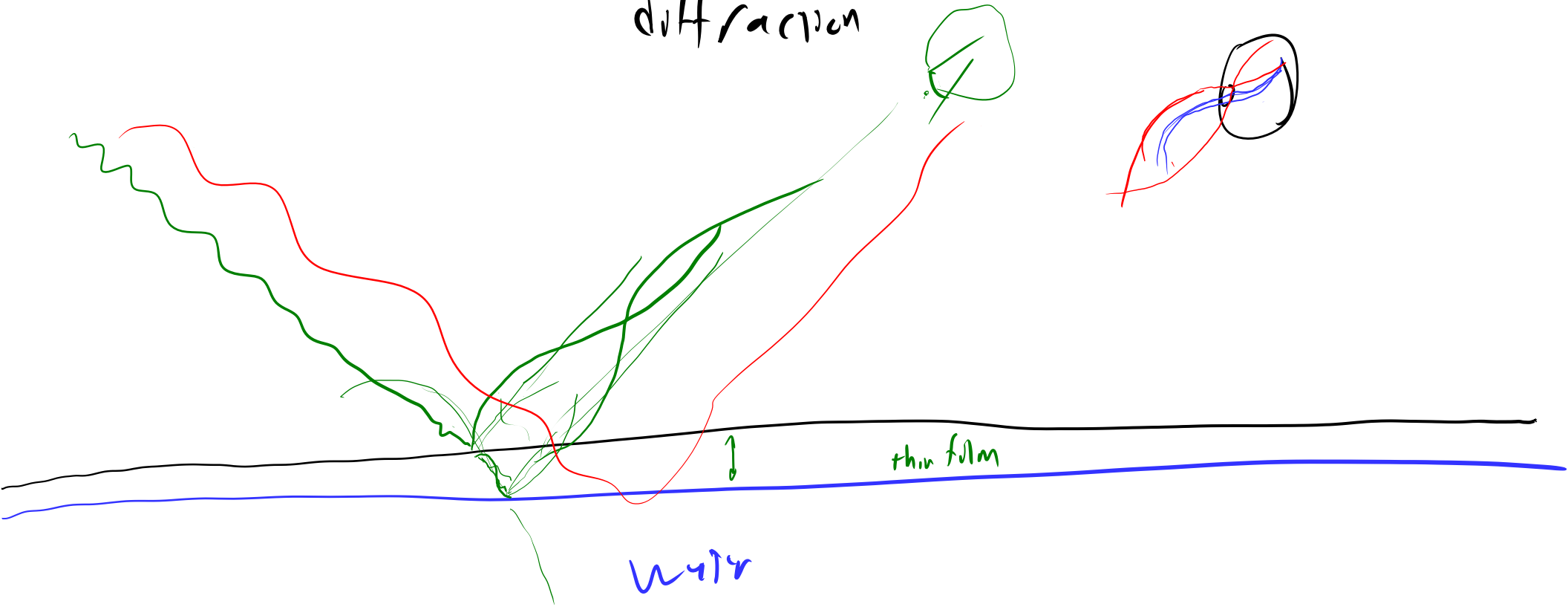


Oil  
diffraction

Quantum



thin film

water

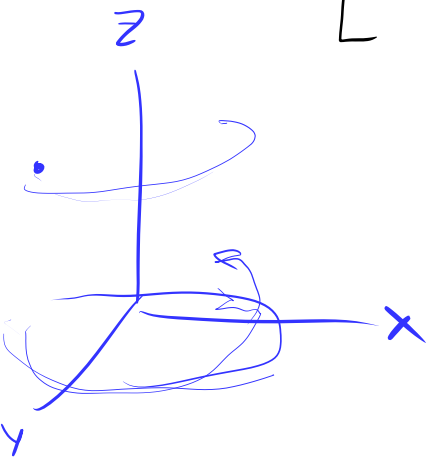
CD



$$\begin{bmatrix} y \end{bmatrix} = \begin{bmatrix} A \end{bmatrix} \begin{bmatrix} x \end{bmatrix}$$

