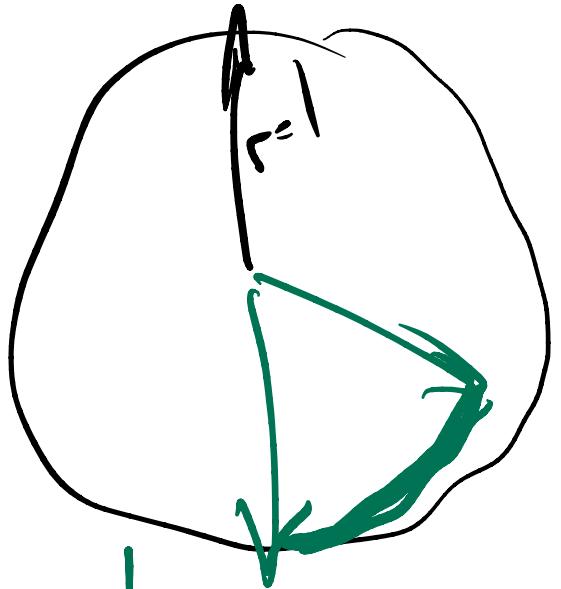


$$\text{circ} = 2\pi$$



$$\text{deg} = \frac{\text{rad}}{\pi} \times 180$$

$$\begin{array}{c} \text{P} \quad \frac{\pi}{2} \\ \downarrow \\ \text{P} \quad \pi \end{array}$$

$\rho_0 r^{\theta}$

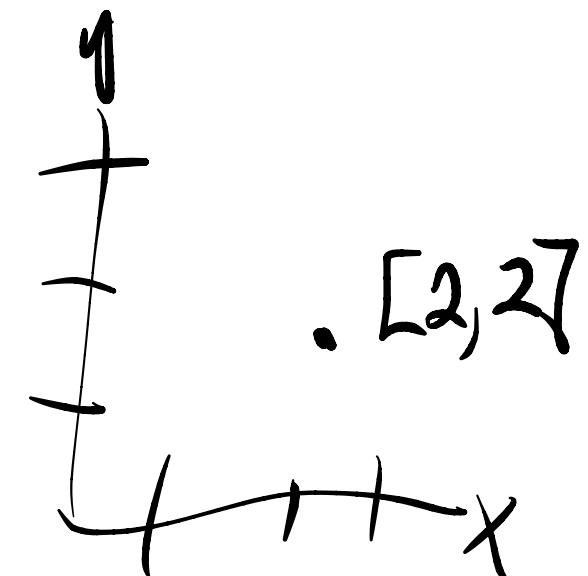
$$\sin \alpha = \frac{d}{h}$$

$$\tan \alpha = \frac{a}{d}$$

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

$$P_1 + P_2 = \begin{bmatrix} x_1 + x_2 \\ y_1 + y_2 \end{bmatrix}$$

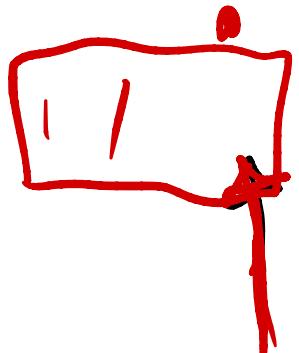
$$P_1 S = \begin{bmatrix} x_1 s \\ y_1 s \end{bmatrix}$$



$$P_1 = \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} \quad P_2 = \begin{bmatrix} x_2 \\ y_2 \end{bmatrix}$$

