# Contents

# Chapter 1

# Triangle

Consider a triangle with vertices

$$\mathbf{A} = \begin{pmatrix} -3 \\ 0 \end{pmatrix}, \mathbf{B} = \begin{pmatrix} 4 \\ 2 \end{pmatrix}, \mathbf{c} = \begin{pmatrix} 1 \\ 4 \end{pmatrix}, \tag{1.1}$$

## 1.1. Vectors

1.1.1. The direction vector of $AB$ is defined as

$$\mathbf{B} - \mathbf{A} \tag{1.1.1.1}$$

Consider a triangle with vertices

$$\mathbf{A} = \begin{pmatrix} -3 \\ 0 \end{pmatrix} \tag{1.1.1.2}$$

$$\mathbf{B} = \begin{pmatrix} 4 \\ 2 \end{pmatrix} \tag{1.1.1.3}$$

$$\mathbf{C} = \begin{pmatrix} 1 \\ 4 \end{pmatrix} \tag{1.1.1.4}$$

The Direction Vector of $AB$ is defined as

$$\mathbf{B} - \mathbf{A} \tag{1.1.1.5}$$

Question1.1.1 :Find the Direction Vectors of $AB$,$BC$,$CA$.

**Solution:**

(a) The Direction vector of $AB$ is

$$= \mathbf{B} - \mathbf{A} \tag{1.1.1.6}$$

$$= \begin{pmatrix} 4 - (-3) \\ 2 - (0) \end{pmatrix} \tag{1.1.1.7}$$

$$= \begin{pmatrix} 7 \\ 2 \end{pmatrix} \tag{1.1.1.8}$$

(b) The Direction vector of $BC$

$$= \mathbf{C} - \mathbf{B} \tag{1.1.1.9}$$

$$= \begin{pmatrix} 1-4 \\ 4-2 \end{pmatrix} \tag{1.1.1.10}$$

$$= \begin{pmatrix} -3 \\ 2 \end{pmatrix} \tag{1.1.1.11}$$

(c) The Direction vector of $CA$

$$= \mathbf{A} - \mathbf{C} \tag{1.1.1.12}$$

$$= \begin{pmatrix} -3-1 \\ 0-(4) \end{pmatrix} \tag{1.1.1.13}$$

$$= \begin{pmatrix} -4 \\ -4 \end{pmatrix} \tag{1.1.1.14}$$

1.1.2. The length of side $BC$ is

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

where

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

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

**Solution:** Solving for BC Given,

$$\mathbf{A} = \begin{pmatrix} -3 \\ 0 \end{pmatrix}, \mathbf{B} = \begin{pmatrix} 4 \\ 2 \end{pmatrix}, \mathbf{C} = \begin{pmatrix} 1 \\ 4 \end{pmatrix} \tag{1.1.2.3}$$

$$\|\mathbf{B} - \mathbf{C}\| = \sqrt{(\mathbf{B} - \mathbf{C})^\top (\mathbf{B} - \mathbf{C})} \tag{1.1.2.4}$$

$$\mathbf{B} - \mathbf{C} = \begin{pmatrix} 4 \\ 2 \end{pmatrix} - \begin{pmatrix} 1 \\ 4 \end{pmatrix} \tag{1.1.2.5}$$

$$\mathbf{B} - \mathbf{C} = \begin{pmatrix} 3 \\ -2 \end{pmatrix} \tag{1.1.2.6}$$

$$(\mathbf{B} - \mathbf{C})^\top = \begin{pmatrix} 3 \\ -2 \end{pmatrix}^\top = \begin{pmatrix} 3 & -2 \end{pmatrix} \tag{1.1.2.7}$$

$$(\mathbf{B} - \mathbf{C})^\top (\mathbf{B} - \mathbf{C}) = \begin{pmatrix} 3 & -2 \end{pmatrix} \begin{pmatrix} 3 \\ -2 \end{pmatrix} \tag{1.1.2.8}$$