SVD

$$\begin{bmatrix} R_{UT} \end{bmatrix} \begin{bmatrix} \text{Scale} \end{bmatrix} \begin{bmatrix} R_{UT} \end{bmatrix}$$



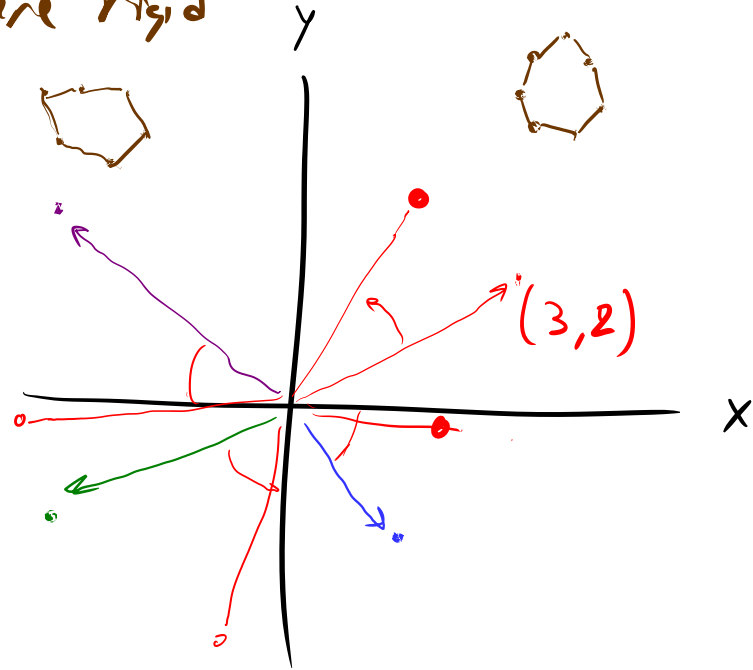
$$\begin{bmatrix} c & s & 0 \\ -s & c & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$c = \cos(\theta)$$

$$s = \sin(\theta)$$

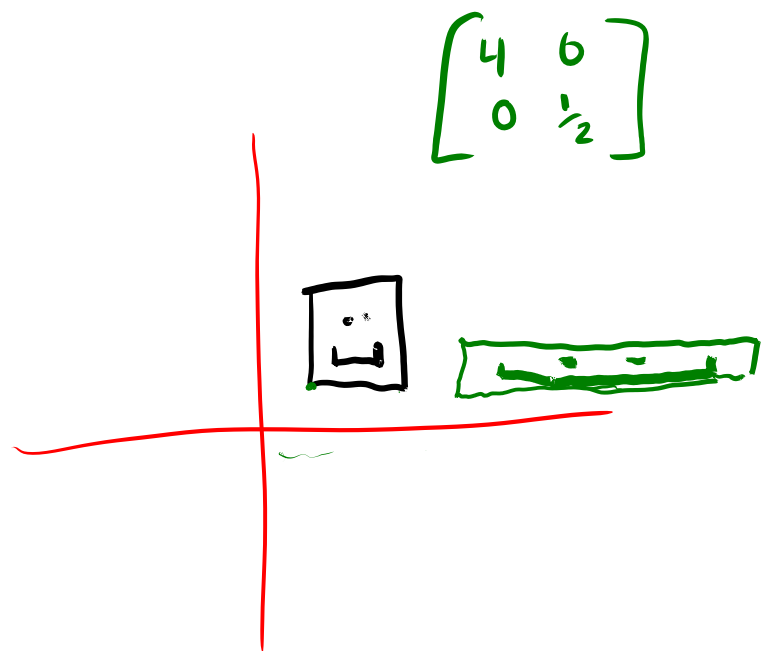
$$\begin{bmatrix} c & s & 0 \\ -s & c & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Rotations are rigid



$$\begin{bmatrix} \end{bmatrix} = \begin{bmatrix} A \end{bmatrix} \begin{bmatrix} 3 \\ 2 \end{bmatrix}$$

$$\begin{bmatrix} x \cdot s_x \\ y \cdot s_y \\ z \cdot s_z \end{bmatrix} = \begin{bmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \\ 0 & 0 & s_z \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$



