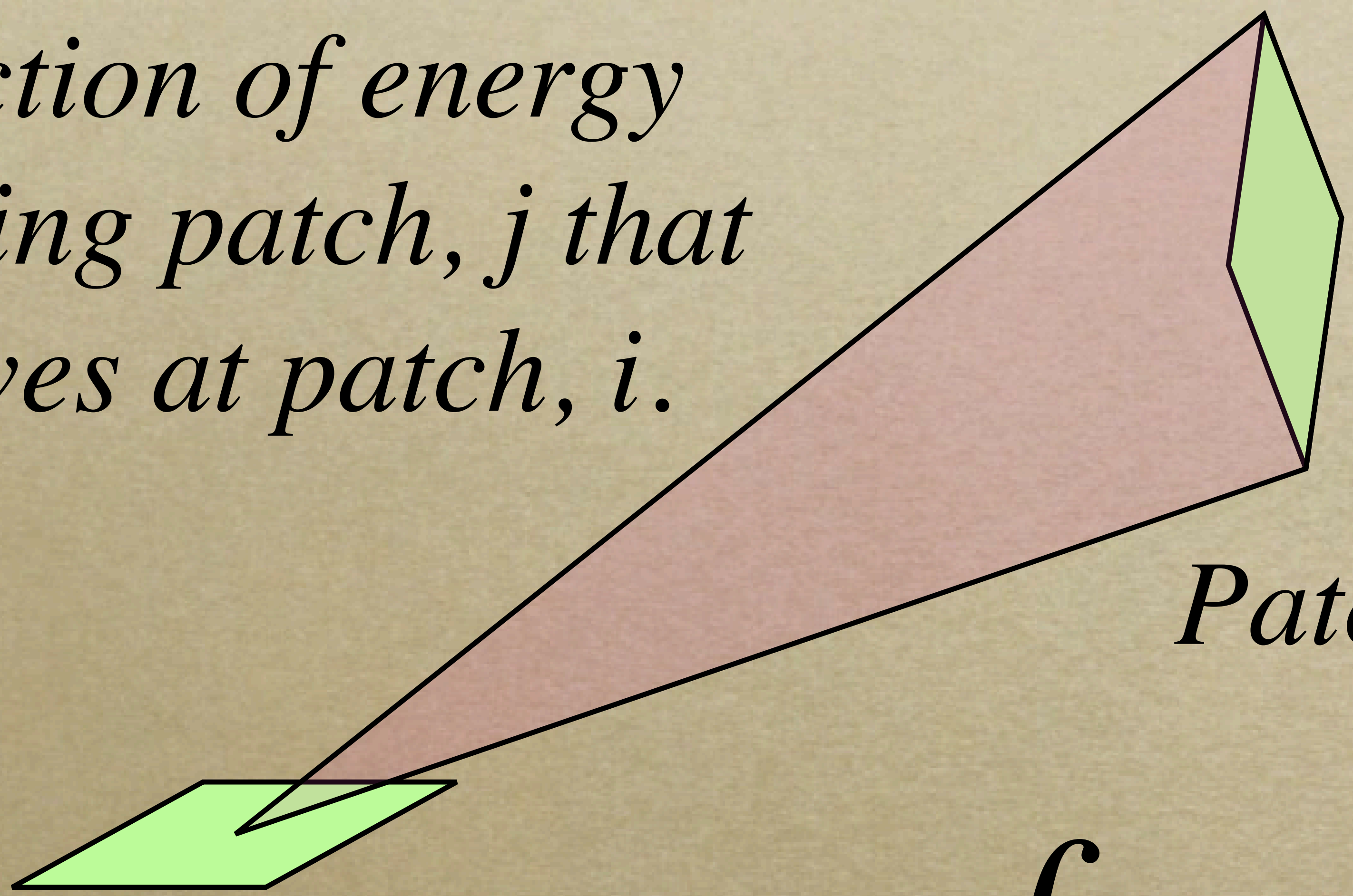
Radiosity

- *Divide the scene into small surface patches.*
- *For every patch pair find form factor.*
- *Find radiosities*
- *Render picture*

Form Factor, $f_{i,j}$

Fraction of energy leaving patch, j that arrives at patch, i.



