Assignment 3

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***Abstract*—This a simple document that explains how to find results using congruency of triangles.**

Download all latex-tikz codes from

https://github.com/saranshbali/EE5609/tree/master/Assignment3

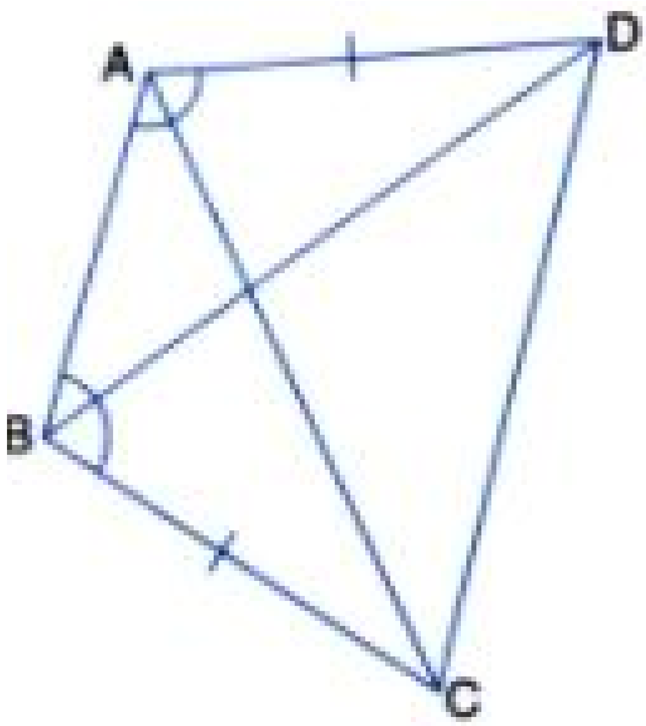

Fig. 1

1 Problem

ABCD is a quadrilateral in which AD = BC and $\angle DAB = \angle CBA$. Prove that

$$a)\quad \triangle ABD \cong \triangle BAC \tag{1.0.1}$$
$$b)\quad BD = AC \tag{1.0.2}$$
$$c)\quad \angle ABD = \angle BAC \tag{1.0.3}$$

2 Some Results used

$$\|\mathbf{A}-\mathbf{B}\| = \|\mathbf{B}-\mathbf{A}\| \tag{2.0.1}$$
$$(\mathbf{B}-\mathbf{A})^T(\mathbf{B}-\mathbf{C}) = \|\mathbf{A}-\mathbf{B}\|^2 - (\mathbf{A}-\mathbf{C})^T(\mathbf{A}-\mathbf{B}) \tag{2.0.2}$$

3 Solution

ABCD is a quadrilateral, where AD=BC and $\angle DAB = \angle CBA$.

To show $\triangle ABD \cong \triangle BAC$, we need to prove

$$\angle DAB = \angle CBA \tag{3.0.1}$$
$$\angle ABD = \angle BAC \tag{3.0.2}$$
$$\angle ADB = \angle BCA \tag{3.0.3}$$

Since, it is given that:

$$\angle DAB = \angle CBA \tag{3.0.4}$$
$$\implies \cos\angle DAB = \cos\angle CBA \tag{3.0.5}$$
$$\frac{(\mathbf{A}-\mathbf{B})^T(\mathbf{A}-\mathbf{D})}{\|\mathbf{A}-\mathbf{B}\|\,\|\mathbf{A}-\mathbf{D}\|} = \frac{(\mathbf{B}-\mathbf{A})^T(\mathbf{B}-\mathbf{C})}{\|\mathbf{B}-\mathbf{A}\|\,\|\mathbf{B}-\mathbf{C}\|} \tag{3.0.6}$$