# Homogeneous Coordinates

$$\forall \vec{y} \in H. \forall x \in \mathbb{R}^+ . \vec{y} = x \cdot \vec{y}$$

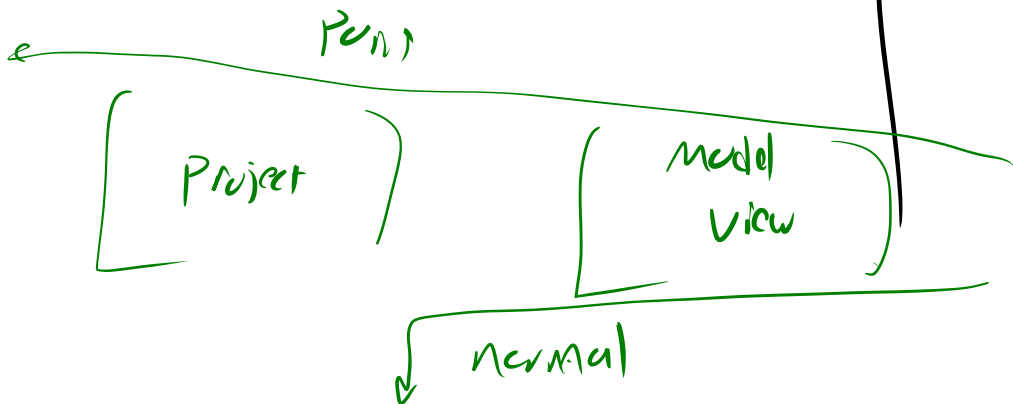
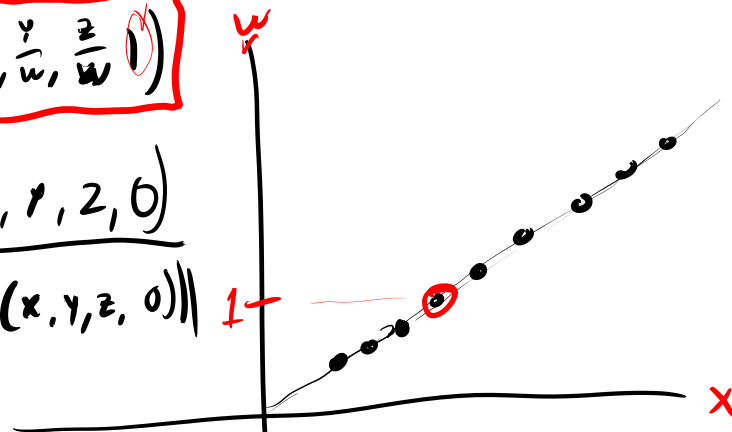
$$(1, 2, 3) = (3, 6, 9)$$

$$(0, 2, 0) = (0, 38, 0)$$

$$(0, 2, 0) \neq (1, 2, 0)$$

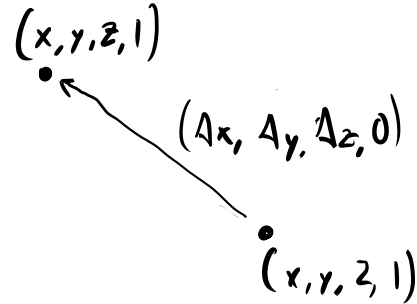
normalized homogeneous vector

$$(x, y, z, w) \begin{cases} \left( \frac{x}{w}, \frac{y}{w}, \frac{z}{w}, 1 \right) \\ \frac{(x, y, z, 0)}{\|(x, y, z, 0)\|} \end{cases}$$