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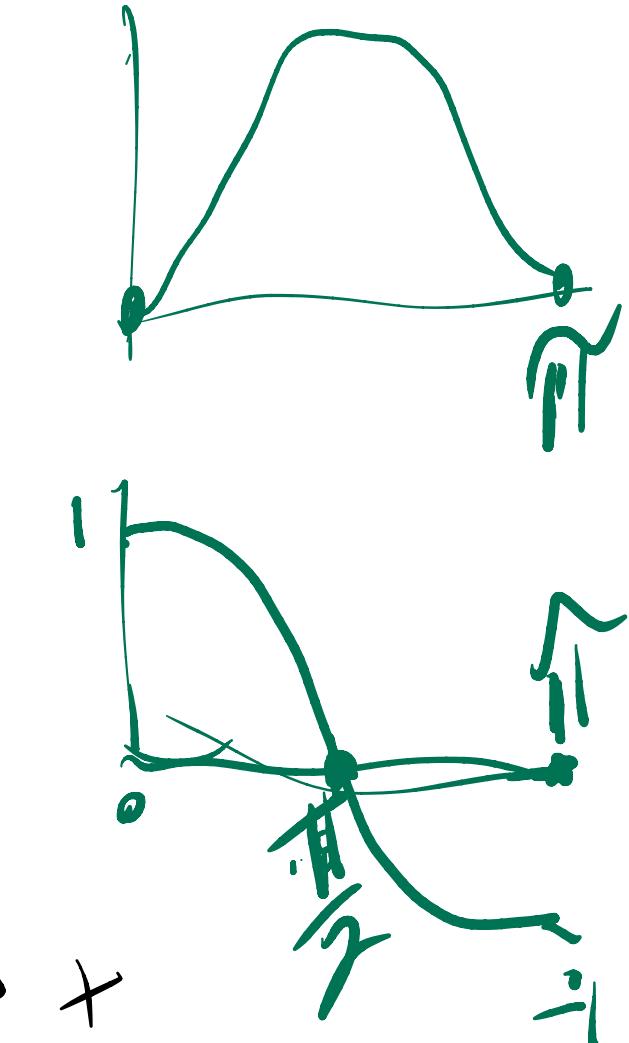
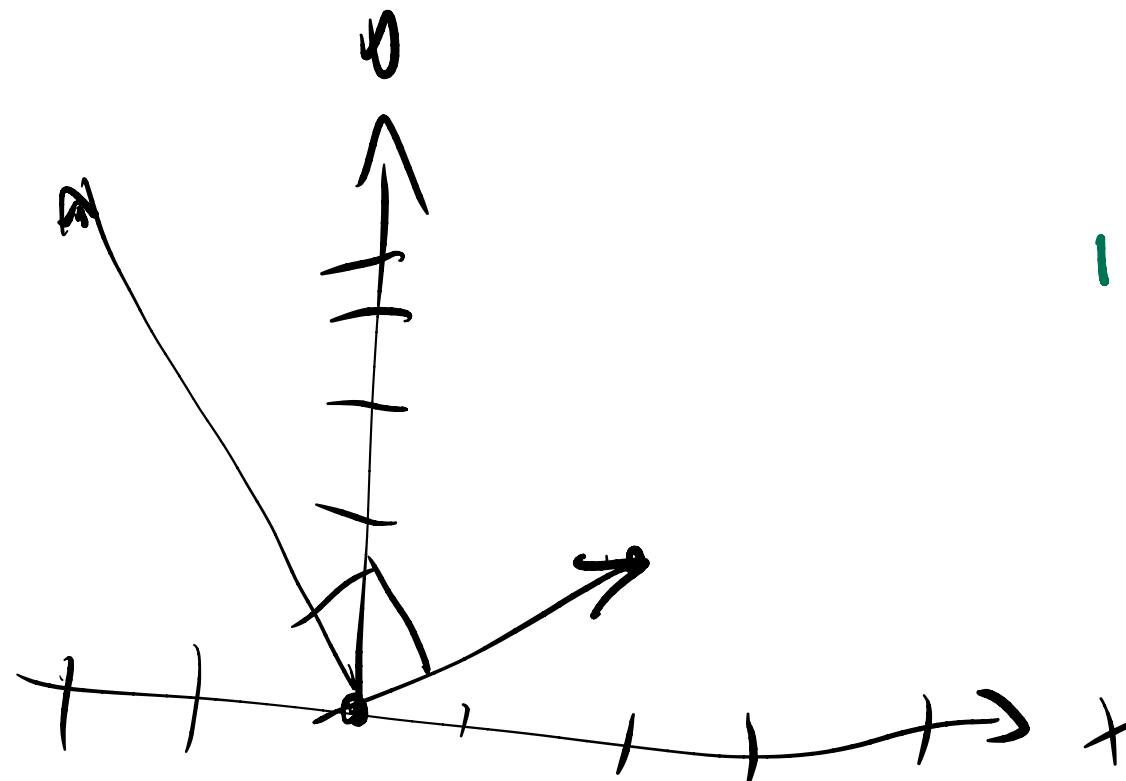
$$P_1 \cdot P_2 = \begin{bmatrix} x_1 \cdot x_2 + y_1 \cdot y_2 \end{bmatrix}$$