$$= 9 + 4 \tag{1.1.2.9}$$

$$= 13 \tag{1.1.2.10}$$

$$\sqrt{(\mathbf{B} - \mathbf{C})^\top (\mathbf{B} - \mathbf{C})} = \sqrt{13} \tag{1.1.2.11}$$

$$\implies \|\mathbf{B} - \mathbf{C}\| = \sqrt{13} \tag{1.1.2.12}$$

Solving for AB Given,

$$\left\|\mathbf{A}-\mathbf{B}\right\| = \sqrt{\left(\mathbf{A}-\mathbf{B}\right)^{\top}\left(\mathbf{A}-\mathbf{B}\right)} \tag{1.1.2.13}$$

$$\mathbf{A}-\mathbf{B} = \begin{pmatrix}-3\\0\end{pmatrix} - \begin{pmatrix}4\\2\end{pmatrix} \tag{1.1.2.14}$$

$$\mathbf{A}-\mathbf{B} = \begin{pmatrix}-7\\-2\end{pmatrix} \tag{1.1.2.15}$$

$$\left(\mathbf{A}-\mathbf{B}\right)^{\top} = \begin{pmatrix}-7\\-2\end{pmatrix}^{\top} = \begin{pmatrix}-7 & -2\end{pmatrix} \tag{1.1.2.16}$$

$$\left(\mathbf{A}-\mathbf{B}\right)^{\top}\left(\mathbf{A}-\mathbf{B}\right) = \begin{pmatrix}-7 & -2\end{pmatrix}\begin{pmatrix}-7\\-2\end{pmatrix} \tag{1.1.2.17}$$

$$= 49 + 4 \tag{1.1.2.18}$$

$$= 53 \tag{1.1.2.19}$$

$$\sqrt{\left(\mathbf{A}-\mathbf{B}\right)^{\top}\left(\mathbf{A}-\mathbf{B}\right)} = \sqrt{53} \tag{1.1.2.20}$$

$$\implies \left\|\mathbf{A}-\mathbf{B}\right\| = \sqrt{53} \tag{1.1.2.21}$$

Solving for CA Given,

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

$$\mathbf{C}-\mathbf{A} = \begin{pmatrix} 1 \\ 4 \end{pmatrix} - \begin{pmatrix} -3 \\ 0 \end{pmatrix} \tag{1.1.2.23}$$

$$\mathbf{C}-\mathbf{A} = \begin{pmatrix} 4 \\ 4 \end{pmatrix} \tag{1.1.2.24}$$

$$(\mathbf{C}-\mathbf{A})^{\top} = \begin{pmatrix} 4 \\ 4 \end{pmatrix}^{\top} = \begin{pmatrix} 4 & 4 \end{pmatrix} \tag{1.1.2.25}$$

$$(\mathbf{C}-\mathbf{A})^{\top}(\mathbf{C}-\mathbf{A}) = \begin{pmatrix} 4 & 4 \end{pmatrix} \begin{pmatrix} -4 \\ 4 \end{pmatrix} \tag{1.1.2.26}$$

$$= 16 + 16 \tag{1.1.2.27}$$

$$= 32 \tag{1.1.2.28}$$

$$\sqrt{(\mathbf{C}-\mathbf{A})^{\top}(\mathbf{C}-\mathbf{A})} = \sqrt{32} \tag{1.1.2.29}$$

$$\implies \|\mathbf{C}-\mathbf{A}\| = \sqrt{32} \tag{1.1.2.30}$$

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

$$\operatorname{rank}\begin{pmatrix} 1 & 1 & 1 \\ \mathbf{A} & \mathbf{B} & \mathbf{C} \end{pmatrix} = 2 \tag{1.1.3.1}$$

Are the given points in (**??**) collinear?