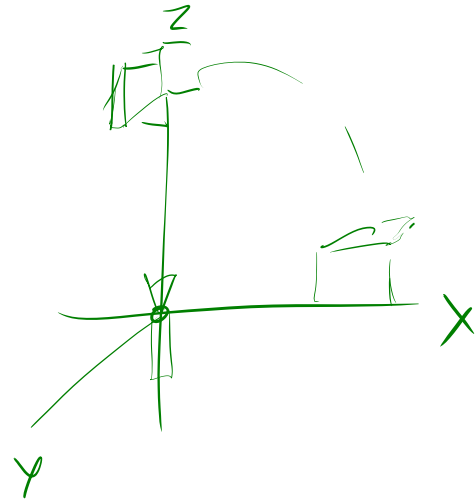


- ✓ Scale
- ✓ Rotation
- Translation
- Perspective/Frustum

$$\begin{bmatrix} 2x \\ 2y \\ 2z \\ 1 \end{bmatrix} = \begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \leftarrow \text{points}$$



$$\begin{bmatrix} ? & 0 & 0 & 0 \\ 0 & ? & 0 & 0 \\ 0 & 0 & a & -1 \end{bmatrix} = \begin{bmatrix} ? & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} c & s & 0 & 0 \\ -s & c & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

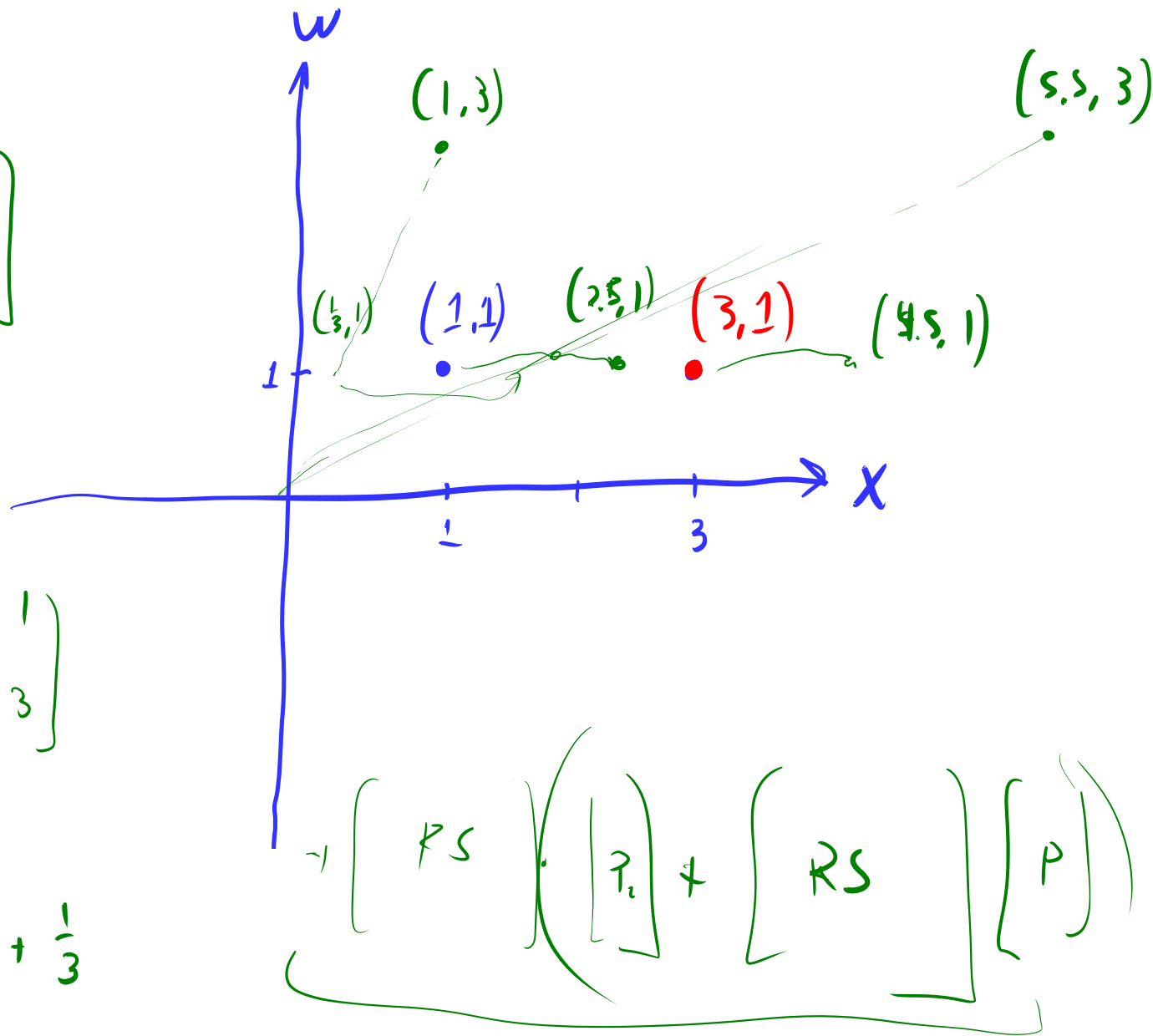




$$\begin{bmatrix} x+y \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & y \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ 1 \end{bmatrix}$$

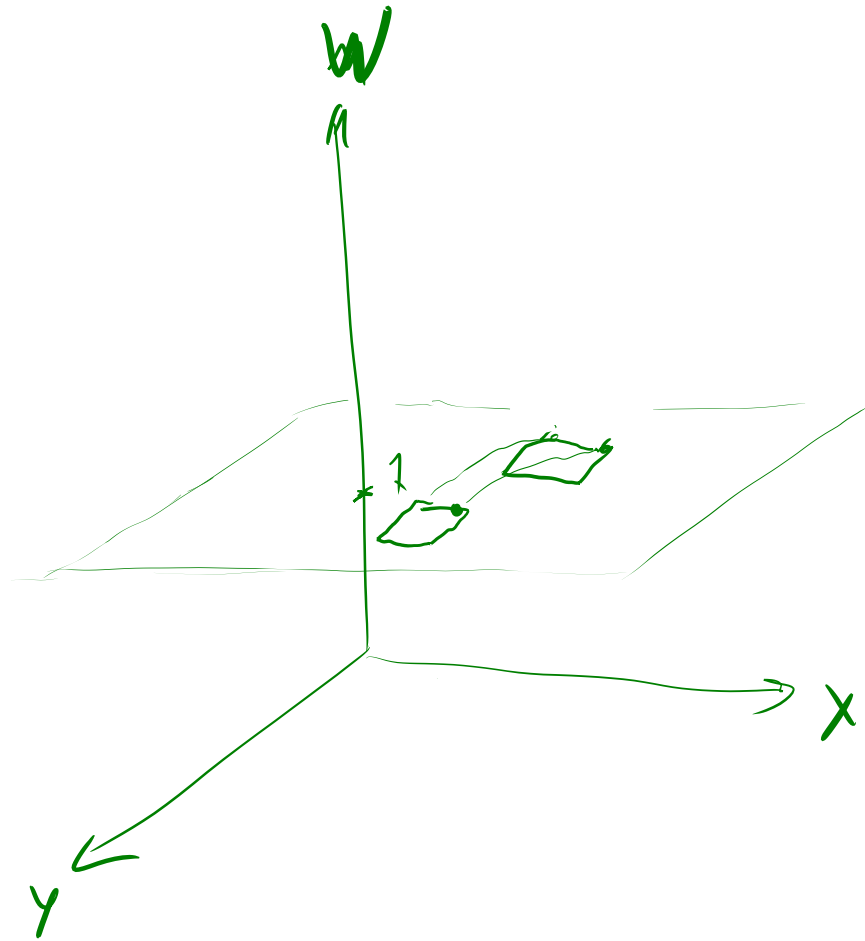
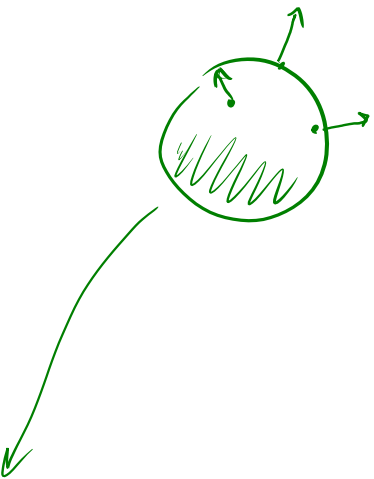
$$\begin{bmatrix} 5.5 \\ 3 \end{bmatrix} = \begin{bmatrix} 1 & 1.5 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 3 \end{bmatrix}$$

