b. A robotic painter is positioned at an unknown location on a digital canvas where the line $4x + 9y + 128 = 0$ intersects the ***x*-axis**. The task for the painter is to draw a straight line from **this starting point** to the point **(-48, -17)**. Using the **Midpoint Line Drawing Algorithm**, **compute** the first 6 (including the starting point) pixels of the line segment the painter needs to use and **show** each step. **[6]**

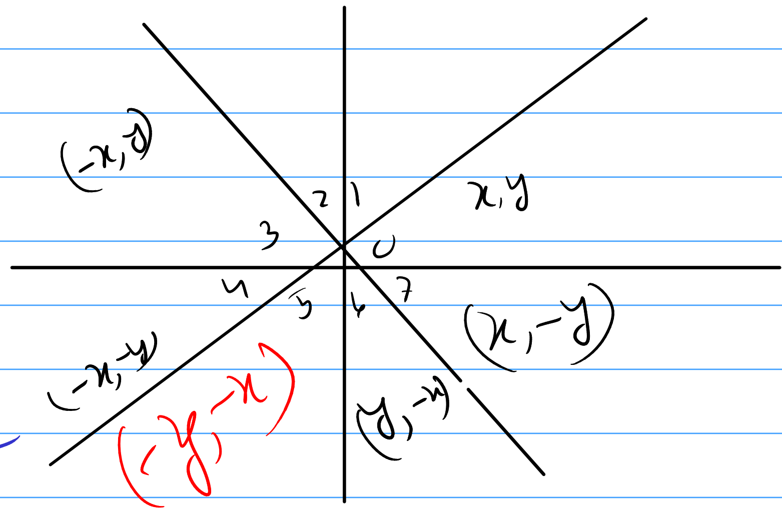
$4x+9y+128=0$

$4x+0+128=0$

$4x=-128$

$x=\frac{-128}{4}=-32$

$y=0$



$\therefore (-32,0) \rightarrow (-48,-17)$

$dx = -48+32 \Rightarrow -16$	$dy = -17$

$\therefore$ Zone 5

Zone 5	Zone 0	
$(-y,x)$	(x,y)	
$(-32,0)$	$(0,32)$	$\rightarrow (x_0, y_0)$
$(-48,-17)$	$(17,48)$	$\rightarrow (x_1, y_1)$

$dx = 17$

$dy = 48-32 \Rightarrow 16$

$$d_{init} = 2dy - dx$$
$$\Rightarrow 2 \times 16 - 17 \Rightarrow 15$$

$$d_{NE} \Rightarrow 2dy - 2dx$$
$$\Rightarrow 2 \times 16 - 2 \times 17$$
$$\Rightarrow -2$$

$$d_E = 2dy = 32$$

x	y	d	NE/E	(x,y) Pixel	$(-y,-x)$ Converted pixel
0	32	15	NE	(0,32)	(−32,0)
1	33	13	NE	(1,33)	(−33,−1)
2	34	11	NE	(2,34)	(−34,−2)
3	35	9	NE	(3,35)	(−35,−3)
4	36	7	NE	(4,36)	(−36,−4)
5	37	5	NE	(5,37)	(−37,−5)

$d_{init} \Rightarrow 15$
$d_{NE} \Rightarrow -2$
$d_E = 32$

Question 2 [CO3]

a. Let's say the viewing region is a rectangle bounded by the points (0,0) and (100, 200). The bits in the region code are defined as follows:

Bit 3	Bit 2	Bit 1	Bit 0
Above	Below	Right	Left

i. Leonard remembers that the number of iterations may vary in the **Cohen-Sutherland Line Clipping Algorithm**. Can you help him come up with an example line segment where the algorithm takes the **maximum number of iterations possible** in the given scenario? **State** the endpoints of your line segment and **draw** a rough illustration of your example. **[4]**

