LECTURE NO 10

05-04-18

CLIPPING :-

In another words cropping.

Cohen-Sutherland proposed algorithm of clipping.

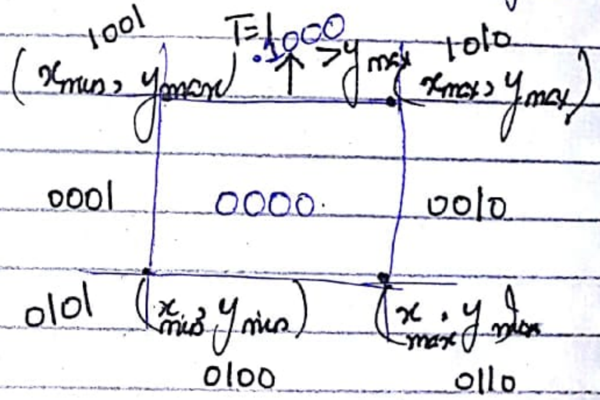
- clipping window is known as ~~sq~~ view port
  - a square shaped window

جو چیز اسکے اندر ہو گی وہ clip ہو جائے گی۔ باقی نہیں ہوگا۔

Steps

① Assign TBRL to clipping window
⇓
Top Bottom Right left

- 4 bit code
- used to assign into the window for this algo



TBRL - 4bit code.

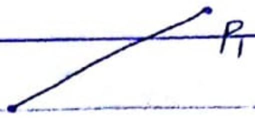
0 0 0 0.

- if $y > y_{max}$ T = 1
- if $y < y_{min}$ B = 1
- if $x > x_{max}$ R = 1
- if $x < x_{min}$ L = 1

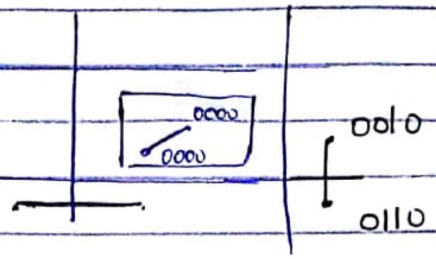
Assign 0000 inside clipping window.

AND
OR
⇓ OR

② If P_0 # P_1 == 0000 then that line is inside clipping window.



then check those points as well
if 0000 then it is inside the clipping window.



OR AND

else if P_0 # P_1 ≠ 0000
outside the clipping window.
totally reject

0110
0010

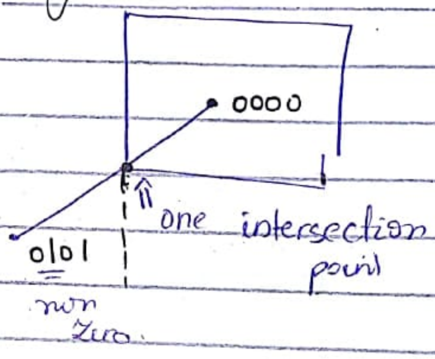
0010
⇑ AND

Another case
Partly inside clipping window.

else

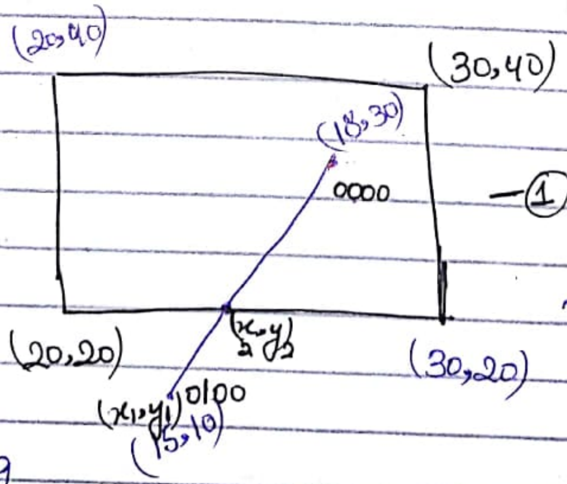
0000
0101

0000.



