SM5083 - BASICS OF PROGRAMMING

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1 PROBLEM

1.1. Find the areas of the triangles formed by the triads of points

$$\mathbf{A} = \begin{pmatrix} 4 \\ 3 \end{pmatrix}, \mathbf{B} = \begin{pmatrix} 1 \\ -3 \end{pmatrix}, \mathbf{C} = \begin{pmatrix} -3 \\ 1 \end{pmatrix} \tag{1.1.1}$$

and

$$\mathbf{P} = \begin{pmatrix} 4 \\ 3 \end{pmatrix}, \mathbf{Q} = \begin{pmatrix} -3 \\ 1 \end{pmatrix}, \mathbf{R} = \begin{pmatrix} 1 \\ -3 \end{pmatrix} \tag{1.1.2}$$

Explain the difference of signs in the two cases.

Solution: The given points are-

$$\mathbf{A} = \begin{pmatrix} 4 \\ 3 \end{pmatrix}, \mathbf{B} = \begin{pmatrix} 1 \\ -3 \end{pmatrix}, \mathbf{C} = \begin{pmatrix} -3 \\ 1 \end{pmatrix} \tag{1.1.3}$$

$$\mathbf{P} = \begin{pmatrix} 4 \\ 3 \end{pmatrix}, \mathbf{Q} = \begin{pmatrix} -3 \\ 1 \end{pmatrix}, \mathbf{R} = \begin{pmatrix} 1 \\ -3 \end{pmatrix} \tag{1.1.4}$$

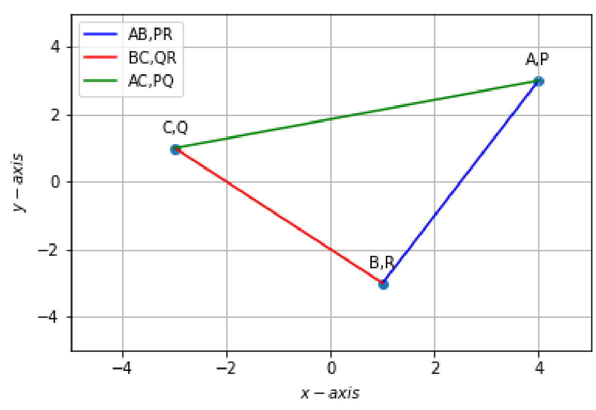

Fig. 1.1. Triangle ABC, Triangle PQR

Area of a $\triangle$ with vertices $\mathbf{A}, \mathbf{B}, \mathbf{C}$ is

$$\Delta = \frac{1}{2} \begin{vmatrix} 1 & 1 & 1 \\ \mathbf{A} & \mathbf{B} & \mathbf{C} \end{vmatrix} \tag{1.1.5}$$

For

$$\mathbf{A} = \begin{pmatrix} x_1 \\ y_1 \end{pmatrix}, \mathbf{B} = \begin{pmatrix} x_2 \\ y_2 \end{pmatrix}, \mathbf{C} = \begin{pmatrix} x_3 \\ y_3 \end{pmatrix}, \tag{1.1.6}$$

$$\Delta = \frac{1}{2} \begin{vmatrix} 1 & 1 & 1 \\ x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 \end{vmatrix} \tag{1.1.7}$$

$\therefore \Delta ABC$

$$= \frac{1}{2} \begin{vmatrix} 1 & 1 & 1 \\ 4 & 1 & -3 \\ 3 & -3 & 1 \end{vmatrix} \xleftrightarrow{C1 \leftrightarrow C1-C3} \frac{1}{2} \begin{vmatrix} 0 & 1 & 1 \\ 7 & 1 & -3 \\ 2 & -3 & 1 \end{vmatrix} \xleftrightarrow{C2 \leftrightarrow C2-C3} \frac{1}{2} \begin{vmatrix} 0 & 0 & 1 \\ 7 & 4 & -3 \\ 2 & -4 & 1 \end{vmatrix} \xleftrightarrow{C2 \leftrightarrow C2/4} \begin{vmatrix} 0 & 0 & 1 \\ 7 & 1 & -3 \\ 2 & -1 & 1 \end{vmatrix} \tag{1.1.8}$$

Expanding along the first row,

$$\begin{aligned} \Delta ABC &= 2\,[1(7(-1) - 2(1))] \\ &= 2\,(-9) = -18 \end{aligned} \tag{1.1.9}$$

For any matrix $\mathbf{X}$, product with $\mathbf{I}$ (identity matrix), gives matrix $\mathbf{X}$ itself,

$$\mathbf{XI} = \mathbf{IX} = \mathbf{X} \tag{1.1.10}$$

where

$$\mathbf{I} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{1.1.11}$$

Also, exchanging the columns of $\mathbf{I}$ in the product, will exchange columns of $\mathbf{X}$ too.

Let $\mathbf{J}$ be the matrix obtained by exchanging $C2$ and $C3$ of $\mathbf{I}$, so that

$$\mathbf{J} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}, where \left|J\right| = 1(0-1) = -1 \tag{1.1.12}$$

$\therefore \triangle ABC$ can be transformed to $\triangle PQR$:

$$\begin{pmatrix} 1 & 1 & 1 \\ 4 & 1 & -3 \\ 3 & -3 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix} = \begin{pmatrix} 1 & 1 & 1 \\ 4 & -3 & 1 \\ 3 & 1 & -3 \end{pmatrix} = \mathbf{PQR} \tag{1.1.13}$$

We know,

$$\left|X\right|\left|Y\right| = \left|XY\right| \tag{1.1.14}$$

From equations (1.1.9) and (1.1.12),

$$\left|ABC\right|\left|J\right| = \left|(ABC)J\right| = (-18)(-1) = 18 \tag{1.1.15}$$

$$\therefore \triangle PQR = \left|PQR\right| = 18 \tag{1.1.16}$$

Hence, the difference in the sign in the areas of $\triangle ABC$ and $\triangle PQR$.