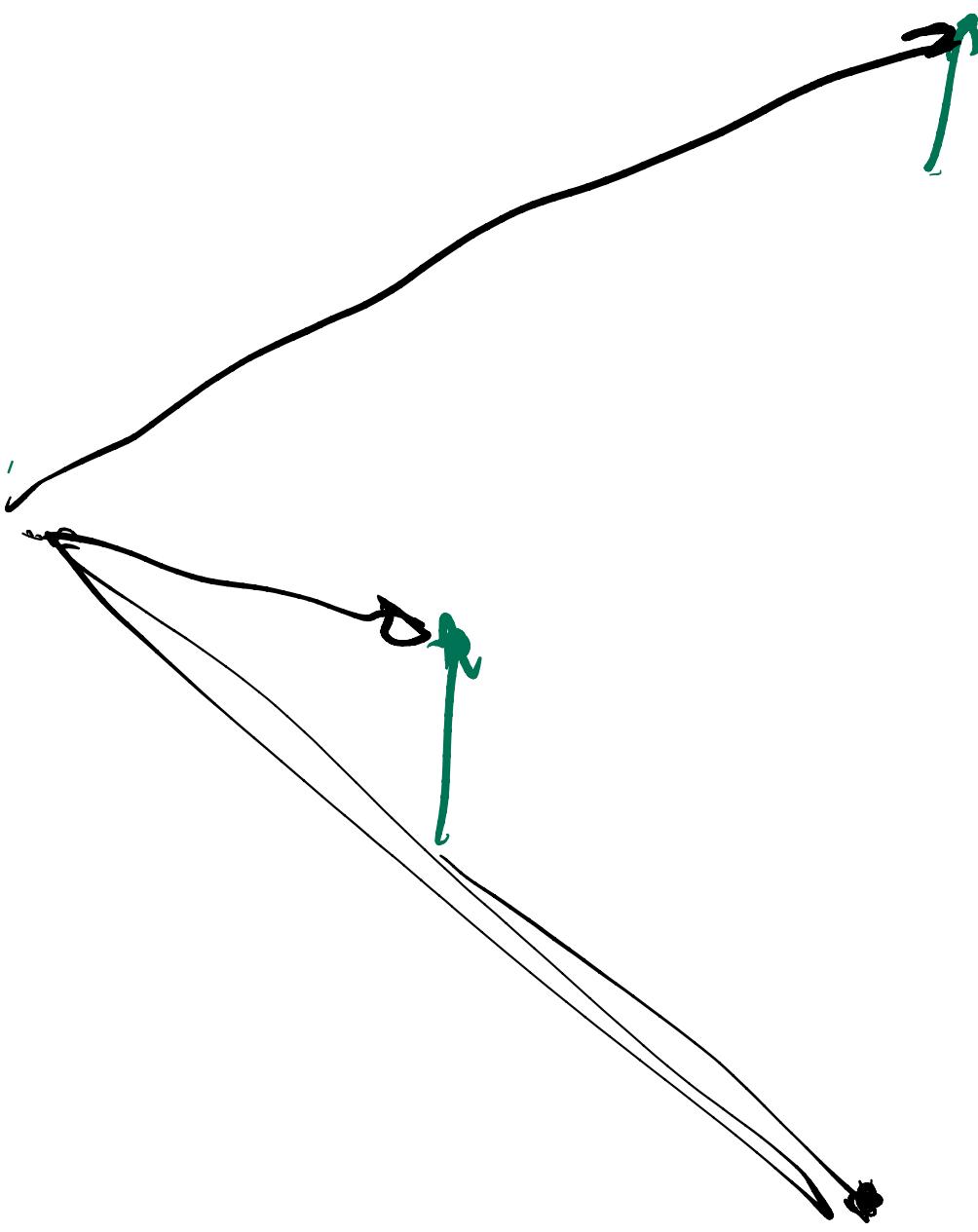


$$\| A \| = \text{Mag. length}$$

$$= \sqrt{x^2 + y^2}$$

$$= -4 + 4 = 0$$





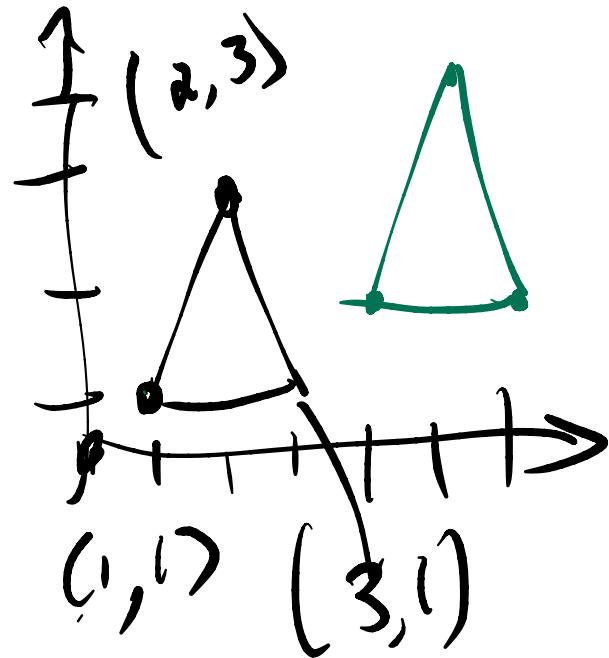


$$\begin{bmatrix} 1 & 0 \\ 2 & 1 \end{bmatrix} \begin{bmatrix} 2 & 2 \\ 2 & 2 \end{bmatrix}$$

$$= \begin{bmatrix} 2 & 2 \\ 6 & 6 \end{bmatrix}$$

[4]
[5]

[2 3]
[1 4] [23]
[24]