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

**Solution:** Given that,

$$\mathbf{A} = \begin{pmatrix} -3 \\ 0 \end{pmatrix} \quad \mathbf{B} = \begin{pmatrix} 4 \\ 2 \end{pmatrix} \quad \mathbf{C} = \begin{pmatrix} 1 \\ 4 \end{pmatrix} \tag{1.1.3.2}$$

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

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

Let

$$\mathbf{R} = \begin{pmatrix} 1 & 1 & 1 \\ -3 & 4 & 1 \\ 0 & 2 & 4 \end{pmatrix} \tag{1.1.3.4}$$

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

$$\begin{pmatrix} 1 & 1 & 1 \\ -3 & 4 & 1 \\ 0 & 2 & 4 \end{pmatrix} \xleftrightarrow{R_2 \leftarrow R_1} \begin{pmatrix} -3 & 4 & 1 \\ 1 & 1 & 1 \\ 0 & 2 & 4 \end{pmatrix} \tag{1.1.3.5}$$

$$\xleftrightarrow{R_1 \leftarrow -R_1/3} \begin{pmatrix} 1 & -4/3 & -1/3 \\ 1 & 1 & 1 \\ 0 & 2 & 4 \end{pmatrix} \tag{1.1.3.6}$$

$$\xleftarrow{R_2 \leftarrow R_2 - R_1} \begin{pmatrix} 1 & -4/3 & -1/3 \\ 0 & 11/3 & 4/3 \\ 0 & 2 & 4 \end{pmatrix} \tag{1.1.3.7}$$

$$\xleftarrow{R_3 \leftarrow R_3 - 2/11 R_2} \begin{pmatrix} 1 & -4/3 & -1/3 \\ 0 & 11/3 & 4/3 \\ 0 & 0 & 8/3 \end{pmatrix} \tag{1.1.3.8}$$

There are no zero rows. So,

$$\text{rank} \begin{pmatrix} 1 & 1 & 1 \\ \mathbf{A} & \mathbf{B} & \mathbf{C} \end{pmatrix} = 3 \tag{1.1.3.9}$$