NonZero آ گیا تو
ہو گا تو ایک Point
intersection point آئے گا
intersection point ورنہ دو
آئیں گے

Example



0000
0100

0000
⇑
accept
ہوئی clipping
- calculate intersection point

formula for intersection Pt
⇓

$$y_2 - y_1 = m(x_2 - x_1) \quad -①$$

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{30 - 10}{18 - 15} = \frac{20}{3}$$

$(x, y) = (x, 20)$

$\Uparrow$ we already know the value of y in this case.

From ① $\Rightarrow$ $\cancel{t}$ $x_2 - x_1 = \frac{1}{m}(y_2 - y_1)$.

$$x_2 - 15 = \frac{3}{20}(20 - 10)$$

$$x_2 - 15 = \frac{3}{2}$$

$$x_2 = \frac{3}{2} + 15$$

$$x_2 = \frac{3+30}{2} \Rightarrow \frac{33}{2} = 16.5$$

in the range of clipping window.

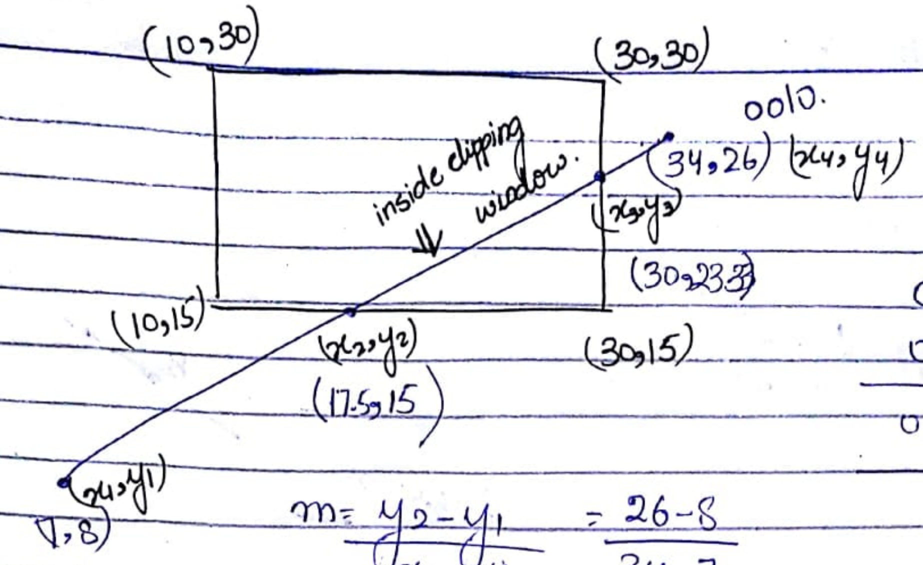
$\Downarrow$

$(16.5, 20)$

$\Uparrow$

not in the range of clipping window

- the line between intersection point and a point inside clipping window will be inside clipping window



$$\begin{array}{r}0010\\0101\\\hline 0000\end{array}$$

$$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{26-8}{34-7}$$

$$m = \frac{18}{27} = \frac{6}{9} \; \frac{2}{3}.$$

y_2: $$x_2 - x_1 = \frac{1}{m}(y_2 - y_1)$$

$$x_2 - 7 = \frac{3}{2}(15-8)$$

$$x_2 = \frac{21}{2} + 7 \Rightarrow \frac{35}{2} = 17.5$$

(17.5, 15)

$$x_4 - x_3 = \frac{1}{m}(y_4 - y_3)$$

$$34 - 30 = \frac{3}{2}(26 - y_3)$$

$$4 = \frac{3}{2}(26 - y_3)$$

$$\frac{8}{3} = 26 - y_3 \Rightarrow y_3 = 26 - \frac{8}{3} = \frac{70}{3} = 23.33$$

(30, 23.33)

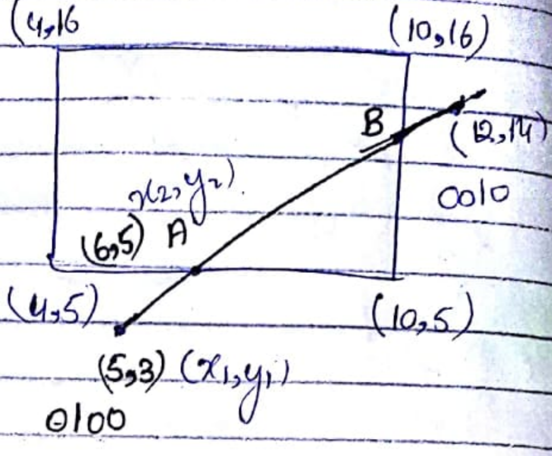
LECTURE NO 11

11-04-18.