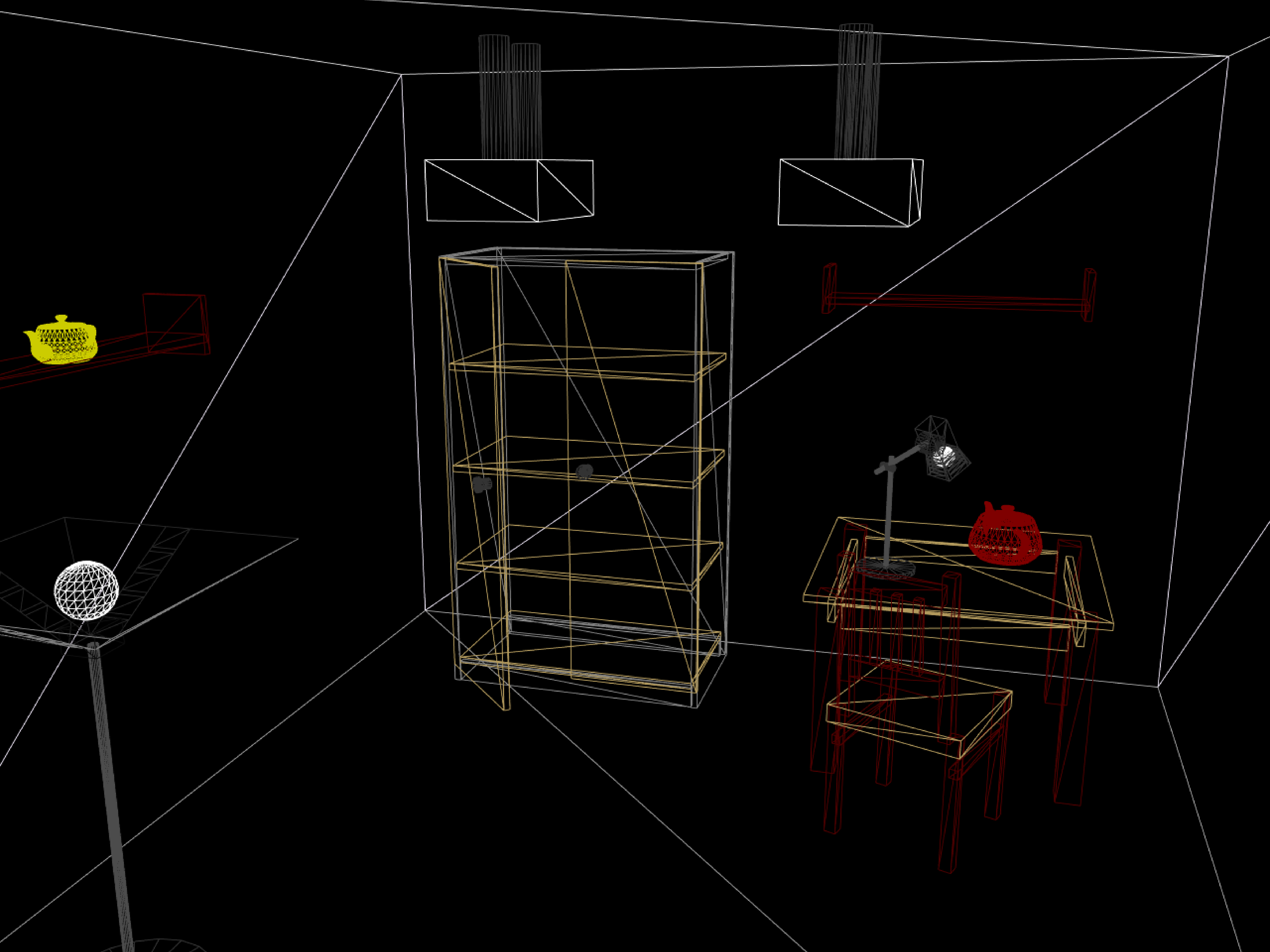
$$f_{ij} = f_{ji}$$

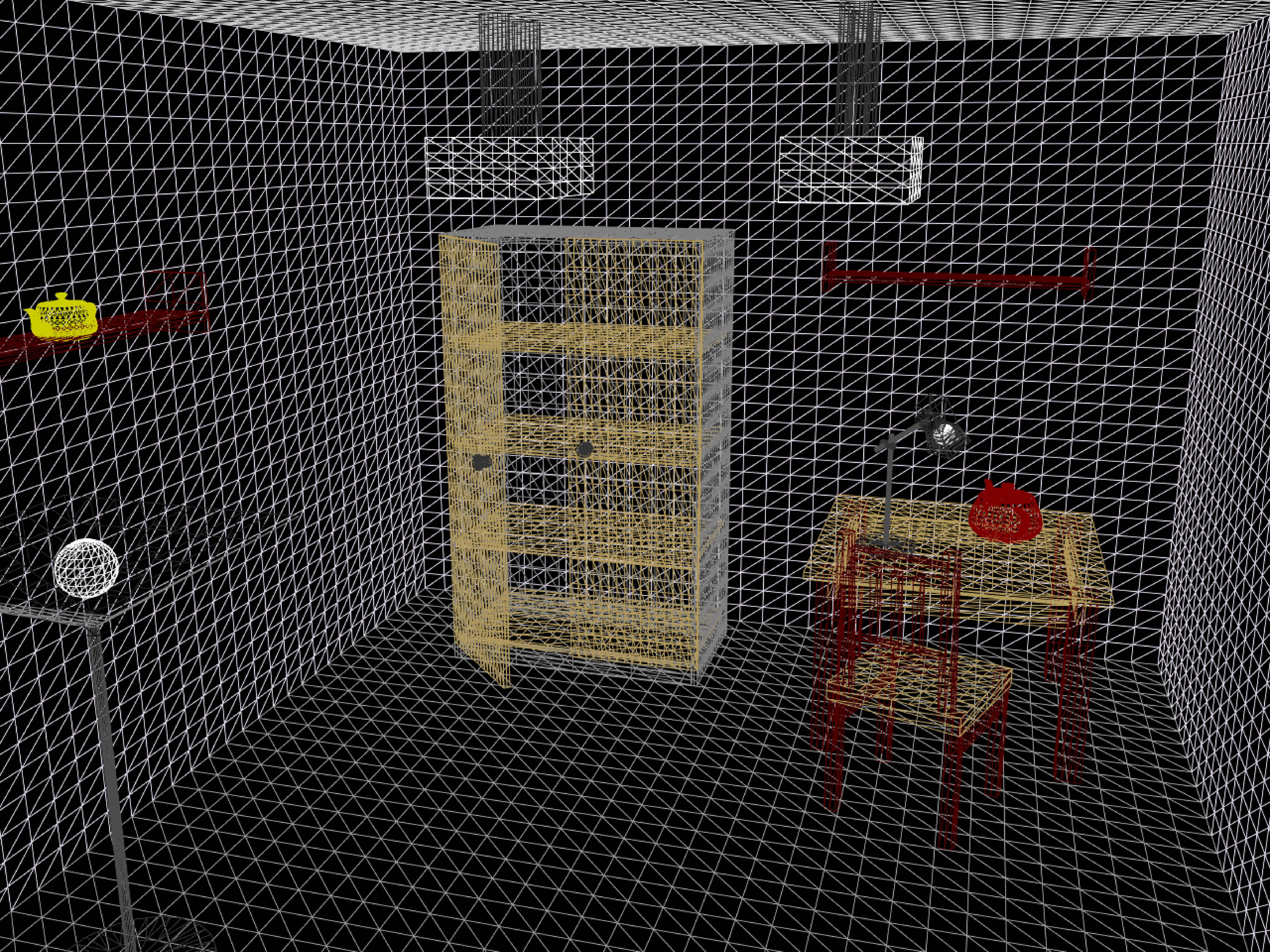
Radiosity Equation

$$R_i = E_i + k_{d,i}(\sum f_{i,j} R_j)$$

Set up this system of equations and solve.