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

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

1.1.4. The parameteric form of the equation of $AB$ is

$$\mathbf{x} = \mathbf{A} + k\mathbf{m} \tag{1.1.4.1}$$

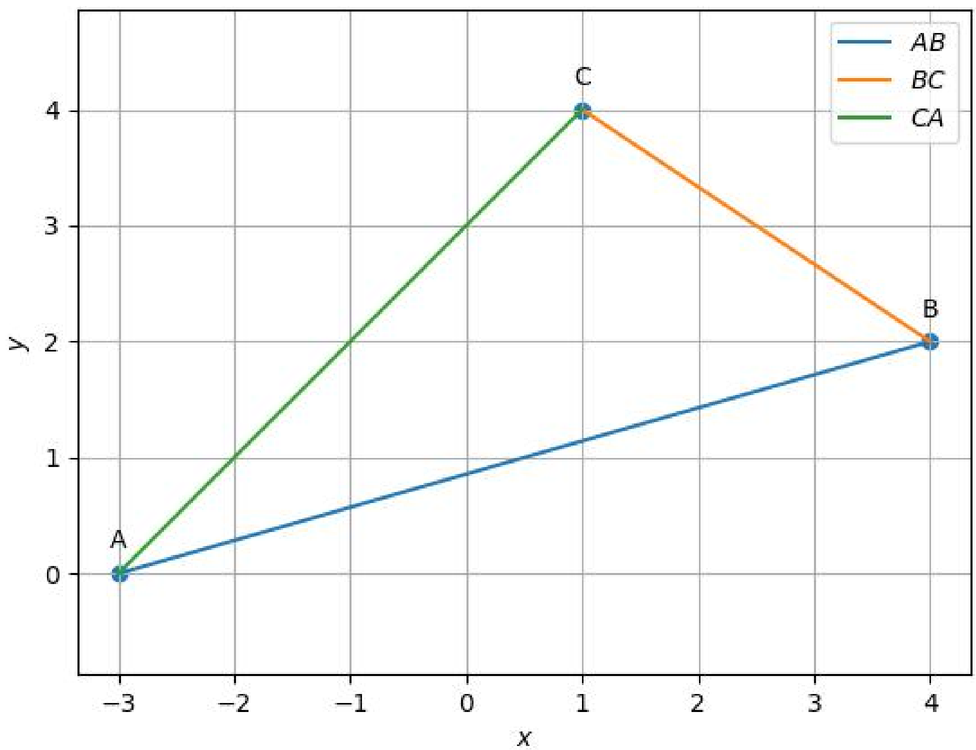


Figure 1.1: $\mathbf{A}, \mathbf{B}, \mathbf{C}$ plot

where

$$\mathbf{m} = \mathbf{B} - \mathbf{A} \tag{1.1.4.2}$$

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

$$\mathbf{x} = \mathbf{A} + k\mathbf{m} \tag{1.1.4.3}$$

$$\text{where, } \mathbf{m} = \mathbf{B} - \mathbf{A} \tag{1.1.4.4}$$

$$= \begin{pmatrix} 7 \\ 2 \end{pmatrix} \tag{1.1.4.5}$$

Hence we get,

$$AB : \mathbf{x} = \begin{pmatrix} -3 \\ 0 \end{pmatrix} + k \begin{pmatrix} 7 \\ 2 \end{pmatrix} \tag{1.1.4.6}$$

Similarly,

$$BC : \mathbf{x} = \begin{pmatrix} 4 \\ 2 \end{pmatrix} + k \begin{pmatrix} -3 \\ 2 \end{pmatrix} \tag{1.1.4.7}$$

$$CA : \mathbf{x} = \begin{pmatrix} 1 \\ 4 \end{pmatrix} + k \begin{pmatrix} -4 \\ -4 \end{pmatrix} \tag{1.1.4.8}$$

1.1.5. The normal form of the equation of $AB$ is

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

where

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

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

$$\mathbf{n}^\top \left(\mathbf{x} - \mathbf{A}\right) = 0 \tag{1.1.5.4}$$

where

$$\mathbf{n}^\top \mathbf{m} = \mathbf{n}^\top \left(\mathbf{B} - \mathbf{A}\right) = 0 \tag{1.1.5.5}$$

or,

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

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

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

$$\implies \mathbf{n}^\top \mathbf{x} = \mathbf{n}^\top \mathbf{A} \tag{1.1.5.8}$$

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

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

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

$$\implies \mathbf{m} = \begin{pmatrix} 5 \\ 4 \end{pmatrix} - \begin{pmatrix} 1 \\ 0 \end{pmatrix} \tag{1.1.5.10}$$

$$= \begin{pmatrix} 4 \\ 4 \end{pmatrix} \tag{1.1.5.11}$$

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

$$\mathbf{n} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \begin{pmatrix} 4 \\ 4 \end{pmatrix} = \begin{pmatrix} 4 \\ -4 \end{pmatrix} \tag{1.1.5.12}$$

The transpose of $\mathbf{n}$ is

$$\mathbf{n}^\top = \begin{pmatrix} 4 & -4 \end{pmatrix} \tag{1.1.5.13}$$

Hence the normal equation of side $AB$ is

$$\begin{pmatrix} 4 & -4 \end{pmatrix} \mathbf{x} = \begin{pmatrix} 4 & -4 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \end{pmatrix} \tag{1.1.5.14}$$

