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Chapter 1

Triangle

Consider a triangle with vertices

$$\mathbf{A} = \begin{pmatrix} 5 \\ -2 \end{pmatrix}, \mathbf{B} = \begin{pmatrix} -5 \\ 5 \end{pmatrix}, \mathbf{c} = \begin{pmatrix} -2 \\ -5 \end{pmatrix}, \quad (1.1)$$

1.1. Vectors

1.1.1. The direction vector of AB is defined as

$$\mathbf{B} - \mathbf{A} \quad (1.1.1.1)$$

Consider a triangle with vertices

$$\mathbf{A} = \begin{pmatrix} 5 \\ -2 \end{pmatrix} \quad (1.1.1.2)$$

$$\mathbf{B} = \begin{pmatrix} -5 \\ 5 \end{pmatrix} \quad (1.1.1.3)$$

$$\mathbf{C} = \begin{pmatrix} -2 \\ -5 \end{pmatrix} \quad (1.1.1.4)$$

The Direction Vector of AB is defined as

$$\mathbf{B} - \mathbf{A} \quad (1.1.1.5)$$

Question 1.1.1 : Find the Direction Vectors of AB, BC, CA .

Solution:

(a) The Direction vector of AB is

$$= \mathbf{B} - \mathbf{A} \quad (1.1.1.6)$$

$$= \begin{pmatrix} -5 - (5) \\ 5 - (-2) \end{pmatrix} \quad (1.1.1.7)$$

$$= \begin{pmatrix} -10 \\ 7 \end{pmatrix} \quad (1.1.1.8)$$

(b) The Direction vector of BC

$$= \mathbf{C} - \mathbf{B} \quad (1.1.1.9)$$

$$= \begin{pmatrix} -2 - (-5) \\ -5 - 5 \end{pmatrix} \quad (1.1.1.10)$$

$$= \begin{pmatrix} 3 \\ -10 \end{pmatrix} \quad (1.1.1.11)$$

(c) The Direction vector of CA

$$= \mathbf{A} - \mathbf{C} \quad (1.1.1.12)$$

$$= \begin{pmatrix} 5 - (-2) \\ -2 - (-5) \end{pmatrix} \quad (1.1.1.13)$$

$$= \begin{pmatrix} 7 \\ 3 \end{pmatrix} \quad (1.1.1.14)$$

1.1.2. The length of side BC is

$$\|\mathbf{B} - \mathbf{A}\| \triangleq \sqrt{(\mathbf{B} - \mathbf{A})^\top \mathbf{B} - \mathbf{A}} \quad (1.1.2.1)$$

where

$$\mathbf{A}^\top \triangleq \begin{pmatrix} 1 & 0 \end{pmatrix} \quad (1.1.2.2)$$

Question 1.1.2 : Find the length of side AB, BC, CA.

Solution: Solving for AB Given,

$$\mathbf{A} = \begin{pmatrix} 5 \\ -2 \end{pmatrix}, \mathbf{B} = \begin{pmatrix} -5 \\ 5 \end{pmatrix}, \mathbf{C} = \begin{pmatrix} -2 \\ -5 \end{pmatrix} \quad (1.1.2.3)$$

$$\|\mathbf{B} - \mathbf{A}\| = \sqrt{(\mathbf{B} - \mathbf{A})^\top (\mathbf{B} - \mathbf{A})} \quad (1.1.2.4)$$

$$\mathbf{B} - \mathbf{A} = \begin{pmatrix} -5 \\ 5 \end{pmatrix} - \begin{pmatrix} 5 \\ -2 \end{pmatrix} \quad (1.1.2.5)$$

$$\mathbf{B} - \mathbf{A} = \begin{pmatrix} -10 \\ 7 \end{pmatrix} \quad (1.1.2.6)$$

$$(\mathbf{B} - \mathbf{A})^\top = \begin{pmatrix} -10 \\ 7 \end{pmatrix}^\top = \begin{pmatrix} -10 & 7 \end{pmatrix} \quad (1.1.2.7)$$