$$\frac{5.5}{3} = 1.5 + \frac{1}{3}$$



Point:  $w=1$

vector:  $w=0$

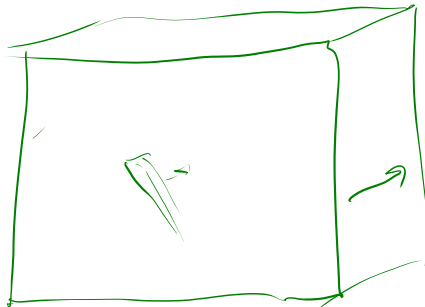
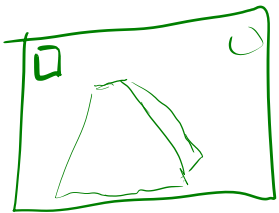
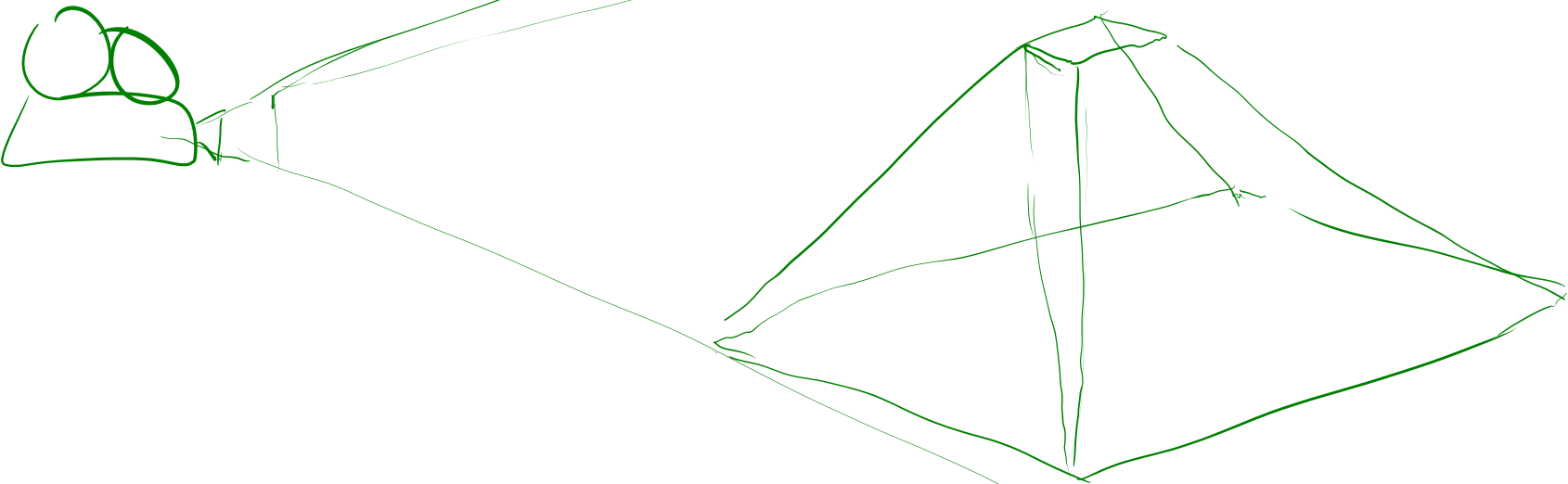


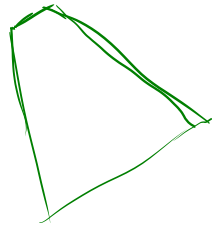
$$\begin{bmatrix} 1 & 0 & dx \\ 0 & 1 & dy \\ 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & dx \\ 0 & 1 & 0 & dy \\ 0 & 0 & 1 & dz \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

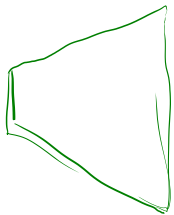
$$\begin{bmatrix} .8 \\ .6 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 2 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} .8 \\ .6 \\ 0 \end{bmatrix}$$