Or use successive approximation.





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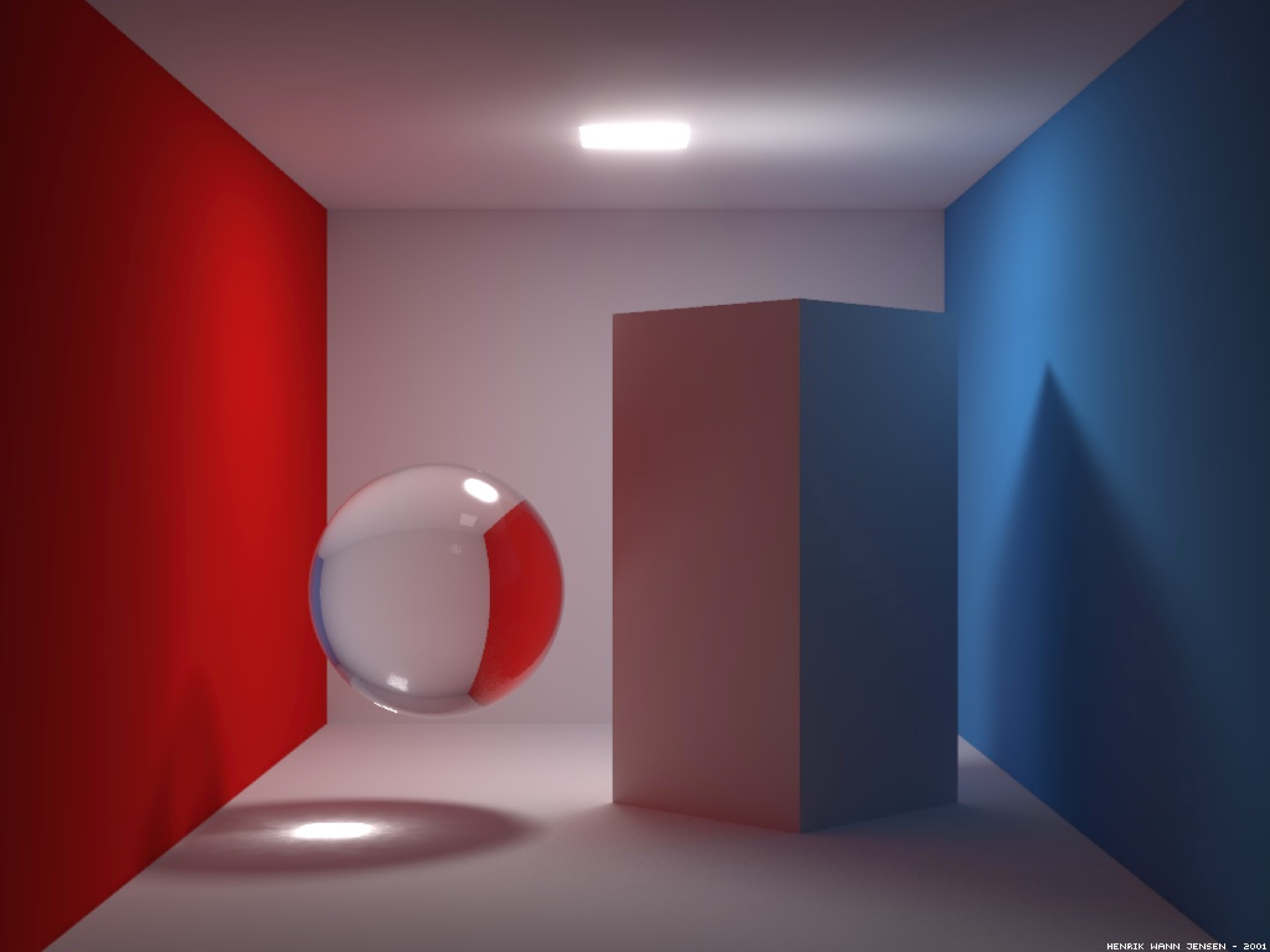
Caustics

- *Can be done by photon mapping.*
- *Shoot light particles (photons) from light sources. They behave like rays.*
- *Store information where they hit surfaces.*
- *Render lighting from the map.*


HENRIK WANN JENSEN - 2002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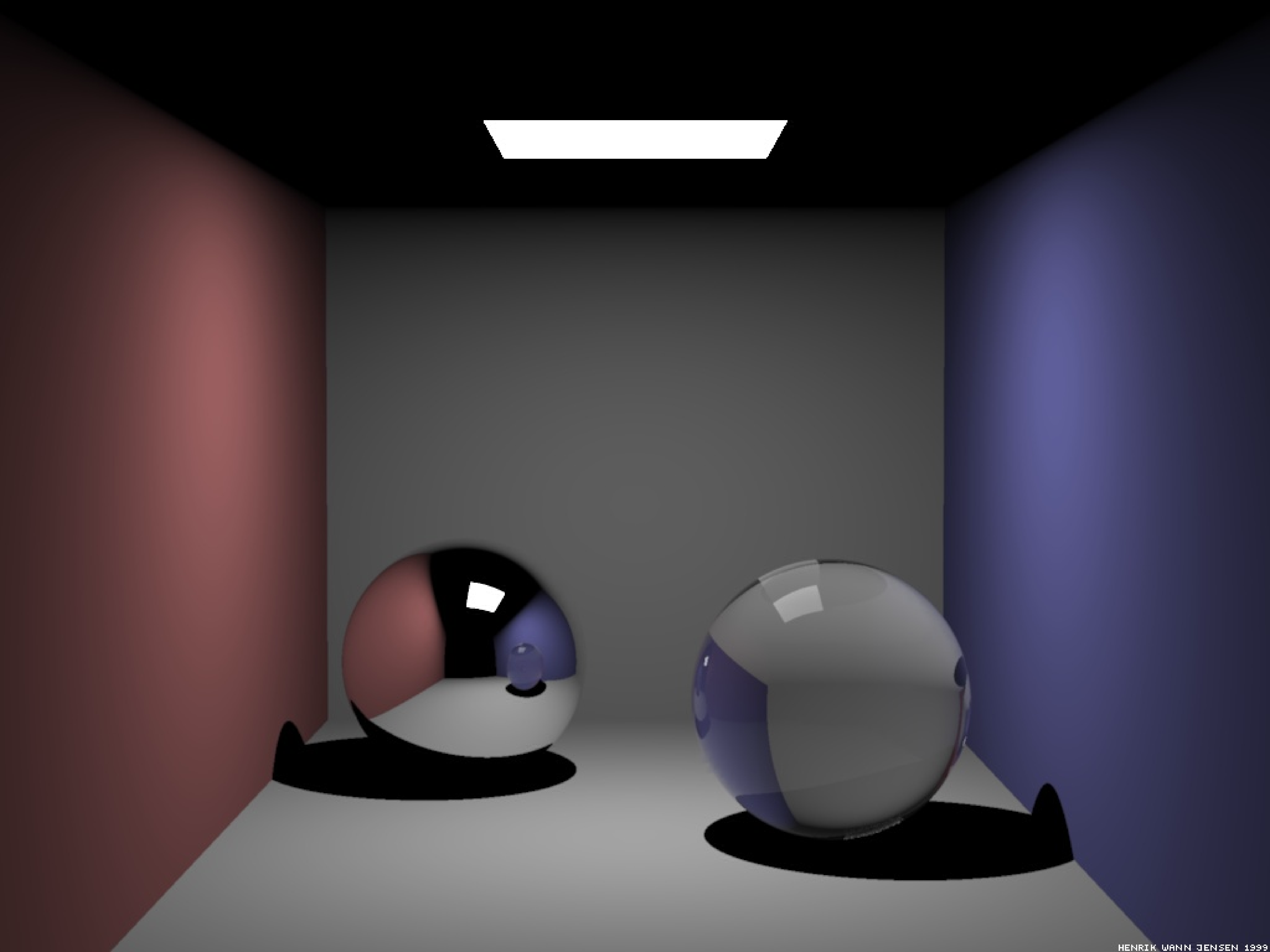
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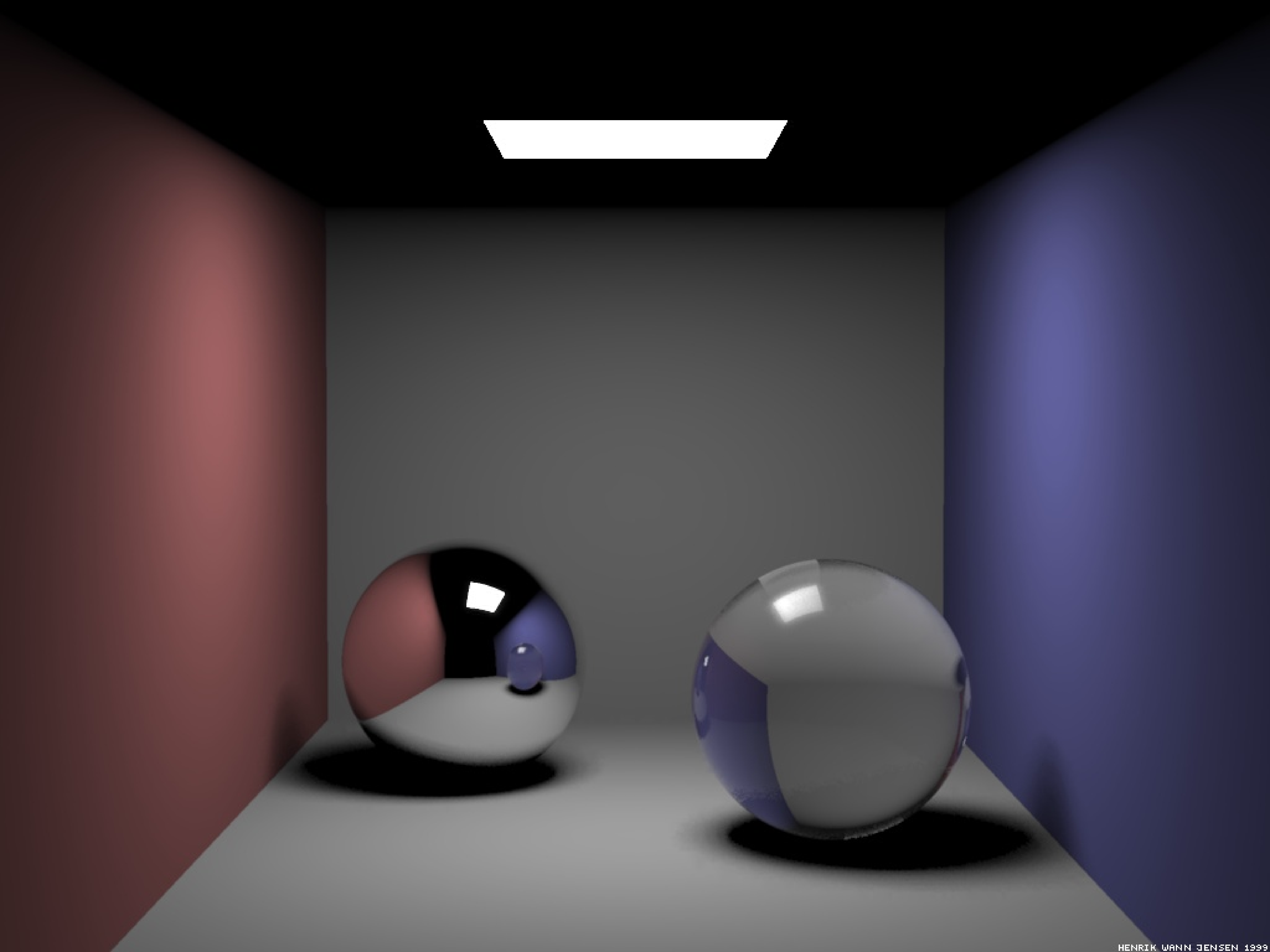
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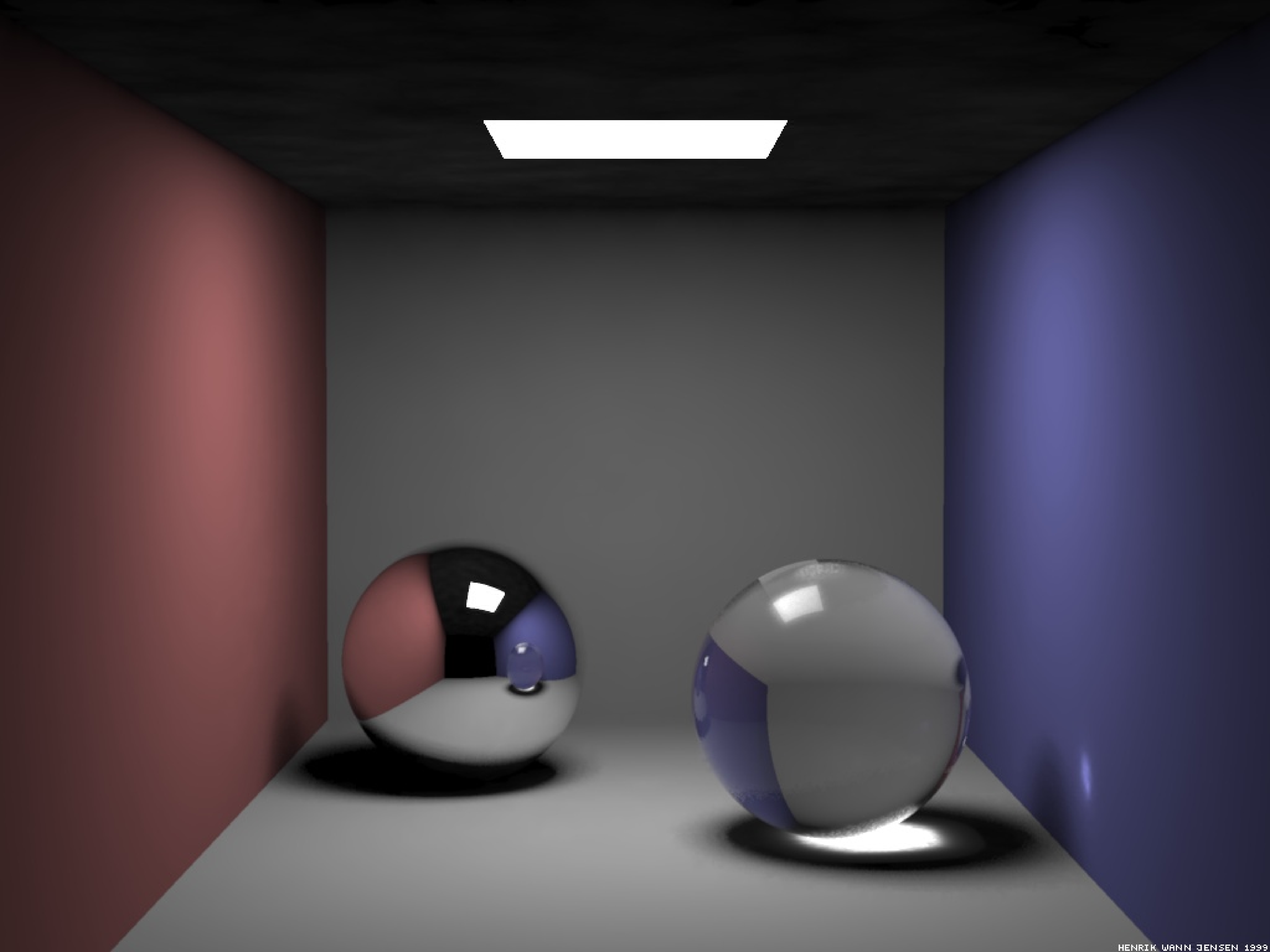