$$(\mathbf{B} - \mathbf{A})^\top (\mathbf{B} - \mathbf{A}) = \begin{pmatrix} -10 & 7 \end{pmatrix} \begin{pmatrix} -10 \\ 7 \end{pmatrix} \quad (1.1.2.8)$$

$$= 100 + 49 \quad (1.1.2.9)$$

$$= 149 \quad (1.1.2.10)$$

$$\sqrt{(\mathbf{B} - \mathbf{A})^\top (\mathbf{B} - \mathbf{A})} = \sqrt{149} \quad (1.1.2.11)$$

$$\Rightarrow \|\mathbf{B} - \mathbf{A}\| = \sqrt{149} \quad (1.1.2.12)$$

Solving for BC Given,

$$\|\mathbf{C} - \mathbf{B}\| = \sqrt{(\mathbf{C} - \mathbf{B})^\top (\mathbf{C} - \mathbf{B})} \quad (1.1.2.13)$$

$$\mathbf{C} - \mathbf{B} = \begin{pmatrix} -2 \\ -5 \end{pmatrix} - \begin{pmatrix} -5 \\ 5 \end{pmatrix} \quad (1.1.2.14)$$

$$\mathbf{C} - \mathbf{B} = \begin{pmatrix} 3 \\ -10 \end{pmatrix} \quad (1.1.2.15)$$

$$(\mathbf{C} - \mathbf{B})^\top = \begin{pmatrix} 3 \\ -10 \end{pmatrix}^\top = \begin{pmatrix} 3 & -10 \end{pmatrix} \quad (1.1.2.16)$$

$$(\mathbf{C} - \mathbf{B})^\top (\mathbf{C} - \mathbf{B}) = \begin{pmatrix} 3 & -10 \end{pmatrix} \begin{pmatrix} 3 \\ -10 \end{pmatrix} \quad (1.1.2.17)$$

$$= 9 + 100 \quad (1.1.2.18)$$

$$= 109 \quad (1.1.2.19)$$

$$\sqrt{(\mathbf{C} - \mathbf{B})^\top (\mathbf{C} - \mathbf{B})} = \sqrt{109} \quad (1.1.2.20)$$

$$\Rightarrow \|\mathbf{C} - \mathbf{B}\| = \sqrt{109} \quad (1.1.2.21)$$

Solving for CA Given,

$$\|\mathbf{C} - \mathbf{A}\| = \sqrt{(\mathbf{C} - \mathbf{A})^\top (\mathbf{C} - \mathbf{A})} \quad (1.1.2.22)$$

$$\mathbf{C} - \mathbf{A} = \begin{pmatrix} -2 \\ -5 \end{pmatrix} - \begin{pmatrix} 5 \\ -2 \end{pmatrix} \quad (1.1.2.23)$$

$$\mathbf{C} - \mathbf{A} = \begin{pmatrix} 7 \\ 3 \end{pmatrix} \quad (1.1.2.24)$$

$$(\mathbf{C} - \mathbf{A})^\top = \begin{pmatrix} 7 \\ 3 \end{pmatrix}^\top = \begin{pmatrix} 7 & 3 \end{pmatrix} \quad (1.1.2.25)$$

$$(\mathbf{C} - \mathbf{A})^\top (\mathbf{C} - \mathbf{A}) = \begin{pmatrix} 7 & 3 \end{pmatrix} \begin{pmatrix} 7 \\ 3 \end{pmatrix} \quad (1.1.2.26)$$

$$= 49 + 9 \quad (1.1.2.27)$$

$$= 58 \quad (1.1.2.28)$$

$$\sqrt{(\mathbf{C} - \mathbf{A})^\top (\mathbf{C} - \mathbf{A})} = \sqrt{58} \quad (1.1.2.29)$$

$$\Rightarrow \|\mathbf{C} - \mathbf{A}\| = \sqrt{58} \quad (1.1.2.30)$$

1.1.3. Points $\mathbf{A}, \mathbf{B}, \mathbf{C}$ are defined to be collinear if

$$\text{rank} \begin{pmatrix} 1 & 1 & 1 \\ \mathbf{A} & \mathbf{B} & \mathbf{C} \end{pmatrix} = 2 \quad (1.1.3.1)$$

Are the given points in (1.1) collinear?