EXAMPLE OF CLIPPING

WP (4,5) (10,16)

LP (5,3) & (12,14)



0100

0010

0000

$A(x,y) = A(x,5)$

$$m = \frac{y_2-y_1}{x_2-x_1} = \frac{14-3}{12-5} = \frac{11}{7}$$

$y_2-y_1 = m(x_2-x_1)$

$5-3 = \frac{11}{7}(x_2-5)$

$2 = \frac{11}{7}(x_2-5)$

$\frac{14}{11}+5 = x_2 \Rightarrow \frac{14+55}{11} \simeq \frac{69}{11} = 6.27$

$x = 6.3$

$\boxed{x=6}$

$A(6,5)$

$B(x_2,y_2) = B(10,y_2)$

$y_2-y_1 = \frac{11}{7}(x_2-x_1) \Rightarrow \cancel{y_2-12} = \frac{11}{7}(\cancel{10-14})$

$$y - 3 = \frac{11}{7}(10-5)$$

$$y = \frac{76}{7}, 11 \qquad B(10, 11)$$

⇒ TRANSFORMATION :-

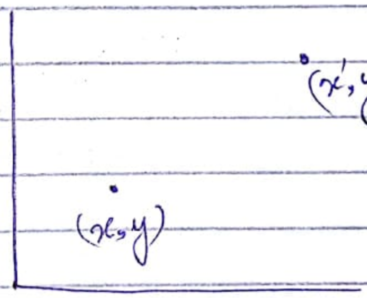
Process in which we can

- Translate (move object from one place to another)
- Rotate
- Sheering
- Zoom in / Zoom out (Scaling)

the object

- We can discuss in 2D / 3D / homogeneous and pivot points.

TRANSLATION



$$x' = x + t_x$$
$$y' = y + t_y$$

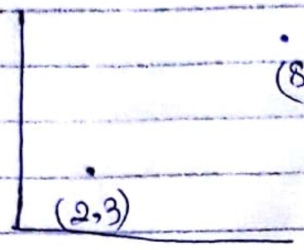
$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix}$$

X' — New coordinate of object

X — old coordinate

Translation matrix

Example



$x' = x + t_x$

$8 = 2 + t_x$

$\boxed{6 = t_x}$

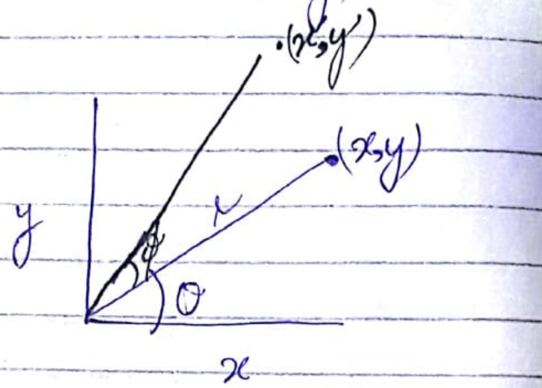
$y' = y + t_y$

$10 = 3 + t_y$

$t_y' = 7$

$(x', y') = (6, 7)$

ROTATION :



$x = r\cos\theta$ — ①

$\frac{x}{r} = \cos\theta$

Angle

Tilt of ~~Source~~ Reference line from ~~source~~ Reference line
Source

$\frac{y}{r} = \sin\theta \Rightarrow y = r\sin\theta$ — ②

$r\cos(\theta + \phi) = x'$

$x' = r[\cos\theta\cos\phi - \sin\theta\sin\phi]$

~~$r\cos\phi\cos$~~

$r\cos\theta\cos\phi - r\sin\theta\sin\phi$

$x' = x\cos\phi - y\sin\phi$ — ③

$y' = r\sin(\theta + \phi)$

$y' = r[\sin\theta\cos\phi + \cos\theta\sin\phi]$

$y' = y\cos\phi + x\sin\phi$

$y' = x\sin\phi + y\cos\phi$ — (4).