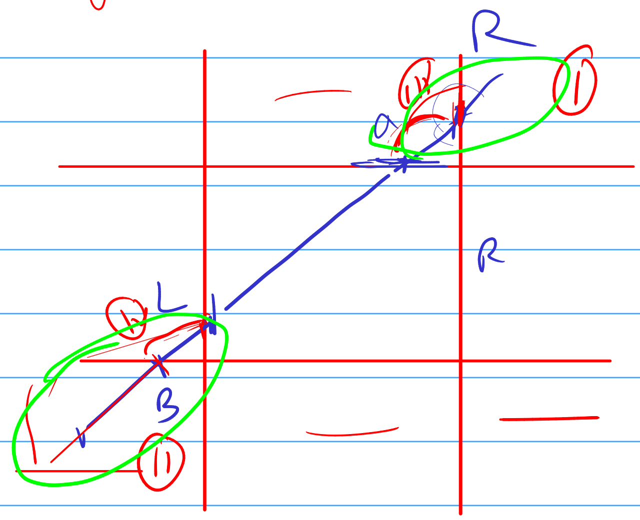
ii. Sheldon looks at Leonard's example and says that he can reduce the number of iterations just by changing the **definition of the bits in the region code**. **State** the new region code definition (Sequence of Bits) that Sheldon has in mind. **[1]**

a) $x_{min} = 0$

$y_{min} = 0$

$x_{max} = 100$

$y_{max} = 200$



RB AL ←

b. A security camera monitors a restricted zone in a warehouse, recording movements only within (2, 2) to (8, 6). A drone follows a linear flight path from (3, 1) to (10, 7). Using the **Cyrus-Beck Line Clipping Algorithm**, **compute** the values of parameter t at which the drone enters and exits the detection area. **Find** the coordinates of the visible portion of the flight path. **[5]**

A B R L ←

L A B R ←

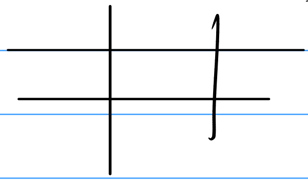
b)

$X_{min} \Rightarrow 2$, $X_{max} = 8$ | $y_{min} = 2$, $y_{max} = 6$ | $(x_0, y_0) = (3,1)$, $(x_1, y_1) = (10,7)$

$D = (P_1 - P_0) = \{(x_1 - x_0), (y_1 - y_0)\}$

$\Rightarrow (10-3), (7-1)$

$\Rightarrow (7, 6)$



$t_{Left} = \frac{-(x_0 - x_{min})}{(x_1 - x_0)} \Rightarrow \frac{-1}{7}$

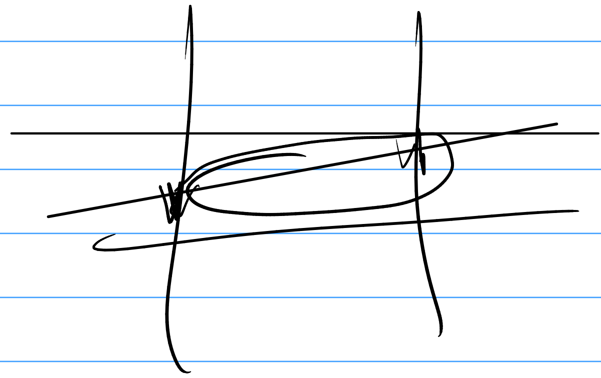
$t_{right} \Rightarrow \frac{-(x_0 - x_{max})}{x_1 - x_0} \Rightarrow \frac{5}{7}$

$t_{above} = \frac{-(y_0 - y_{max})}{y_1 - y_0} \Rightarrow \frac{5}{6}$

$t_{Below} = \frac{-(y_0 - y_{min})}{6} \Rightarrow \frac{-(1-2)}{6} \Rightarrow \frac{1}{6}$

D	N	N.D	PE/PL	t	t_E = 0 (max(0,t))	t_L = 1 (min(1,t))
Left	(-1,0)	-7	PE	-0.14	0	1
Right	(1,0)	7	PL	0.71	0	0.71
Above	(0,1)	6	PL	0.833	0	0.71
Below	(0,-1)	-6	PE	0.17	0.17	0.71

$t_L > t_E \Rightarrow$ Partially Clipped



$t = 0.17$

$$\underbrace{P_0}_{(x_0,\, y_0)} + t(\underbrace{P_1}_{(x_1,\, y_1)} - P_0)$$

$$\Rightarrow (3,1) + 0.17(7,6)$$

$$\Rightarrow (3,1) + (1.19,\ 1.02)$$

$$\Rightarrow (4.19,\ 2.02) \Rightarrow (x_0, y_0)$$

$t = 0.71$

$$P_0 + t(P_1 - P_0)$$

$$\Rightarrow (3,1) + 0.71(7,6)$$

$$\Rightarrow (3,1) + (4.97,\ 4.26)$$

$$\Rightarrow (7.97,\ 5.26) \rightarrow (x_1, y_1)$$

$$(4.19, 2.02) \longrightarrow (7.97, 3.24)$$

b. In a 3D gallery setup, a spotlight's position was adjusted through a sequence of transformations to properly illuminate a new painting. The adjustments were applied in this order:

- **Rotation:** The point was rotated 90° clockwise about the Z-axis, around the origin.
- **Shear:** The rotated point then underwent a shear via $(x + 3y, y, z + 4y)$.
- **Translation:** The point was finally translated by $(-4, 2, 5)$.