Question 1.1.3 : Check the collinearity of $\mathbf{A}, \mathbf{B}, \mathbf{C}$

Solution: Given that,

$$\mathbf{A} = \begin{pmatrix} 5 \\ -2 \end{pmatrix} \quad \mathbf{B} = \begin{pmatrix} -5 \\ 5 \end{pmatrix} \quad \mathbf{C} = \begin{pmatrix} -2 \\ -5 \end{pmatrix} \quad (1.1.3.2)$$

Given that $\mathbf{A}, \mathbf{B}, \mathbf{C}$ are collinear if

$$\text{rank} \begin{pmatrix} 1 & 1 & 1 \\ \mathbf{A} & \mathbf{B} & \mathbf{C} \end{pmatrix} < 3 \quad (1.1.3.3)$$

Let

$$\mathbf{R} = \begin{pmatrix} 1 & 1 & 1 \\ 5 & -5 & -2 \\ -2 & 5 & -5 \end{pmatrix} \quad (1.1.3.4)$$

The matrix \mathbf{R} can be row reduced as follows,

$$\begin{pmatrix} 1 & 1 & 1 \\ 5 & -5 & -2 \\ -2 & 5 & -5 \end{pmatrix} \xleftrightarrow{R_2 \leftarrow R_2 - 5R_1} \begin{pmatrix} 1 & 1 & 1 \\ 0 & -10 & -7 \\ -2 & 5 & -5 \end{pmatrix} \quad (1.1.3.5)$$

$$\xleftrightarrow{R_3 \leftarrow R_3 + 2R_1} \begin{pmatrix} 1 & 1 & 1 \\ 0 & -10 & -7 \\ 0 & 7 & -3 \end{pmatrix} \quad (1.1.3.6)$$

$$\xleftrightarrow{R_3 \leftarrow R_3 + 7R_2/10} \begin{pmatrix} 1 & 1 & 1 \\ 0 & -10 & -7 \\ 0 & 0 & -79/10 \end{pmatrix} \quad (1.1.3.7)$$

There are no zero rows. So,

$$\text{rank} \begin{pmatrix} 1 & 1 & 1 \\ \mathbf{A} & \mathbf{B} & \mathbf{C} \end{pmatrix} = 3 \quad (1.1.3.8)$$

Hence, from (1.1.3.3) the points $\mathbf{A}, \mathbf{B}, \mathbf{C}$ are not collinear.

From Fig. 1.1, We can see that $\mathbf{A}, \mathbf{B}, \mathbf{C}$ are not collinear .