$$\implies \begin{pmatrix} 4 & -4 \end{pmatrix} \mathbf{x} = 4 \tag{1.1.5.15}$$

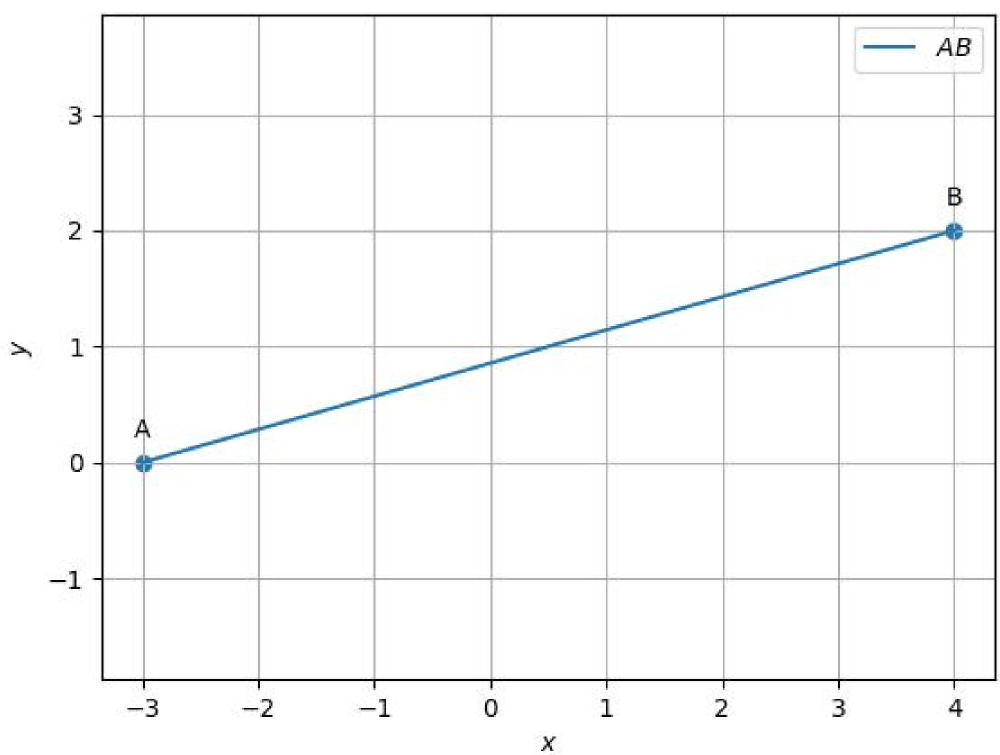


Figure 1.2: The line **AB** plotted using python

The normal equation for the side $BC$ is

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

$$\implies \mathbf{n}^\top \mathbf{x} = \mathbf{n}^\top \mathbf{B} \tag{1.1.5.17}$$

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

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

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

$$\implies \mathbf{m} = \begin{pmatrix} -4 \\ 0 \end{pmatrix} - \begin{pmatrix} 5 \\ 4 \end{pmatrix} \tag{1.1.5.19}$$

$$= \begin{pmatrix} -9 \\ -4 \end{pmatrix} \tag{1.1.5.20}$$

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

$$\mathbf{n} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \begin{pmatrix} -9 \\ -4 \end{pmatrix} = \begin{pmatrix} -4 \\ 9 \end{pmatrix} \tag{1.1.5.21}$$