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

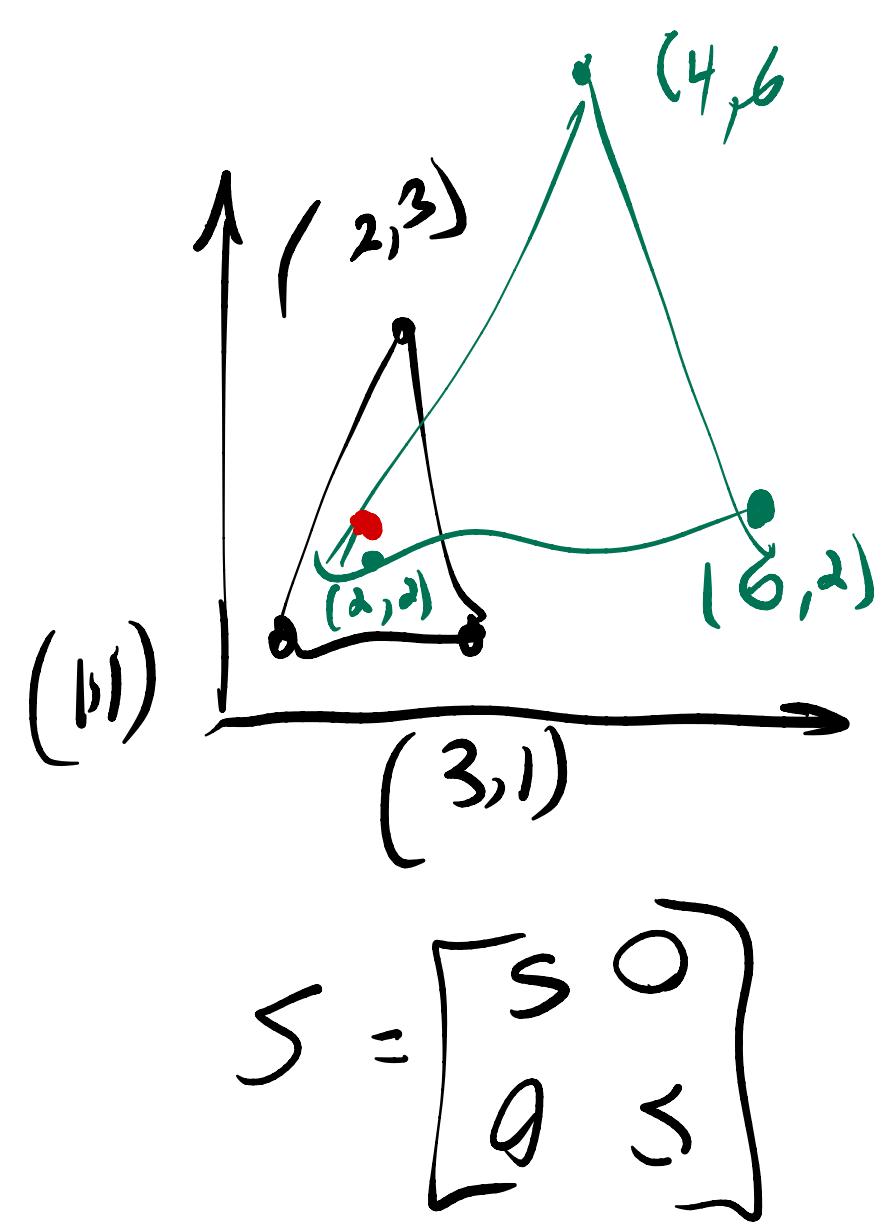
move 3
1 up in y

$$\begin{aligned} x' &= x + 3 \\ y' &= y + 1 \end{aligned}$$

$$P' = P + T$$



$$\begin{aligned} P' &= \begin{bmatrix} x' \\ y' \end{bmatrix} \\ T &= \begin{bmatrix} dx \\ dy \end{bmatrix} \end{aligned}$$



scale by $s = 2$

$$x' = x \cdot s$$

$$y' = y \cdot s$$

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

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

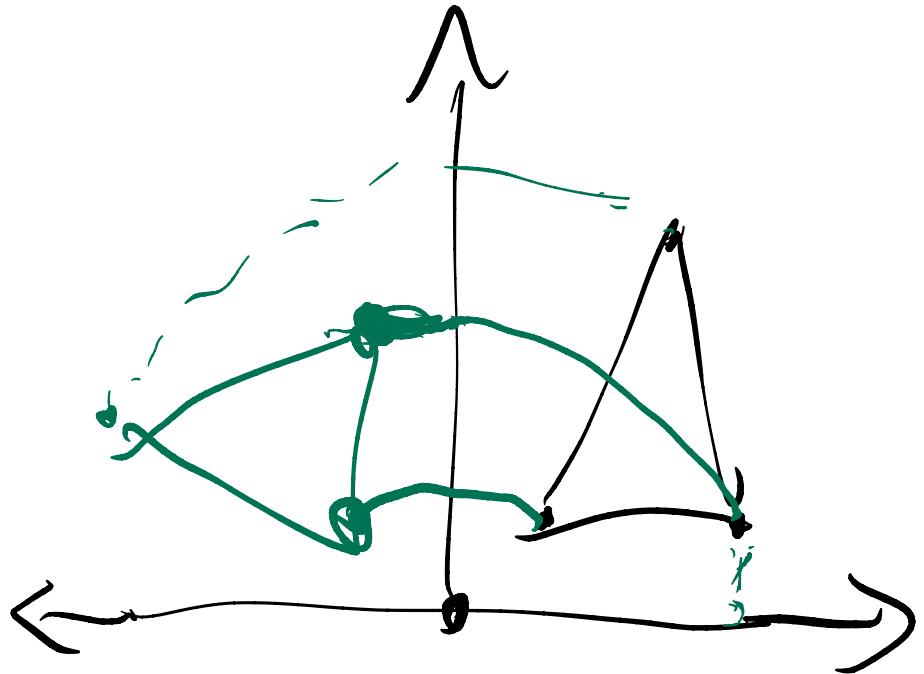
$$P' = \begin{bmatrix} x' \\ y' \end{bmatrix}$$

$$s = \begin{pmatrix} s & 0 \\ 0 & s \end{pmatrix}$$

$$P' = \begin{bmatrix} sx + d \\ 0 + sy \end{bmatrix}$$

$$s = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix}$$

rotate 90° counter-clockwise
[ccw]



$$x' = x \cdot \cos\theta - y \cdot \sin\theta$$
$$y' = x \cdot \sin\theta + y \cdot \cos\theta$$

$$R = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = P'$$

points (x, y) $P = \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$
 \rightarrow