ϕ movement => Rotation

New position = old position (x,y) + Angle of movement ϕ

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \cancel{\begin{bmatrix} x \\ y \end{bmatrix}} \begin{bmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$\Downarrow$ X' $\qquad$ $\Downarrow$ R $\qquad$ $\Downarrow$ X

Rotation Matrix.

Example

4, 3 $\quad \phi = 45°$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos 45 & -\sin 45 \\ \sin 45 & \cos 45 \end{bmatrix} \begin{bmatrix} 4 \\ 3 \end{bmatrix}$$

$$= \begin{bmatrix} 4\frac{1}{\sqrt{2}} - 3\frac{1}{\sqrt{2}} \\ 4\frac{1}{\sqrt{2}} + \frac{3}{\sqrt{2}} \end{bmatrix} \Rightarrow \begin{bmatrix} 1/\sqrt{2} \\ 7/\sqrt{2} \end{bmatrix} = \begin{bmatrix} 1 \\ 5 \end{bmatrix}$$

v.imp

Example 2

(4,3) old $\quad$ (2,8) new $\quad \phi = ?$

$$\begin{bmatrix} 2 \\ 8 \end{bmatrix} = \begin{bmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} 4 \\ 3 \end{bmatrix}$$

$2 = 4\cos\phi - 3\sin\phi$ $\qquad$ $2 = -3\sin\phi + 4\cos\phi$

$8 = 4\sin\phi + 3\cos\phi$ $\qquad$ $8 = 4\sin\phi + 3\cos\phi$

$6 = -9\sin\phi + 12\cos\phi$

$32 = 16\sin\phi + 12\cos\phi$

$-26 = -25\sin\phi$

$\frac{-26}{-25} = \sin\phi$

$+1.04 = \sin\phi \simeq S$

$\cancel{\phi = \sin^{-1}(1.04)}$ $\qquad$ $\cancel{\sin\phi = 1}$

$\cancel{\phi = 90}$.

$8 = -12\sin\phi + 16\cos\phi$

$24 = 12\sin\phi + 9\cos\phi$

$32 = 25\cos\phi$

$\cos\phi = 1.28$

$\tan\phi = \frac{\sin\phi}{\cos\phi} = \frac{1.04}{1.28} = 0.8125$

$\phi = \tan^{-1}(0.8125)$

$\phi = 39^\circ$.

3) SCALING

$$x' = x S_x \qquad\qquad (0,0) \text{ object is disolved}$$

$$y' = y S_y. \qquad\qquad S_x, S_y > 1 \text{ object size } \uparrow$$

$$\cancel{\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} x \\ y \end{bmatrix} \begin{bmatrix} S_x \\ S_y \end{bmatrix}} \qquad\qquad S_x, S_y < 1 \text{ object size } \downarrow$$

$$\cancel{\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} x & y \\ 0 & 0 \end{bmatrix} \begin{bmatrix} S_x \\ S_y \end{bmatrix}}$$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$$X' = S \quad X$$

$$\Downarrow$$

Scaling Matrix.

Scanned by CamScanner

LECTURE NO 12

12-04-18

TRANSFORMATION IN HOMOGENEOUS - COORDINATES.

- Must include depth.

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \\ 1 \end{bmatrix}$$ ⇐ TRANSLATION

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ \underbrace{0 \quad\quad 0}_{\text{to calculate depth.}} & & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$ ⇐ ROTATION

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} S_x & 0 & 0 \\ 0 & S_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$ SCALING.

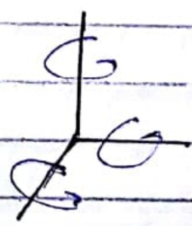
3D

$x\ y\ z$

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & t_x \\ 0 & 1 & 0 & t_y \\ 0 & 0 & 1 & t_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$ ⇐ translation

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} S_x & 0 & 0 & 0 \\ 0 & S_y & 0 & 0 \\ 0 & 0 & S_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$ ⇐ SCALING.