After all transformations, the spotlight's **final position** was recorded as $(3, -1, 4)$.

Using homogeneous coordinate matrices and proper composition of transformations, **determine** the **original** position of the spotlight before any transformation was applied. **[6]**

$$M = \begin{vmatrix} 1 & 0 & 0 & -4 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 1 & 5 \\ 0 & 0 & 0 & 1 \end{vmatrix} \times \begin{vmatrix} 1 & 3 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 4 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix} \times \begin{vmatrix} \cos-90 & -\sin(90) & 0 & 0 \\ \sin(-90) & \cos(-90) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

$$\begin{vmatrix} \cos 90 & \sin 90 & 0 & 0 \\ \sin 90 & \cos 90 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix} \times \begin{vmatrix} 1 & -3 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & -4 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix} \times \begin{vmatrix} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & -2 \\ 0 & 0 & 1 & -5 \\ 0 & 0 & 0 & 1 \end{vmatrix} \times P'$$

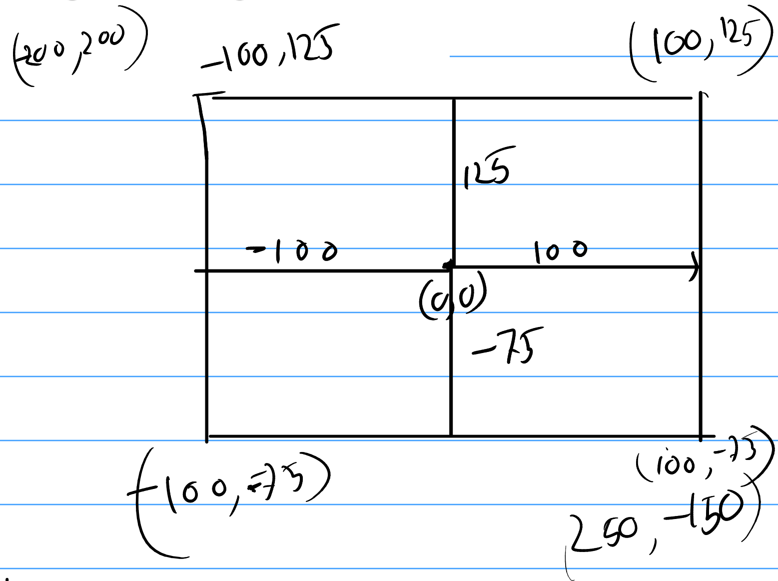
$$P = \begin{vmatrix} 3 \\ 16 \\ 11 \\ 1 \end{vmatrix} \Rightarrow \quad (x, y, z) \to (3, 16, 11)$$

b. In a highly restricted military region, a classified research lab is located at the origin $(0,\ 0)$. To secure the facility, a no-fly perimeter has been established around it.
This rectangular no-fly zone is defined relative to the lab as follows:

- 100 meters to the East of the lab
- 100 meters to the West of the lab
- 125 meters to the North of the lab
- 75 meters to the South of the lab

A drone is flying in a diagonal path from a location 200 meters West and 200 meters North of the secret lab to a location 250 meters East and 150 meters South of the lab.