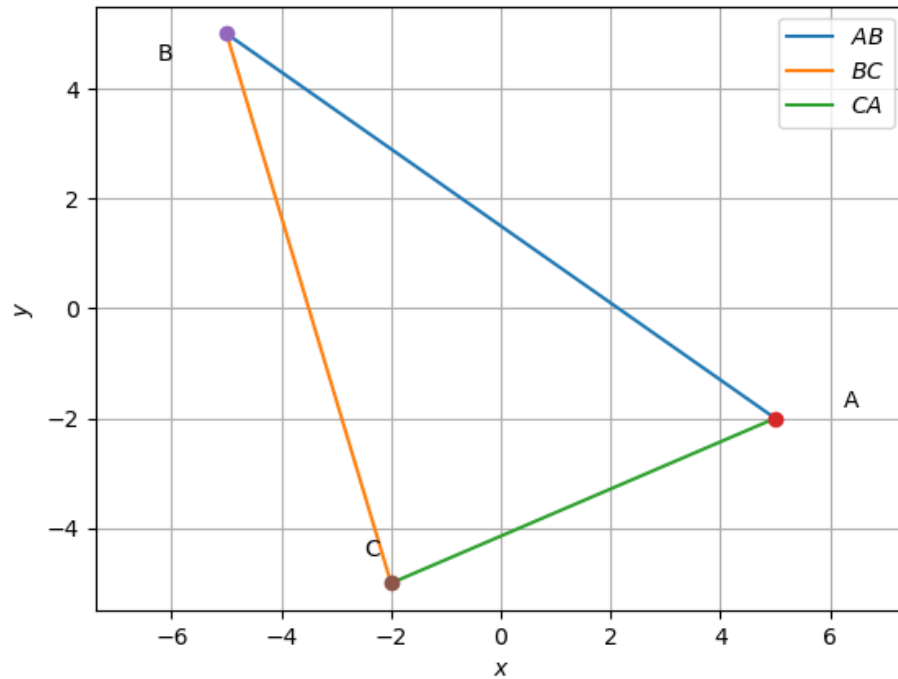


Figure 1.1: $\mathbf{A}, \mathbf{B}, \mathbf{C}$ plot

1.1.4. The parametric form of the equation of AB is

$$\mathbf{x} = \mathbf{A} + k\mathbf{m} \quad (1.1.4.1)$$

where

$$\mathbf{m} = \mathbf{B} - \mathbf{A} \quad (1.1.4.2)$$

is the direction vector of AB .

Question 1.1.4 :Find the parametric equation of AB, BC, CA .

Solution: The parametric equation for AB is given by

$$\mathbf{x} = \mathbf{A} + k\mathbf{m} \quad (1.1.4.3)$$

$$\text{where, } \mathbf{m} = \mathbf{B} - \mathbf{A} \quad (1.1.4.4)$$

$$= \begin{pmatrix} -10 \\ 7 \end{pmatrix} \quad (1.1.4.5)$$

Hence we get,

$$AB : \mathbf{x} = \begin{pmatrix} 5 \\ -2 \end{pmatrix} + k \begin{pmatrix} -10 \\ 7 \end{pmatrix} \quad (1.1.4.6)$$

Similarly,

$$BC : \mathbf{x} = \begin{pmatrix} -5 \\ 5 \end{pmatrix} + k \begin{pmatrix} 3 \\ -10 \end{pmatrix} \quad (1.1.4.7)$$

$$CA : \mathbf{x} = \begin{pmatrix} -2 \\ -5 \end{pmatrix} + k \begin{pmatrix} 7 \\ -3 \end{pmatrix} \quad (1.1.4.8)$$

1.1.5. The normal form of the equation of AB is

$$\mathbf{n}^\top (\mathbf{x} - \mathbf{A}) = 0 \quad (1.1.5.1)$$

where

$$\mathbf{n}^\top \mathbf{m} = \mathbf{n}^\top (\mathbf{B} - \mathbf{A}) = 0 \quad (1.1.5.2)$$

$$\text{or, } \mathbf{n} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \mathbf{m} \quad (1.1.5.3)$$

$$\mathbf{n}^\top \begin{pmatrix} \mathbf{x} - \mathbf{A} \end{pmatrix} = 0 \quad (1.1.5.4)$$

where

$$\mathbf{n}^\top \mathbf{m} = \mathbf{n}^\top \begin{pmatrix} \mathbf{B} - \mathbf{A} \end{pmatrix} = 0 \quad (1.1.5.5)$$

or,

$$\mathbf{n} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \mathbf{m} \quad (1.1.5.6)$$

Question 1.1.5: Find the normal form of the equations of AB , BC and CA .

Solution: : The normal equation for the side AB is

$$\mathbf{n}^\top (\mathbf{x} - \mathbf{A}) = 0 \quad (1.1.5.7)$$

$$\implies \mathbf{n}^\top \mathbf{x} = \mathbf{n}^\top \mathbf{A} \quad (1.1.5.8)$$

Now our task is to find the \mathbf{n} so that we can find \mathbf{n}^\top . As given in the question

$$\mathbf{n} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \mathbf{m} \quad (1.1.5.9)$$