- z fixed ⇒ xy Rotation
- x fixed ⇒ yz rotation
- y fixed ⇒ xz rotation



z- fixed ⇒ xy domain

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

x fixed ⇒ yz domain

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}.$$

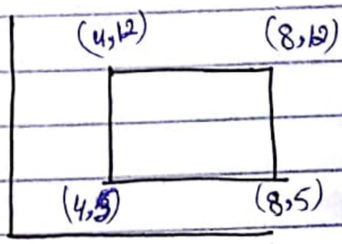
Y- fixed ⇒ xz domain

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 & \sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

⇒ origin based transformation:- transformation of object on the basis of its origin.

⇒ Pivot Point Transformation:- Transformation on the basis of fixed point not origin of an object

Example



30° rotation around origin ⇒ take all vertex points as original point and apply rotation of 30°.

final

v.imp // Pivot Point Algorithm. (TRT)

① Transfer fixed point to origin. ⇒ Translate point to origin (subtract the point)

② Produce rotation of θ degree at origin.

③ convert back at original point.

(4,5) at of 30°.

$$\begin{array}{ccc} \text{Translate back to origin} & \text{Rotation} & \text{Translate back to original point} \\ \begin{bmatrix} 1 & 0 & -4 \\ 0 & 1 & -5 \\ 0 & 0 & 1 \end{bmatrix} & \begin{bmatrix} \cos 30^\circ & -\sin 30^\circ & 0 \\ \sin 30^\circ & \cos 30^\circ & 0 \\ 0 & 0 & 1 \end{bmatrix} & \begin{bmatrix} 1 & 0 & 4 \\ 0 & 1 & 5 \\ 0 & 0 & 1 \end{bmatrix} \end{array}$$

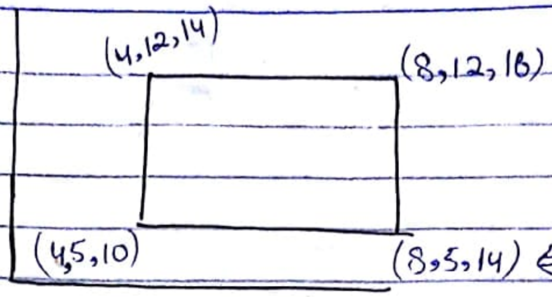
$$= \begin{bmatrix} 0.86 & -0.5 & -3.03 \\ 0.5 & 0.86 & 1.33 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 8 \\ 5 \\ 1 \end{bmatrix} =$$

⇒ Multiply result with remaining point

TSRT Pivot Point

Translation ⇒ Scaling ⇒ Rotation ⇒ Translation

Example



TSRT

fix ~~x-y plane~~ yz plane

90°

Size = double

$$\begin{bmatrix}1&0&0&-8\\0&1&0&-5\\0&0&1&-14\\0&0&0&1\end{bmatrix}\begin{bmatrix}2&0&0&0\\0&2&0&0\\0&0&2&0\\0&0&0&1\end{bmatrix}\begin{bmatrix}\cos 90&-\sin 90&0&0\\0&0&-1&0\\0&1&0&0\\0&0&0&1\end{bmatrix}$$

$$\begin{bmatrix}1&0&0&8\\0&1&0&5\\0&0&1&14\\0&0&0&1\end{bmatrix}$$

$$=\begin{bmatrix}\cancel{2+0+0-8}\ 2&\cancel{0+2}\ 0&0&-8\\0&2&0&-5\\0&0&2&-14\\0&0&0&1\end{bmatrix}\begin{bmatrix}1&0&0&0\\0&0&-1&0\\0&1&0&0\\0&0&0&1\end{bmatrix}$$

$$\begin{bmatrix}1&0&0&8\\0&1&0&5\\0&0&1&14\\0&0&0&1\end{bmatrix}=\begin{bmatrix}2&0&0&-8\\0&0&-2&-5\\0&2&0&-14\\0&0&0&1\end{bmatrix}\begin{bmatrix}1&0&0&8\\0&1&0&5\\0&0&1&14\\0&0&0&1\end{bmatrix}$$

$$\begin{bmatrix}2&0&0&8\\0&0&-2&-33\\0&2&0&-4\\0&0&0&1\end{bmatrix}$$

At (4, 5, 10)

$$\begin{bmatrix} 2 & 0 & 0 & 8 \\ 0 & 0 & -2 & -33 \\ 0 & 2 & 0 & -4 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 4 \\ 5 \\ 10 \\ 1 \end{bmatrix} = \begin{bmatrix} 16 \\ -53 \\ 6 \\ 1 \end{bmatrix}$$