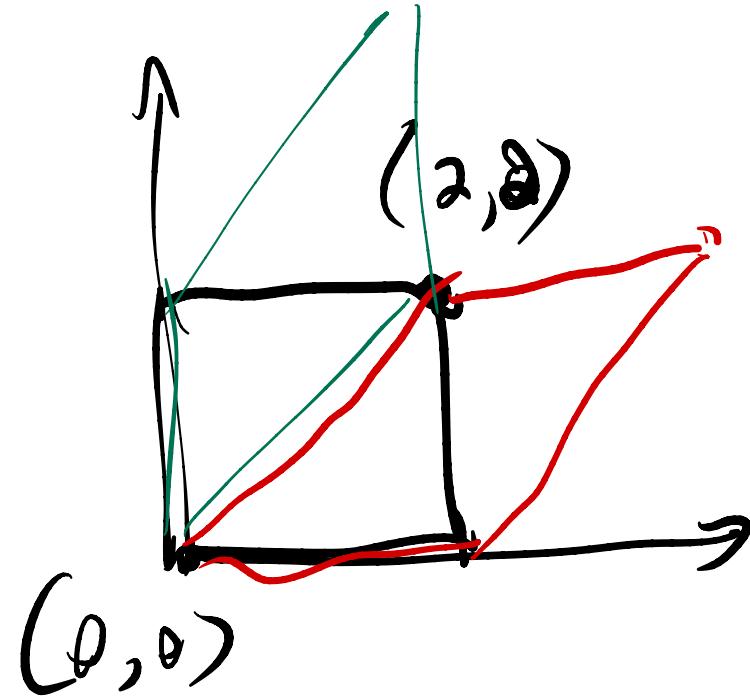
$$\begin{aligned} P' &= S \cdot P \\ P' &= R \cdot P \\ P' &= T \cdot P \end{aligned}$$

$$\begin{aligned} c &= \cos \theta \\ s &= \sin \theta \end{aligned}$$

$$S = \begin{bmatrix} S_x & 0 \\ 0 & S_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad S \cdot P = \begin{bmatrix} S_x x \\ S_y y \\ 1 \end{bmatrix}$$

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

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



$$\begin{matrix} x' \\ y' \end{matrix} = \begin{matrix} x + ay \\ b \end{matrix}$$

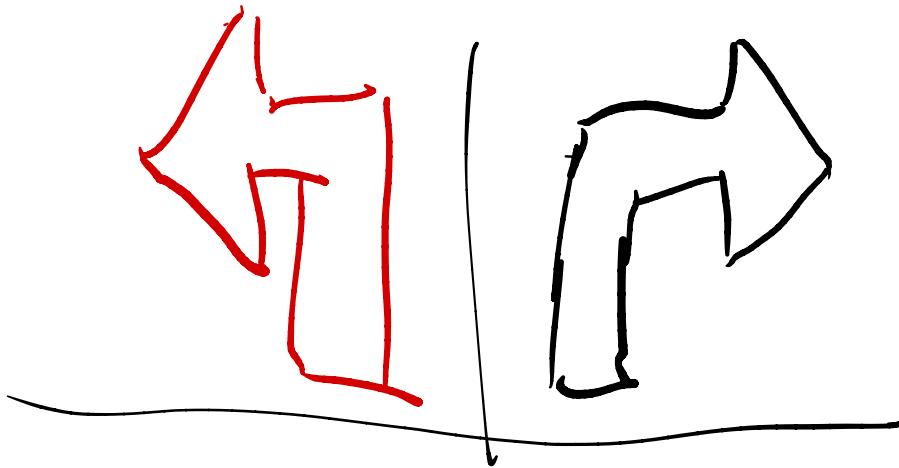
$$a=2$$

$$Sh_x = \begin{bmatrix} 1 & a & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

y_1

$$\begin{matrix} x' = x \\ y' = y + dx \end{matrix}$$

$$Sh_y = \begin{bmatrix} 1 & 0 & 0 \\ a & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$