Here $\mathbf{m} = \mathbf{B} - \mathbf{A}$ for side \mathbf{AB}

$$\implies \mathbf{m} = \begin{pmatrix} -5 \\ 5 \end{pmatrix} - \begin{pmatrix} 5 \\ -2 \end{pmatrix} \quad (1.1.5.10)$$

$$= \begin{pmatrix} -10 \\ 7 \end{pmatrix} \quad (1.1.5.11)$$

Now as we have obtained vector \mathbf{m} . we can use this to obtain vector \mathbf{n}

$$\mathbf{n} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \begin{pmatrix} -10 \\ 7 \end{pmatrix} = \begin{pmatrix} 7 \\ 10 \end{pmatrix} \quad (1.1.5.12)$$

The transpose of \mathbf{n} is

$$\mathbf{n}^\top = \begin{pmatrix} 7 & 10 \end{pmatrix} \quad (1.1.5.13)$$

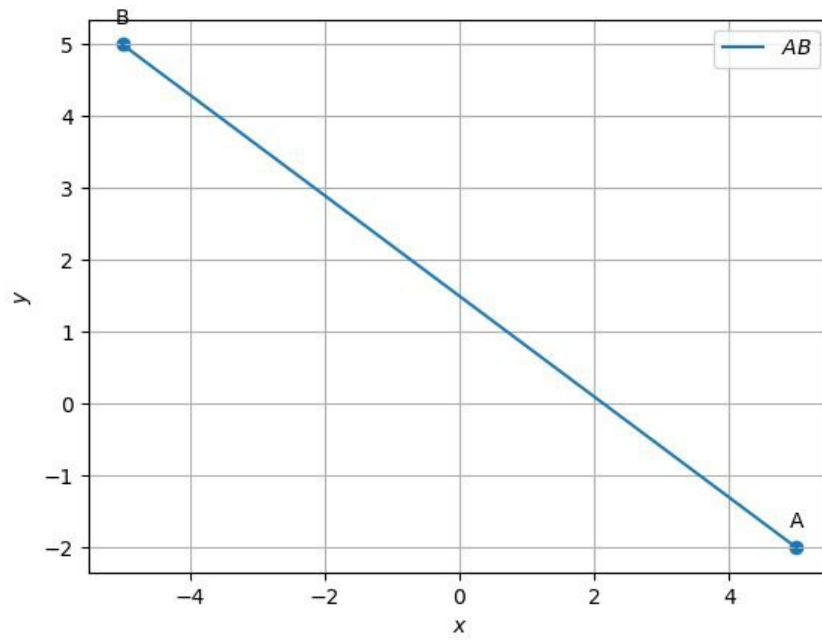


Figure 1.2: The line **AB** plotted using python

Hence the normal equation of side AB is

$$\begin{pmatrix} 7 & 10 \end{pmatrix} \mathbf{x} = \begin{pmatrix} 7 & 10 \end{pmatrix} \begin{pmatrix} 5 \\ -2 \end{pmatrix} \quad (1.1.5.14)$$

$$\Rightarrow \begin{pmatrix} 7 & 10 \end{pmatrix} \mathbf{x} = 15 \quad (1.1.5.15)$$

The normal equation for the side BC is

$$\mathbf{n}^\top (\mathbf{x} - \mathbf{B}) = 0 \quad (1.1.5.16)$$

$$\implies \mathbf{n}^\top \mathbf{x} = \mathbf{n}^\top \mathbf{B} \quad (1.1.5.17)$$

Now our task is to find the \mathbf{n} so that we can find \mathbf{n}^\top . As given in the question

$$\mathbf{n} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \mathbf{m} \quad (1.1.5.18)$$

Here $\mathbf{m} = \mathbf{C} - \mathbf{B}$ for side \mathbf{BC}

$$\implies \mathbf{m} = \begin{pmatrix} -2 \\ -5 \end{pmatrix} - \begin{pmatrix} -5 \\ 5 \end{pmatrix} \quad (1.1.5.19)$$

$$= \begin{pmatrix} 3 \\ -10 \end{pmatrix} \quad (1.1.5.20)$$

Now as we have obtained vector \mathbf{m} . we can use this to obtain vector \mathbf{n}

$$\mathbf{n} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \begin{pmatrix} 3 \\ -10 \end{pmatrix} = \begin{pmatrix} -10 \\ -3 \end{pmatrix} \quad (1.1.5.21)$$