At (8, 12, 16)

$$\begin{bmatrix} 2 & 0 & 0 & 8 \\ 0 & 0 & -2 & -33 \\ 0 & 2 & 0 & -4 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 8 \\ 12 \\ 16 \\ 1 \end{bmatrix} = \begin{bmatrix} 24 \\ -65 \\ 20 \\ 1 \end{bmatrix}$$

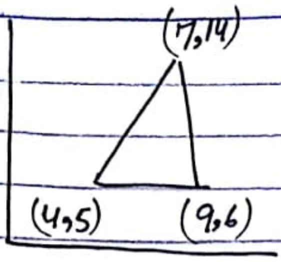
At (4, 12, 14)

$$\begin{bmatrix} 2 & 0 & 0 & 8 \\ 0 & 0 & -2 & -33 \\ 0 & 2 & 0 & -4 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 4 \\ 12 \\ 14 \\ 1 \end{bmatrix} = \begin{bmatrix} 16 \\ -61 \\ 20 \\ 1 \end{bmatrix}$$

Submit till next thursday
MS word
hard & soft copy

Assignment 2

Q1



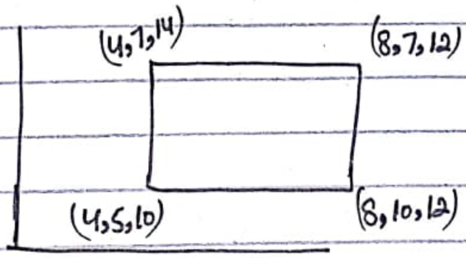
Rotate the triangle about 45° about origin and draw new.

Q2 Provide 3x3 Matrix by fixing point (4,5) at angle of 30°.

Assignment 3

Q3 Provide 4x4 Matrix (4,5,12) at angle of 45° and $S_x = S_y = 0.5$ and $S_z = 2.5$ => y-axis.

Q4



Provide a rotation of 75° about origin and draw it.

Quiz
clipping & transformation on next wednesday

Assignment 2

Solution

Q1

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

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos 45 & -\sin 45 \\ \sin 45 & \cos 45 \end{bmatrix} \begin{bmatrix} 4 \\ 5 \end{bmatrix}$$

$$= \begin{bmatrix} 1/\sqrt{2} & -1/\sqrt{2} \\ 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \begin{bmatrix} 4 \\ 5 \end{bmatrix}$$

$$= \begin{bmatrix} 4/\sqrt{2} - 5/\sqrt{2} \\ 4/\sqrt{2} + 5/\sqrt{2} \end{bmatrix} = \begin{bmatrix} -1/\sqrt{2} \\ 9/\sqrt{2} \end{bmatrix} = \begin{bmatrix} -0.70 \\ 6.36 \end{bmatrix}$$

$$\approx \begin{bmatrix} -1 \\ 6 \end{bmatrix}.$$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos 45 & -\sin 45 \\ \sin 45 & \cos 45 \end{bmatrix} \begin{bmatrix} 9 \\ 6 \end{bmatrix}$$