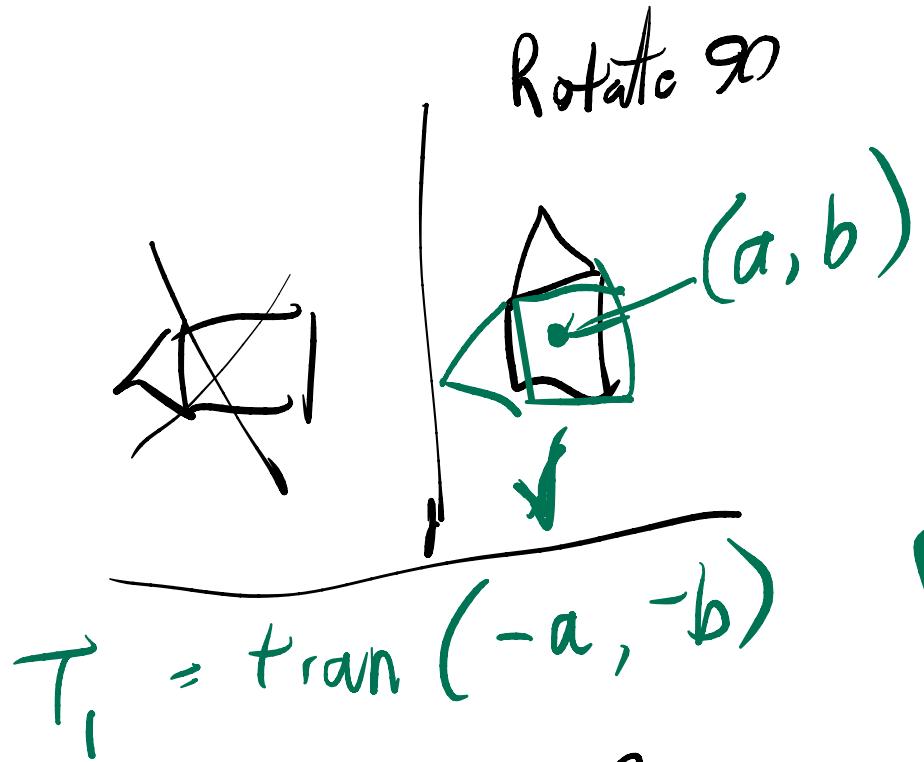
$$x' = -x$$

$$y' = y$$

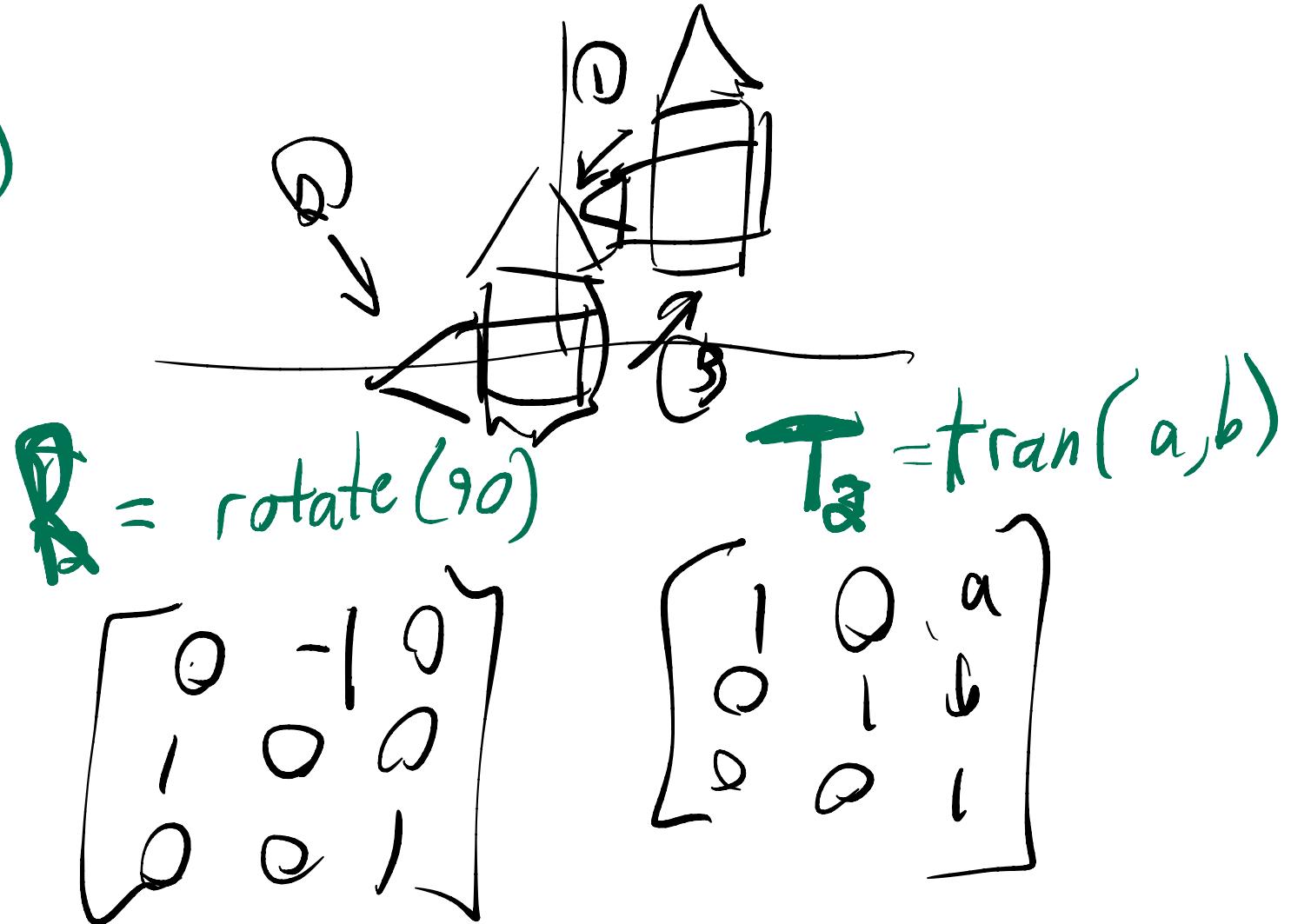
$$RF_x = \begin{bmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$s_x = -1$
 $s_y = 1$