Using the Cyrus-Beck Line Clipping Algorithm, **determine** whether the drone's flight path intrudes into the no-fly zone. If intrusion occurs, **calculate** the entry and exit points of the segment inside the restricted airspace. **[6]**



$$D = \{ (x_1 - x_0)\ (y_1 - y_0) \}$$

$$\Rightarrow (300, -275)$$

$$t_{left} \Rightarrow \frac{-(x_0 - x_{min})}{300}$$

$$\Rightarrow 0.33$$

$$t_{right} = 1$$

$$t_{above} \Rightarrow \frac{-(y_0 - y_{max})}{y_1 - y_0}$$

$$\Rightarrow 0.27$$

$$t_{below} \Rightarrow 1$$

Dir	N	ND	PE/PL	t	tE 0	tL 1
Left	(-1,0)	-300	PE	0.33	0.33	1
Right	(1,0)	300	PL	1	0.33	1
Below	(0,-1)	275	PL	1	0.33	1
above	(0,1)	-275	PE	0.27	0.33	1

$t = 0.33$

$\Rightarrow (-200, 200) + 0.33(300, -275)$

$\Rightarrow (-100, 108.33)$

$t = 1$

$\Rightarrow (100, -75)$

b. Suppose you are positioned at the intersection point of the lines $2x - y - 10 = 0$ and $-2x - 50 = 0$, while your friend stands at the coordinate $(-10, 15)$ on a floor composed of square grid tiles. To reach you, your friend wishes to move step by step along the grid, constrained to adjacent tiles, and aims to follow the straight-line path to your location as closely as possible. Using the Mid-point Line Drawing Algorithm, **determine** the **first six** grid tiles (including the starting tile) that your friend will step on during the approach. Show the calculations in a table. **[6]**

$2x - y - 10 = 0 \Rightarrow -y - 60 = 0$

$-2x - 50 = 0 \Rightarrow -y = 60$

$-2x = 50 \Rightarrow y = -60$

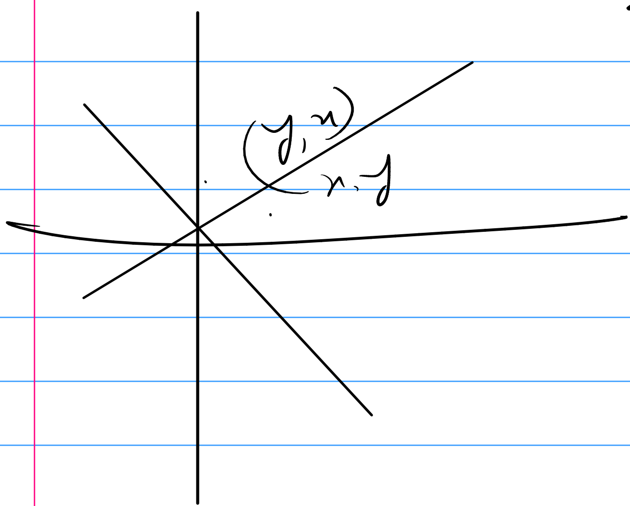
$x = \frac{5\cancel{0}}{\cancel{2}} = -25$

$(x_0, y_0) = (-25, -60)$

$(x_1, y_1) = (-10, 15)$

$dx \Rightarrow -10 + 25 \Rightarrow 15$

$dy \Rightarrow 15 + 60 \Rightarrow 75$



Zone = 1

$(-25, -60)$

$(-10, 15)$

Zone 0

$(-60, -25)$

$(15, -10)$

$dx \Rightarrow 75$

$dy = 15$

$d_{init} = 2dy - dx$

$\Rightarrow -45$

$d_{NE} = 2dy - 2dx$

$\Rightarrow 30 - 150$

$\Rightarrow -120$

$dE = 2dy$

$\Rightarrow 30$

x	y	d	NE/E	Pixel (y,x)	
-60	-25	-45	E	-60, -25	-25, -60
-59	~~-25~~	~~-15~~	E	-59, -25	-25, -59
-58	-25	15	NE	~~-58~~, -25	-25, -58
-57	-24	~~-105~~	E	-57, -24	-24, -57
-56	-24	-75	E	-56, -24	-24, -56
-55	-24	-45	E	-55, -24	-24, -55

Question 1 [CO1]

a. The starting point of a line segment is (− 423, − 25) and the ending point is (− 430, 12). Using the DDA algorithm, **compute** the first 3 pixels (including the starting pixel) to be colored for the given line segment. **How** many times will the value of **y** be increased to draw the complete line?
[3 + 1]

$$m = \frac{12+25}{-430+423} = -5.28$$

$y_1 > y_0$

$y = y + 1$

$x = x + \frac{1}{m}$

(-423, -25)

(-423, -24)

(-423, -23)

$\Delta dx \Rightarrow -7,$

$\Delta dy \Rightarrow 37$

$\therefore$ 37 times