The transpose of \mathbf{n} is

$$\mathbf{n}^\top = \begin{pmatrix} 10 & -3 \end{pmatrix} \quad (1.1.5.22)$$

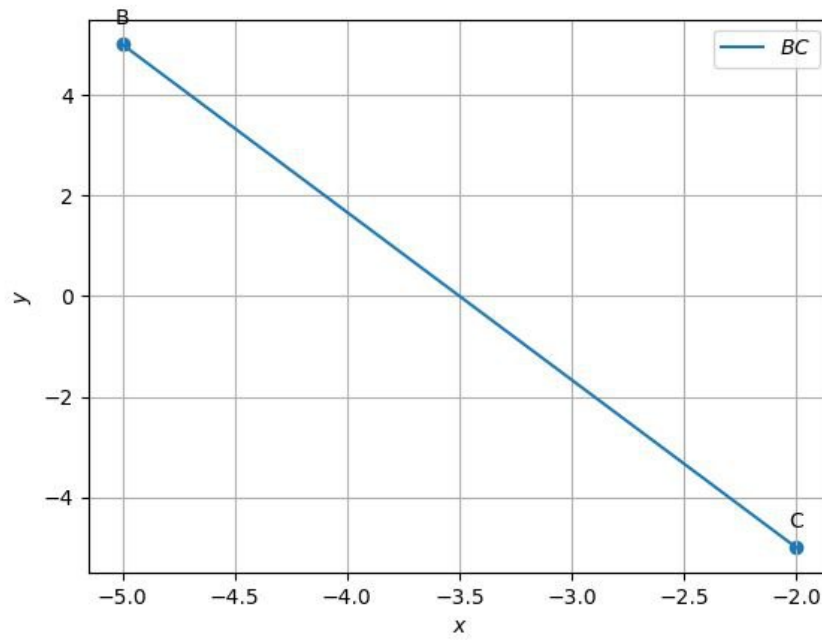


Figure 1.3: The line **BC** plotted using python

Hence the normal equation of side BC is

$$\begin{pmatrix} 10 & -3 \end{pmatrix} \mathbf{x} = \begin{pmatrix} 10 & -3 \end{pmatrix} \begin{pmatrix} -5 \\ 5 \end{pmatrix} \quad (1.1.5.23)$$

$$\Rightarrow \begin{pmatrix} 10 & -3 \end{pmatrix} \mathbf{x} = -35 \quad (1.1.5.24)$$

The normal equation for the side CA is

$$\mathbf{n}^\top (\mathbf{x} - \mathbf{C}) = 0 \quad (1.1.5.25)$$

$$\implies \mathbf{n}^\top \mathbf{x} = \mathbf{n}^\top \mathbf{C} \quad (1.1.5.26)$$

Now our task is to find the \mathbf{n} so that we can find \mathbf{n}^\top . As given in the question

$$\mathbf{n} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \mathbf{m} \quad (1.1.5.27)$$

Here $\mathbf{m} = \mathbf{A} - \mathbf{C}$ for side CA

$$\implies \mathbf{m} = \begin{pmatrix} 5 \\ -2 \end{pmatrix} - \begin{pmatrix} -2 \\ -5 \end{pmatrix} \quad (1.1.5.28)$$

$$= \begin{pmatrix} 7 \\ 3 \end{pmatrix} \quad (1.1.5.29)$$

Now as we have obtained vector \mathbf{m} . we can use this to obtain vector \mathbf{n}

$$\mathbf{n} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \begin{pmatrix} 7 \\ 3 \end{pmatrix} = \begin{pmatrix} 3 \\ -7 \end{pmatrix} \quad (1.1.5.30)$$