The transpose of $\mathbf{n}$ is

$$\mathbf{n}^\top = \begin{pmatrix} -4 & 9 \end{pmatrix} \tag{1.1.5.22}$$

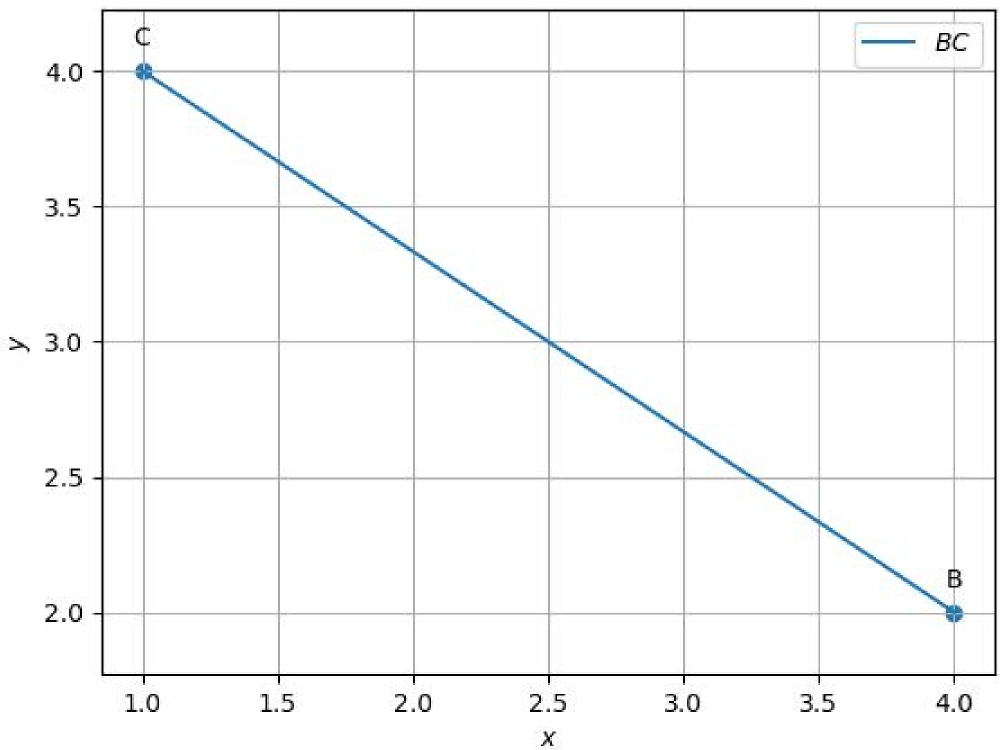


Figure 1.3: The line **BC** plotted using python

Hence the normal equation of side $BC$ is

$$\begin{pmatrix} -4 & 9 \end{pmatrix} \mathbf{x} = \begin{pmatrix} -4 & 9 \end{pmatrix} \begin{pmatrix} 5 \\ 4 \end{pmatrix} \tag{1.1.5.23}$$

$$\implies \begin{pmatrix} -4 & 9 \end{pmatrix} \mathbf{x} = 16 \tag{1.1.5.24}$$

The normal equation for the side $CA$ is

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

$$\implies \mathbf{n}^\top \mathbf{x} = \mathbf{n}^\top \mathbf{C} \tag{1.1.5.26}$$

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

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

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

$$\implies \mathbf{m} = \begin{pmatrix} 1 \\ 0 \end{pmatrix} - \begin{pmatrix} -4 \\ 0 \end{pmatrix} \tag{1.1.5.28}$$

$$= \begin{pmatrix} 5 \\ 0 \end{pmatrix} \tag{1.1.5.29}$$

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

$$\mathbf{n} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \begin{pmatrix} 5 \\ 0 \end{pmatrix} = \begin{pmatrix} 0 \\ -5 \end{pmatrix} \tag{1.1.5.30}$$