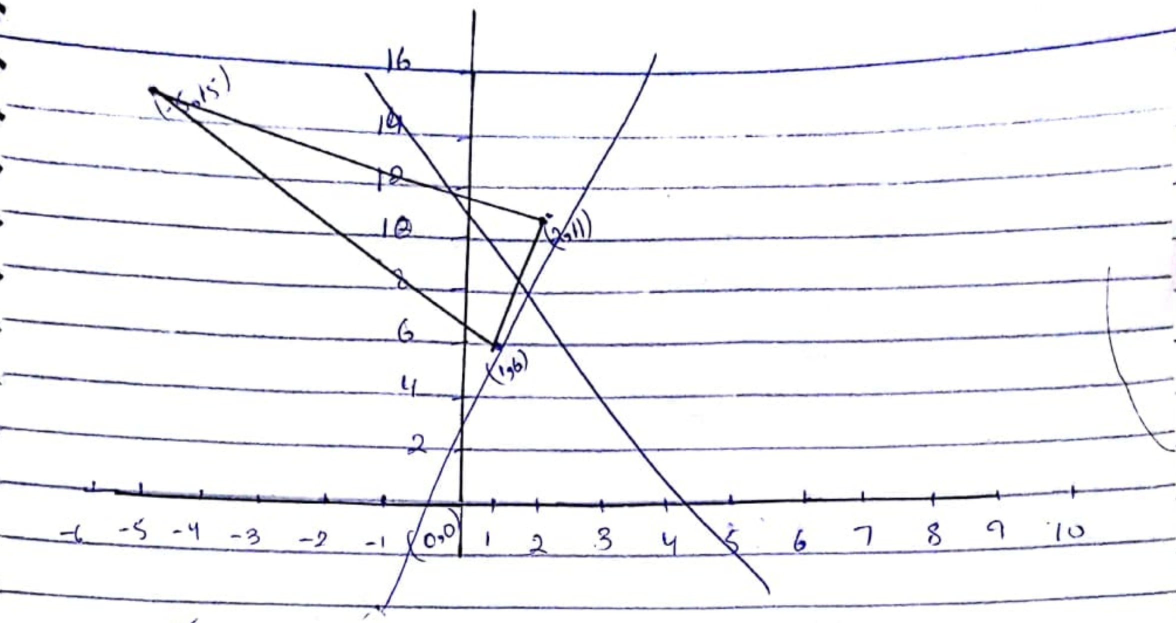
$$= \begin{bmatrix} 1/\sqrt{2} & -1/\sqrt{2} \\ 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \begin{bmatrix} 9 \\ 6 \end{bmatrix} = \begin{bmatrix} 9/\sqrt{2} - 6/\sqrt{2} \\ 9/\sqrt{2} + 6/\sqrt{2} \end{bmatrix}$$

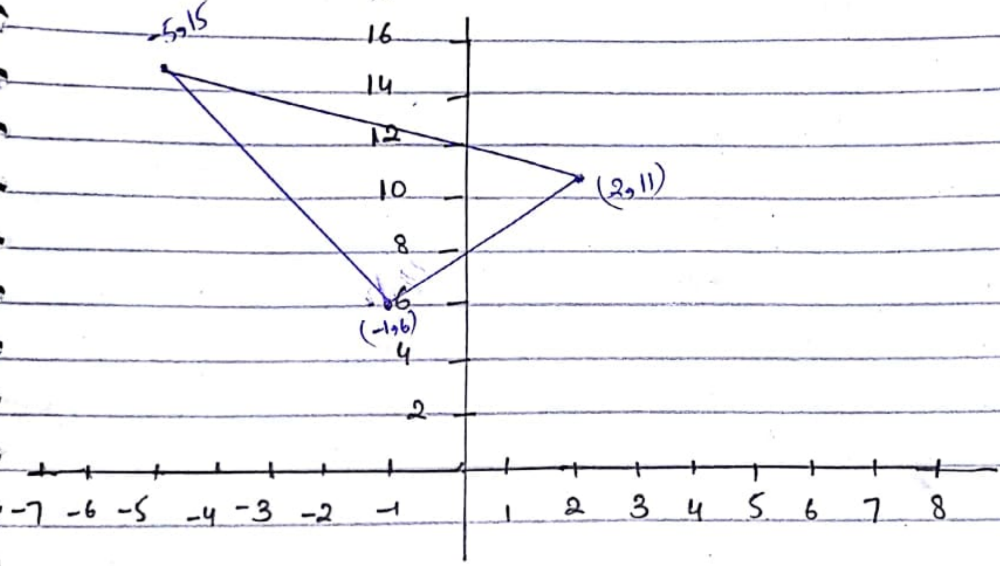
$$= \begin{bmatrix} 3/\sqrt{2} \\ 15/\sqrt{2} \end{bmatrix} = \begin{bmatrix} 2.12 \\ 10.60 \end{bmatrix} = \begin{bmatrix} 2 \\ 11 \end{bmatrix}$$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos 45 & -\sin 45 \\ \sin 45 & \cos 45 \end{bmatrix} \begin{bmatrix} 7 \\ 14 \end{bmatrix} =$$