The transpose of \mathbf{n} is

$$\mathbf{n}^\top = \begin{pmatrix} 3 & -7 \end{pmatrix} \quad (1.1.5.31)$$

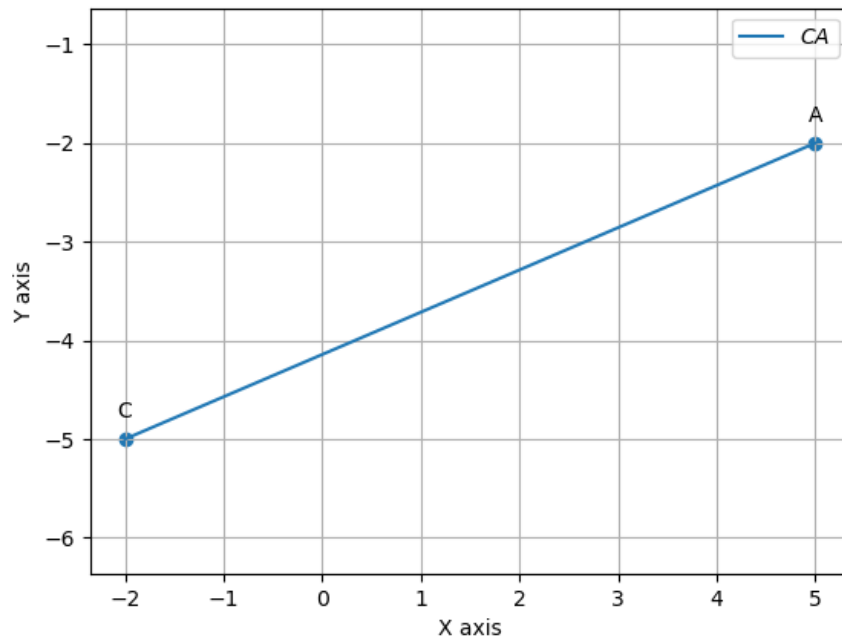


Figure 1.4: The line **CA** plotted using python

Hence the normal equation of side CA is

$$\begin{pmatrix} 3 & -7 \end{pmatrix} \mathbf{x} = \begin{pmatrix} 3 & -7 \end{pmatrix} \begin{pmatrix} -2 \\ -5 \end{pmatrix} \quad (1.1.5.32)$$

$$\Rightarrow \begin{pmatrix} 3 & -7 \end{pmatrix} \mathbf{x} = 29 \quad (1.1.5.33)$$

1.1.6. The area of $\triangle ABC$ is defined as

$$\frac{1}{2} \|(\mathbf{A} - \mathbf{B}) \times \mathbf{A} - \mathbf{C}\| \quad (1.1.6.1)$$

where

$$\mathbf{A} \times \mathbf{B} \triangleq \begin{vmatrix} 5 & -2 \\ -5 & 5 \end{vmatrix} \quad (1.1.6.2)$$

Question 1.1.6: Find the area of $\triangle ABC$.

Solution: Given,

$$\mathbf{A} = \begin{pmatrix} 5 \\ -2 \end{pmatrix}; \mathbf{B} = \begin{pmatrix} -5 \\ 5 \end{pmatrix}; \mathbf{C} = \begin{pmatrix} -2 \\ -5 \end{pmatrix} \quad (1.1.6.3)$$

$$\mathbf{A} - \mathbf{B} = \begin{pmatrix} 5 \\ -2 \end{pmatrix} - \begin{pmatrix} -5 \\ 5 \end{pmatrix} = \begin{pmatrix} 7 \\ -7 \end{pmatrix} \quad (1.1.6.4)$$

$$\mathbf{A} - \mathbf{C} = \begin{pmatrix} 5 \\ -2 \end{pmatrix} - \begin{pmatrix} -2 \\ -5 \end{pmatrix} = \begin{pmatrix} 7 \\ 3 \end{pmatrix} \quad (1.1.6.5)$$

$$\therefore (\mathbf{A} - \mathbf{B}) \times (\mathbf{A} - \mathbf{C}) = \begin{vmatrix} -7 & 7 \\ -7 & 3 \end{vmatrix} \quad (1.1.6.6)$$

$$= 70 \quad (1.1.6.7)$$

$$\Rightarrow \frac{1}{2} \|(\mathbf{A} - \mathbf{B}) \times (\mathbf{A} - \mathbf{C})\| = \frac{70}{2} = 35 \quad (1.1.6.8)$$