The transpose of $\mathbf{n}$ is

$$\mathbf{n}^\top = \begin{pmatrix} 0 & -5 \end{pmatrix} \tag{1.1.5.31}$$

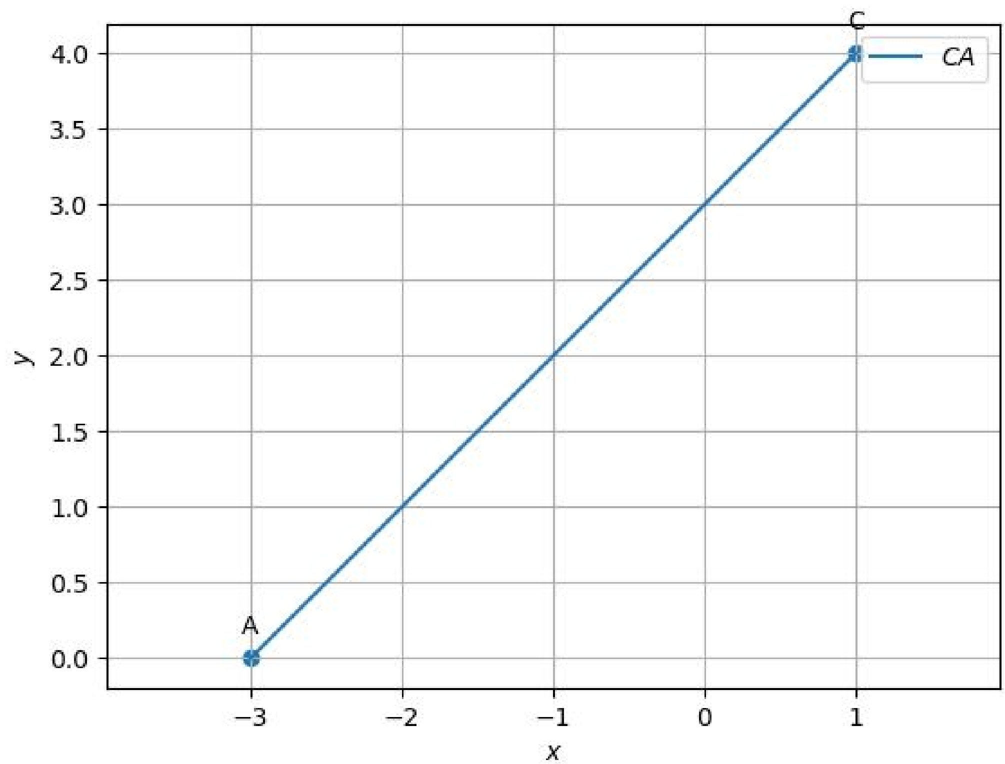


Figure 1.4: The line **CA** plotted using python

Hence the normal equation of side $CA$ is

$$\begin{pmatrix} 0 & -5 \end{pmatrix} \mathbf{x} = \begin{pmatrix} 0 & -5 \end{pmatrix} \begin{pmatrix} -4 \\ 0 \end{pmatrix} \tag{1.1.5.32}$$

$$\implies \begin{pmatrix} 0 & -5 \end{pmatrix} \mathbf{x} = 0 \tag{1.1.5.33}$$

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

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

where

$$\mathbf{A}\times\mathbf{B}\triangleq\begin{vmatrix}-3 & 0\\ 4 & 2\end{vmatrix} \tag{1.1.6.2}$$

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

**Solution:** Given,

$$\mathbf{A}=\begin{pmatrix}-3\\0\end{pmatrix};\mathbf{B}=\begin{pmatrix}4\\2\end{pmatrix};\mathbf{C}=\begin{pmatrix}1\\4\end{pmatrix} \tag{1.1.6.3}$$

$$\mathbf{A}-\mathbf{B}=\begin{pmatrix}-3\\0\end{pmatrix}-\begin{pmatrix}4\\2\end{pmatrix}=\begin{pmatrix}-7\\-2\end{pmatrix} \tag{1.1.6.4}$$

$$\mathbf{A}-\mathbf{C}=\begin{pmatrix}-3\\0\end{pmatrix}-\begin{pmatrix}1\\4\end{pmatrix}=\begin{pmatrix}-4\\-4\end{pmatrix} \tag{1.1.6.5}$$

$$\therefore(\mathbf{A}-\mathbf{B})\times(\mathbf{A}-\mathbf{C})=\begin{vmatrix}-7 & -2\\ -4 & -4\end{vmatrix} \tag{1.1.6.6}$$

$$=20 \tag{1.1.6.7}$$

$$\implies\frac{1}{2}\left\|(\mathbf{A}-\mathbf{B})\times(\mathbf{A}-\mathbf{C})\right\|=\frac{20}{2}=10 \tag{1.1.6.8}$$