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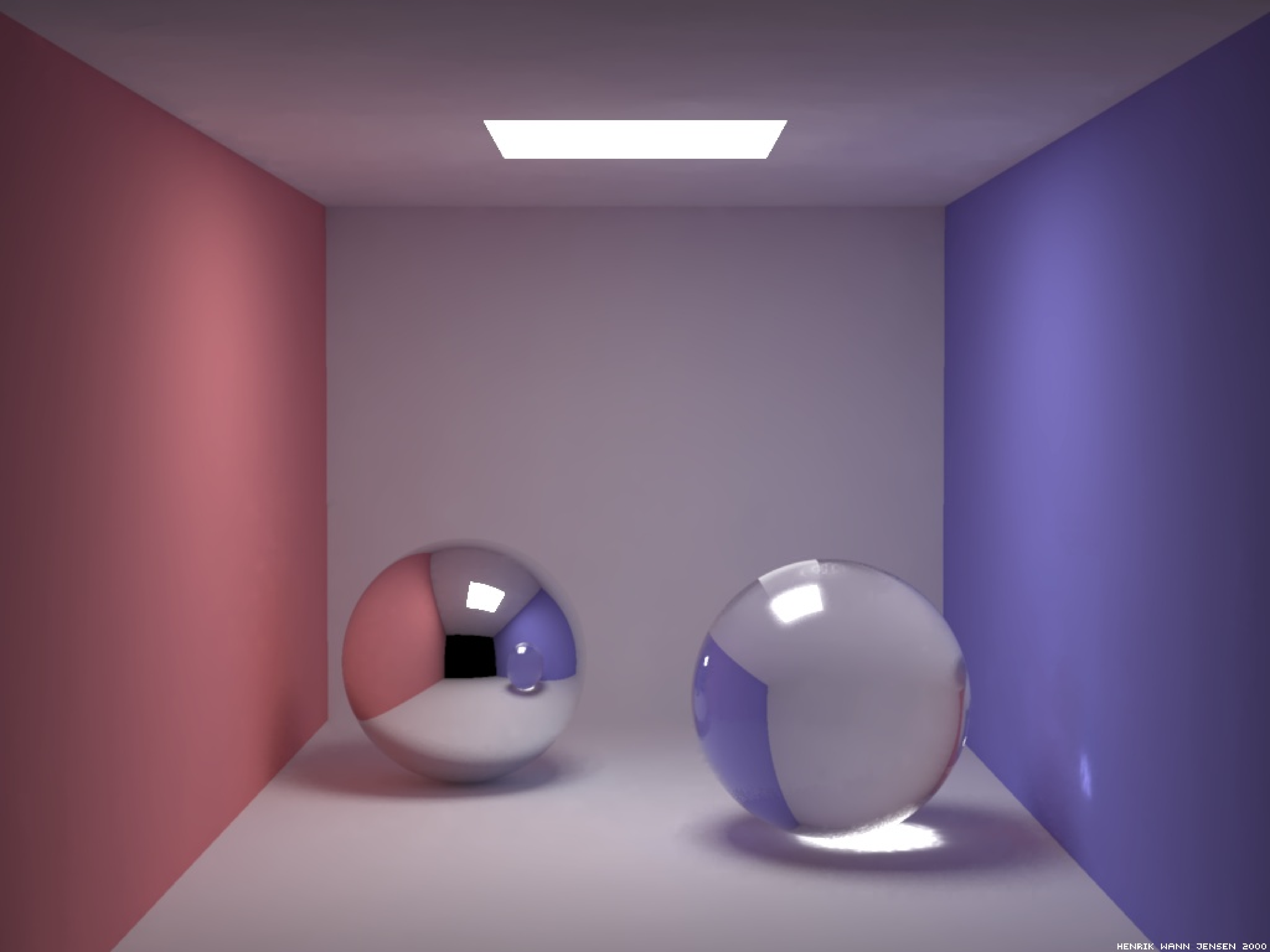
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Links

- *More on global illumination* http://escience.anu.edu.au/lecture/cg/GlobalIllumination/printNotes.en.html
- *Our radiosity example used:* http://dudka.cz/rrv/gallery?lang=cz
- *Cornell Box model:* http://graphics.ucsd.edu/~henrik/images/cbox.html