1.1.7. Question 1.1.7: Find the angles $\mathbf{A}, \mathbf{B}, \mathbf{C}$, given that

$$\cos A \triangleq \frac{(\mathbf{B} - \mathbf{A}) \cdot (\mathbf{C} - \mathbf{A})}{\|\mathbf{B} - \mathbf{A}\| \|\mathbf{C} - \mathbf{A}\|} \quad (1.1.7.1)$$

Solution:

From the given values of $\mathbf{A}, \mathbf{B}, \mathbf{C}$,

(a) Finding the value of angle A

$$\mathbf{B} - \mathbf{A} = \begin{pmatrix} -10 \\ 7 \end{pmatrix} \quad (1.1.7.2)$$

and

$$\mathbf{C} - \mathbf{A} = \begin{pmatrix} -7 \\ -3 \end{pmatrix} \quad (1.1.7.3)$$

also calculating the values of norms

$$\|\mathbf{B} - \mathbf{A}\| = \sqrt{149} \quad (1.1.7.4)$$

$$\|\mathbf{C} - \mathbf{A}\| = \sqrt{58} \quad (1.1.7.5)$$

and by doing matrix multiplication we get,

$$\begin{aligned} (\mathbf{B} - \mathbf{A})^\top (\mathbf{C} - \mathbf{A}) &= \begin{pmatrix} -10 & 7 \end{pmatrix} \begin{pmatrix} -7 \\ -3 \end{pmatrix} \\ &= 49 \end{aligned} \quad (1.1.7.6)$$

so

$$\cos A = \frac{49}{\sqrt{149}\sqrt{58}} \implies A = \cos^{-1} \frac{49}{\sqrt{149}\sqrt{58}} \quad (1.1.7.7)$$

(b) Finding the value of angle B

$$\mathbf{C} - \mathbf{B} = \begin{pmatrix} 3 \\ -10 \end{pmatrix} \quad (1.1.7.8)$$

and

$$\mathbf{A} - \mathbf{B} = \begin{pmatrix} 10 \\ -7 \end{pmatrix} \quad (1.1.7.9)$$

also calculating the values of norms

$$\|\mathbf{C} - \mathbf{B}\| = \sqrt{109} \quad (1.1.7.10)$$

$$\|\mathbf{A} - \mathbf{B}\| = \sqrt{149} \quad (1.1.7.11)$$

and by doing matrix multiplication we get,

$$\begin{aligned} (\mathbf{C} - \mathbf{B})^\top (\mathbf{A} - \mathbf{B}) &= \begin{pmatrix} 3 & -10 \end{pmatrix} \begin{pmatrix} 10 \\ -7 \end{pmatrix} \\ &= 100 \end{aligned} \quad (1.1.7.12)$$

so

$$\cos B = \frac{100}{\sqrt{109}\sqrt{149}} \implies B = \cos^{-1} \frac{100}{\sqrt{109}\sqrt{149}} \quad (1.1.7.13)$$

(c) Finding the value of angle C

$$\mathbf{A} - \mathbf{C} = \begin{pmatrix} 7 \\ 3 \end{pmatrix} \quad (1.1.7.14)$$

and

$$\mathbf{B} - \mathbf{C} = \begin{pmatrix} -3 \\ 10 \end{pmatrix} \quad (1.1.7.15)$$

also calculating the values of norms

$$\|\mathbf{A} - \mathbf{C}\| = \sqrt{58} \quad (1.1.7.16)$$

$$\|\mathbf{B} - \mathbf{C}\| = \sqrt{109} \quad (1.1.7.17)$$

and by doing matrix multiplication we get,

$$\begin{aligned} (\mathbf{A} - \mathbf{C})^\top (\mathbf{B} - \mathbf{C}) &= \begin{pmatrix} 7 & 3 \end{pmatrix} \begin{pmatrix} -3 \\ 10 \end{pmatrix} \\ &= 9 \end{aligned} \quad (1.1.7.18)$$

so

$$\cos C = \frac{9}{\sqrt{58}\sqrt{109}} \implies C = \cos^{-1} \frac{9}{\sqrt{58}\sqrt{109}} \quad (1.1.7.19)$$