# Frustum

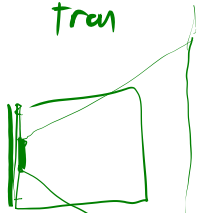




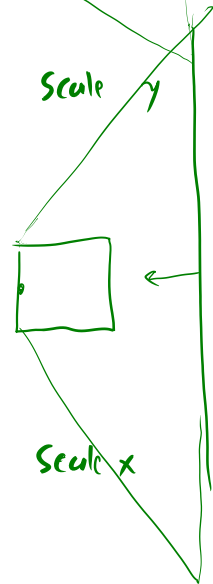
rot ↻



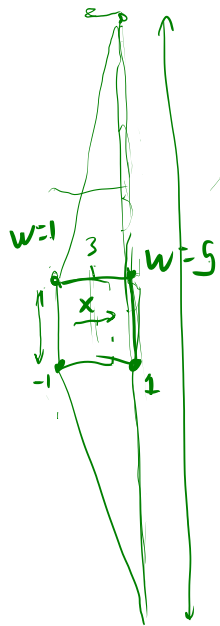
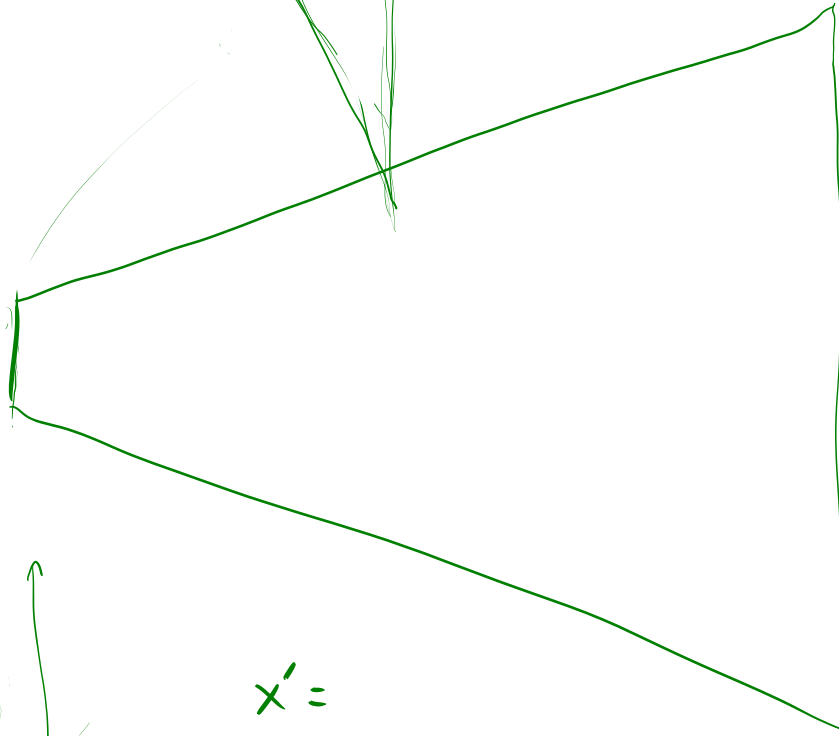
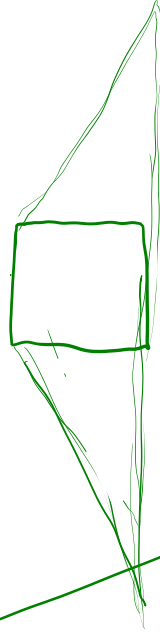
tran



Scale y



Scale x

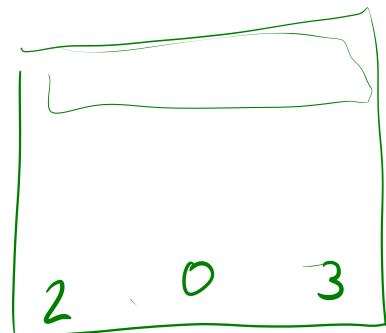


$$x' =$$

$$w = (2x + 3)$$

$$x = -1, w = 1$$

$$x = 1, w = 5$$



$$w = \frac{5-1}{1-(-1)} x + \frac{4}{2}$$