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

$$\cos A \triangleq \frac{(\mathbf{B}-\mathbf{A})\top(\mathbf{C}-\mathbf{A})}{\|\mathbf{B}-\mathbf{A}\| \, \|\mathbf{C}-\mathbf{A}\|} \tag{1.1.7.1}$$

**Solution:**

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

(a) Finding the value of angle A

$$\mathbf{B}-\mathbf{A} = \begin{pmatrix} 7 \\ 2 \end{pmatrix} \tag{1.1.7.2}$$

and

$$\mathbf{C}-\mathbf{A} = \begin{pmatrix} 4 \\ 4 \end{pmatrix} \tag{1.1.7.3}$$

also calculating the values of norms

$$\|\mathbf{B}-\mathbf{A}\| = \sqrt{53} \tag{1.1.7.4}$$

$$\|\mathbf{C}-\mathbf{A}\| = \sqrt{32} \tag{1.1.7.5}$$

and by doing matrix multiplication we get,

$$(\mathbf{B}-\mathbf{A})^\top(\mathbf{C}-\mathbf{A}) = \begin{pmatrix} 7 & 2 \end{pmatrix} \begin{pmatrix} 4 \\ 4 \end{pmatrix} \tag{1.1.7.6}$$

$$= 36$$

so

$$\cos A = \frac{36}{\sqrt{53}\sqrt{32}} \implies A = \cos^{-1}\frac{36}{\sqrt{53}\sqrt{32}} \tag{1.1.7.7}$$

(b) Finding the value of angle B

$$\mathbf{C} - \mathbf{B} = \begin{pmatrix} -3 \\ 2 \end{pmatrix} \tag{1.1.7.8}$$

and

$$\mathbf{A} - \mathbf{B} = \begin{pmatrix} -7 \\ -2 \end{pmatrix} \tag{1.1.7.9}$$

also calculating the values of norms

$$\|\mathbf{C} - \mathbf{B}\| = \sqrt{53} \tag{1.1.7.10}$$

$$\|\mathbf{A} - \mathbf{B}\| = \sqrt{13} \tag{1.1.7.11}$$

and by doing matrix multiplication we get,

$$\begin{aligned}(\mathbf{C} - \mathbf{B})^\top(\mathbf{A} - \mathbf{B}) &= \begin{pmatrix} -3 & 2 \end{pmatrix}\begin{pmatrix} -7 \\ -2 \end{pmatrix} \\ &= 17 \end{aligned} \tag{1.1.7.12}$$

so

$$\cos B = \frac{17}{\sqrt{53}\sqrt{13}} \implies B = \cos^{-1}\frac{17}{\sqrt{53}\sqrt{13}} \tag{1.1.7.13}$$

(c) Finding the value of angle C

$$\mathbf{A} - \mathbf{C} = \begin{pmatrix} -4 \\ -4 \end{pmatrix} \tag{1.1.7.14}$$

and

$$\mathbf{B} - \mathbf{C} = \begin{pmatrix} 3 \\ 2 \end{pmatrix} \tag{1.1.7.15}$$

also calculating the values of norms

$$\|\mathbf{A} - \mathbf{C}\| = \sqrt{32} \tag{1.1.7.16}$$

$$\|\mathbf{B} - \mathbf{C}\| = \sqrt{13} \tag{1.1.7.17}$$

and by doing matrix multiplication we get,

$$\begin{aligned}(\mathbf{A} - \mathbf{C})^\top (\mathbf{B} - \mathbf{C}) &= \begin{pmatrix} -4 & -4 \end{pmatrix} \begin{pmatrix} 3 \\ 2 \end{pmatrix} \\ &= -20 \end{aligned} \tag{1.1.7.18}$$

so

$$\cos C = \frac{-20}{\sqrt{32}\sqrt{13}} \implies C = \cos^{-1} \frac{-20}{\sqrt{32}\sqrt{13}} \tag{1.1.7.19}$$