$$RF_y = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$



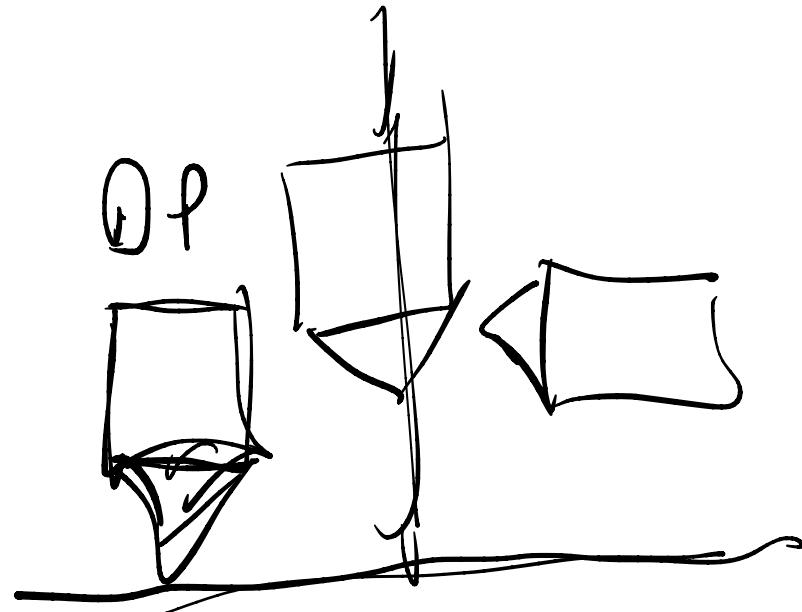
$$\begin{bmatrix} 0 & 0 & -a \\ 0 & 0 & -b \\ 1 & 0 & 1 \end{bmatrix}$$



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

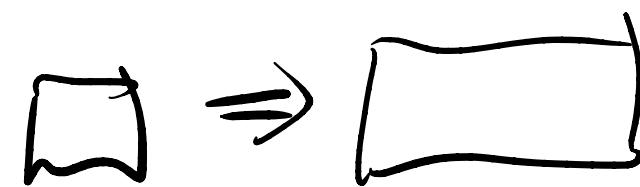
$$\begin{bmatrix} 1 & 0 & a \\ 0 & 1 & b \\ 0 & 0 & 1 \end{bmatrix}$$

$$\begin{aligned}
 p' &= T_2 \cdot p \cdot T_1 \cdot p \\
 &= T_2 (R(T_1 \cdot p)) \\
 &= (T_2 R T_1) p \\
 ? \neq & (T_1 T_2 R) p
 \end{aligned}$$

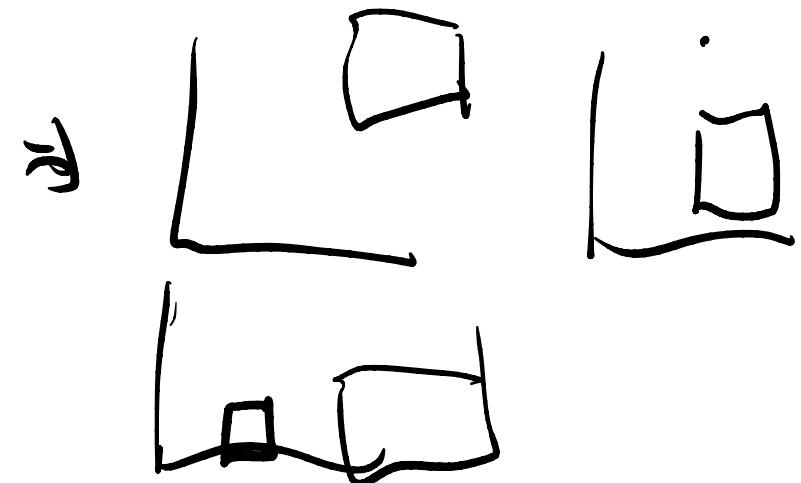
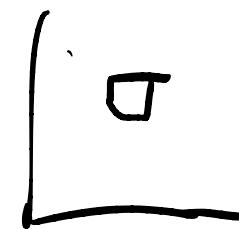
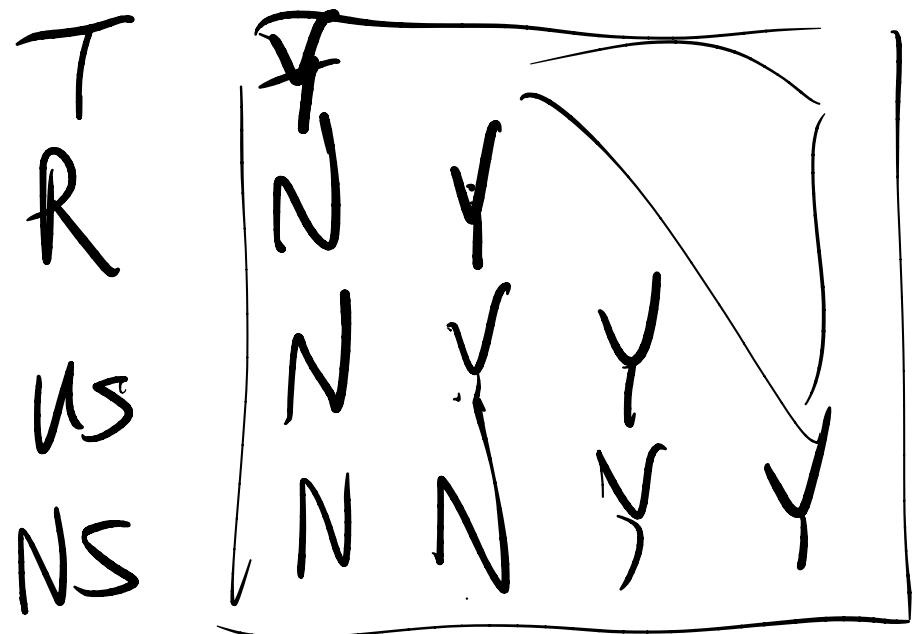