-4.94

$$= \begin{bmatrix} 1/\sqrt{2} & -1/\sqrt{2} \\ 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \begin{bmatrix} 7 \\ 14 \end{bmatrix} = \begin{bmatrix} 7/\sqrt{2} - 14/\sqrt{2} \\ 7/\sqrt{2} + 14/\sqrt{2} \end{bmatrix} = \begin{bmatrix} -5 \\ 15 \end{bmatrix}$$





Q2 TRT

$$\cancel{\begin{bmatrix} t_x & 0 & 0 \\ 0 & t_y & 0 \\ 0 & 0 & 1 \end{bmatrix}} \quad \begin{bmatrix} 1 & 0 & -4 \\ 0 & 1 & -5 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos 30 & -\sin 30 & 0 \\ \sin 30 & \cos 30 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 4 \\ 0 & 1 & 5 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0.86 & -0.5 & -3.03 \\ 0.5 & 0.86 & 1.33 \\ 0 & 0 & 1 \end{bmatrix}$$

Assignment 3

Q3 T S R T

$$\begin{bmatrix} 1 & 0 & 0 & -4 \\ 0 & 1 & 0 & -5 \\ 0 & 0 & 1 & -12 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0.5 & 0 & 0 & 0 \\ 0 & 0.5 & 0 & 0 \\ 0 & 0 & 2.5 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos 45 & 0 & \sin 45 & 0 \\ 0 & 1 & 0 & 0 \\ -\sin 45 & 0 & \cos 45 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & +12 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0.5 & 0 & 0 & -4 \\ 0 & 0.5 & 0 & -5 \\ 0 & 0 & 2.5 & -12 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1/\sqrt{2} & 0 & 1/\sqrt{2} & 0 \\ 0 & 1 & 0 & 0 \\ -1/\sqrt{2} & 0 & 1/\sqrt{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & +12 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0.35 & 0 & 0.35 & -4 \\ 0 & 0.5 & 0 & -5 \\ -1.76 & 0 & 1.76 & -12 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & 12 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0.35 & 0 & 0.35 & 1.6 \\ 0 & 0.5 & 0 & -2.5 \\ -1.76 & 0 & 1.76 & 2.08 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Q4 Rotation of 75° about origin

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos 75 & -\sin 75 & 0 & 0 \\ \sin 75 & \cos 75 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 4 \\ 3 \\ 10 \\ 1 \end{bmatrix}$$

At (4,5,10)

$$\begin{bmatrix} 0.258 & -0.965 & 0 & 0 \\ 0.965 & 0.258 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 4 \\ 5 \\ 10 \\ 1 \end{bmatrix} = \begin{bmatrix} -3.79 \\ 5.1 \\ 10 \\ 1 \end{bmatrix} \Rightarrow \begin{bmatrix} -4 \\ 5 \\ 10 \\ 1 \end{bmatrix}$$

At (8,10,12)

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 0.258 & -0.965 & 0 & 0 \\ 0.965 & 0.258 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 8 \\ 10 \\ 12 \\ 1 \end{bmatrix} = \begin{bmatrix} -7.58 \\ \overset{10.31}{\cancel{12.24}} \\ 12 \\ 1 \end{bmatrix} \Rightarrow \begin{bmatrix} -8 \\ 10 \\ 12 \\ 1 \end{bmatrix}$$

At (4,7,14)

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 0.258 & -0.965 & 0 & 0 \\ 0.965 & 0.258 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 4 \\ 7 \\ 14 \\ 1 \end{bmatrix} = \begin{bmatrix} -5.72 \\ 5.67 \\ 14 \\ 1 \end{bmatrix} \Rightarrow \begin{bmatrix} -6 \\ 6 \\ 14 \\ 1 \end{bmatrix}$$

At (8,7,12)

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 0.258 & -0.965 & 0 & 0 \\ 0.965 & 0.258 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 8 \\ 7 \\ 12 \\ 1 \end{bmatrix} = \begin{bmatrix} -4.69 \\ 9.53 \\ 12 \\ 1 \end{bmatrix} \Rightarrow \begin{bmatrix} -5 \\ 10 \\ 12 \\ 1 \end{bmatrix}$$