Since,

$$\|\mathbf{A}-\mathbf{D}\| = \|\mathbf{B}-\mathbf{C}\| \tag{3.0.7}$$
$$\frac{(\mathbf{A}-\mathbf{B})^T(\mathbf{A}-\mathbf{D})}{\|\mathbf{A}-\mathbf{B}\|} = \frac{(\mathbf{B}-\mathbf{A})^T(\mathbf{B}-\mathbf{C})}{\|\mathbf{B}-\mathbf{A}\|} \tag{3.0.8}$$
$$(\mathbf{A}-\mathbf{B})^T(\mathbf{A}-\mathbf{D}) = (\mathbf{B}-\mathbf{A})^T(\mathbf{B}-\mathbf{C}) \tag{3.0.9}$$
$$\|\mathbf{A}-\mathbf{B}\|^2 - (\mathbf{B}-\mathbf{A})^T(\mathbf{B}-\mathbf{D}) = \|\mathbf{A}-\mathbf{B}\|^2 - (\mathbf{A}-\mathbf{B})^T(\mathbf{A}-\mathbf{C}) \tag{3.0.10}$$
$$(\mathbf{B}-\mathbf{A})^T(\mathbf{B}-\mathbf{D}) = (\mathbf{A}-\mathbf{B})^T(\mathbf{A}-\mathbf{C}) \tag{3.0.11}$$
$$\|\mathbf{B}-\mathbf{A}\|\,\|\mathbf{B}-\mathbf{D}\|\cos\angle ABD = \|\mathbf{A}-\mathbf{B}\|\,\|\mathbf{A}-\mathbf{C}\|\cos\angle BAC \tag{3.0.12}$$
$$\|\mathbf{B}-\mathbf{D}\|\cos\angle ABD = \|\mathbf{A}-\mathbf{C}\|\cos\angle BAC \tag{3.0.13}$$

Now, we pove $\|\mathbf{B}-\mathbf{D}\| = \|\mathbf{A}-\mathbf{C}\|$. By 3.0.11

$$(\mathbf{B}-\mathbf{A})^T(\mathbf{B}-\mathbf{D}) = (\mathbf{A}-\mathbf{B})^T(\mathbf{A}-\mathbf{C}) \tag{3.0.14}$$

$$\|\mathbf{B}-\mathbf{D}\|^2 - (\mathbf{D}-\mathbf{B})^T(\mathbf{D}-\mathbf{A}) = \tag{3.0.15}$$

$$\|\mathbf{A}-\mathbf{C}\|^2 - (\mathbf{C}-\mathbf{B})^T(\mathbf{C}-\mathbf{A}) \tag{3.0.16}$$

$$\|\mathbf{B}-\mathbf{D}\|^2 - (\|\mathbf{A}-\mathbf{D}\|^2 - (\mathbf{A}-\mathbf{B})^T(\mathbf{A}-\mathbf{D})) = \tag{3.0.17}$$

$$\|\mathbf{A}-\mathbf{C}\|^2 - (\|\mathbf{B}-\mathbf{C}\|^2 - (\mathbf{B}-\mathbf{A})^T(\mathbf{B}-\mathbf{C})) \tag{3.0.18}$$

We know that

$$\|\mathbf{A}-\mathbf{D}\| = \|\mathbf{B}-\mathbf{C}\| \tag{3.0.19}$$

From 3.0.19, we found out that

$$\|\mathbf{B}-\mathbf{D}\|^2 + (\mathbf{A}-\mathbf{B})^T(\mathbf{A}-\mathbf{D}) = \|\mathbf{A}-\mathbf{C}\|^2 + (\mathbf{B}-\mathbf{A})^T(\mathbf{B}-\mathbf{C}) \tag{3.0.20}$$

$$\|\mathbf{B}-\mathbf{D}\|^2 + \|\mathbf{A}-\mathbf{B}\|\,\|\mathbf{A}-\mathbf{D}\|\cos\angle DAB = \tag{3.0.21}$$

$$\|\mathbf{A}-\mathbf{C}\|^2 + \|\mathbf{B}-\mathbf{A}\|\,\|\mathbf{B}-\mathbf{C}\|\cos\angle CBA \tag{3.0.22}$$

Since, we are already given that $\angle DAB = \angle CBA$ and $\|\mathbf{A}-\mathbf{D}\| = \|\mathbf{B}-\mathbf{C}\|$. Then by 3.0.22

$$\|\mathbf{B}-\mathbf{D}\|^2 = \|\mathbf{A}-\mathbf{C}\|^2 \tag{3.0.23}$$

$$\|\mathbf{B}-\mathbf{D}\| = \|\mathbf{A}-\mathbf{C}\| \tag{3.0.24}$$

$$Hence,\ \ BD = AC\ \ proving\ \ (b). \tag{3.0.25}$$

Now, by 3.0.25 and 3.0.13

$$\cos\angle ABD = \cos\angle BAC \tag{3.0.26}$$

$$\angle ABD = \angle BAC\ \ proving\ \ (c) \tag{3.0.27}$$

Since, By Angle Sum Property of a $\triangle$, Sum of all angles of a $\triangle = 180^{\cdot}$. Thus, third angle of both the triangles $\triangle ABD$ and $\triangle BAC$ are equal.

$$\angle ADB = \angle ACB \tag{3.0.28}$$

Thus, by 3.0.27, 3.0.28 and 3.0.1 and AAA congruency criteria $\triangle ABD \cong \triangle BAC$.