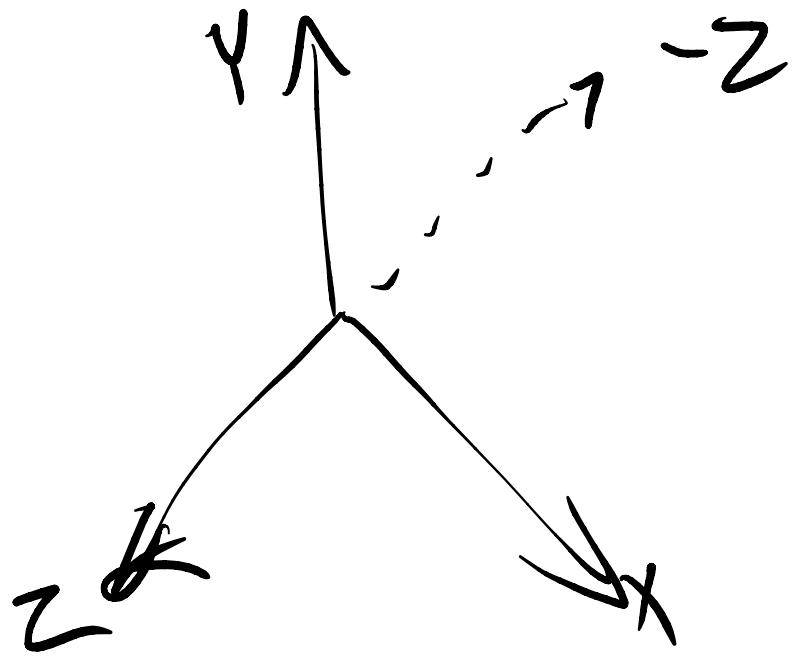
$$S = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

\rightarrow Non-uniform



TR US NS



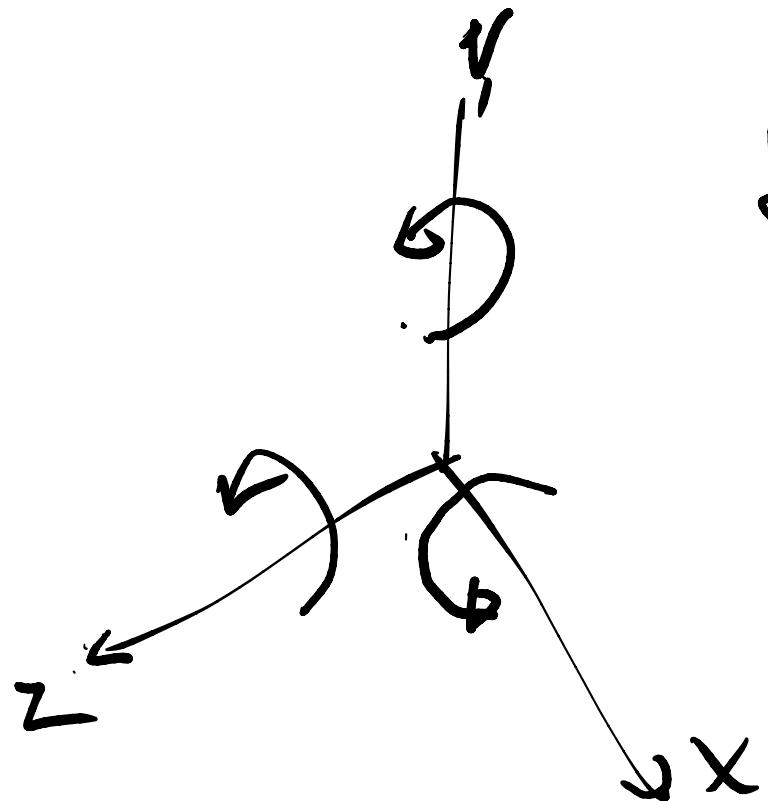


$$\bar{T} = \begin{bmatrix} 1 & & & t_x \\ & 1 & & t_y \\ & & 1 & t_z \\ & & & 1 \end{bmatrix}$$

$$S = \begin{bmatrix} s_x & & \\ & s_y & \\ & & s_z \end{bmatrix}$$

Rotation

$$R_{x\theta} \begin{bmatrix} 1 & & \\ 0 & c & -s \\ 0 & s & c \end{bmatrix} \quad R_z \begin{bmatrix} c & -s & \\ s & c & \\ 0 & 0 & 1 \end{bmatrix}$$



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

R is NOT commutative in 30

