Test for Concyclic points: Converse, angles in the same segment

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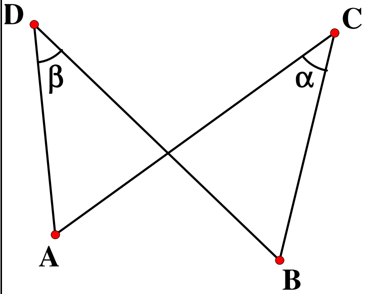
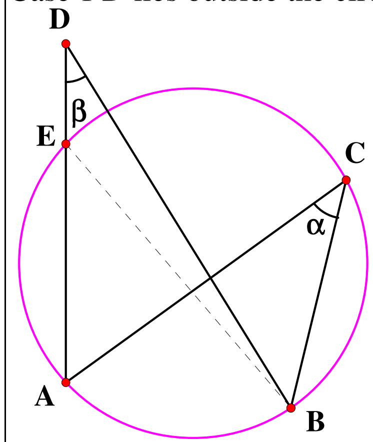


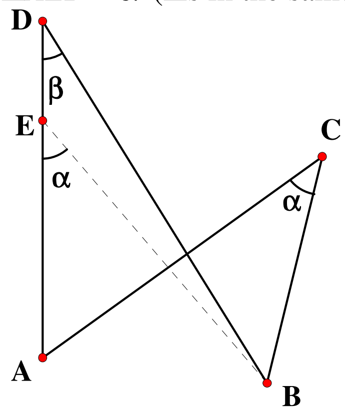
In the figure,
if α = β, then
A, *B*, *C*, *D* are concyclic.
Abbreviation:
Converse,
∠s in the same segment

Proof: Assume that any 3 points are not collinear. Draw a circle which passes through *A*, *B* and *C*. There are 3 different cases:

Case 1 *D* lies outside the circle



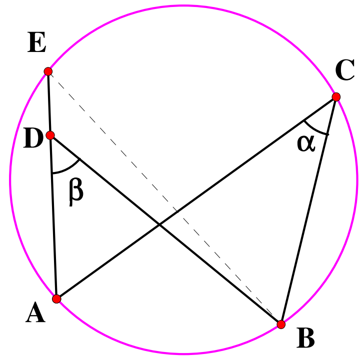
AD cuts the circle at *E* .
Join *BE* .
∠*AEB* = α (∠s in the same segment *ACB*)



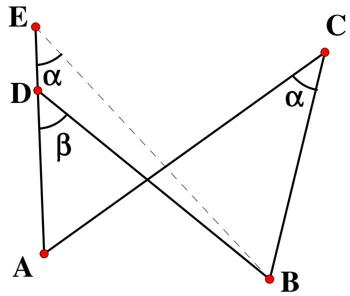
∵ α = β (given)

∴ *BE* // *BD* (corr. ∠s eq.)
This is impossible because there are two different parallel lines which meet at *B*.
∴ Case 1 is impossible.

Case 2 *D* lies inside the circle



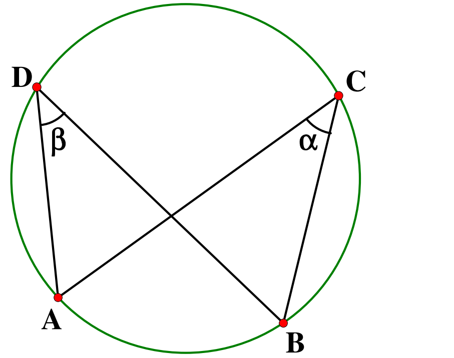
Produce *AD* which cuts the circle at *E* .
Join *BE* .
∠*AEB* = α (∠s in the same segment *ACB*)



∵ α = β (given)

∴ *BE* // *BD* (corr. ∠s eq.)
This is impossible because there are two different parallel lines which meet at *B*.
∴ Case 2 is impossible.

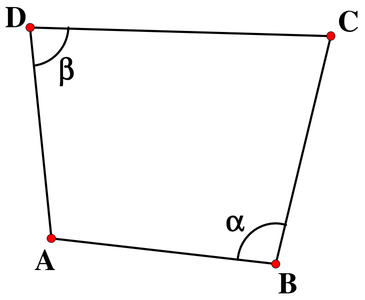
Case 3 *D* lies on the circle *ABC*.



∵ Case 1 and case 2 are impossible

∴The only possible case is case 3.
i.e. *D* must lie on the circle
This is known as indirect proof.
(反證法)
∴ *A*, *B*, *C*, *D* are concyclic.

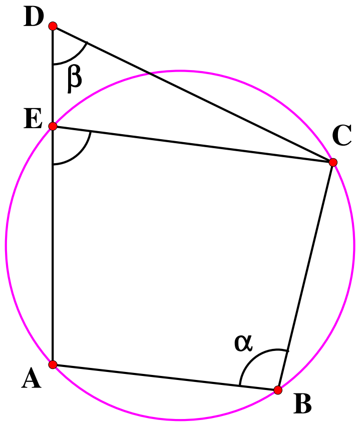
Test for Concyclic points: Opposite angles supplementary

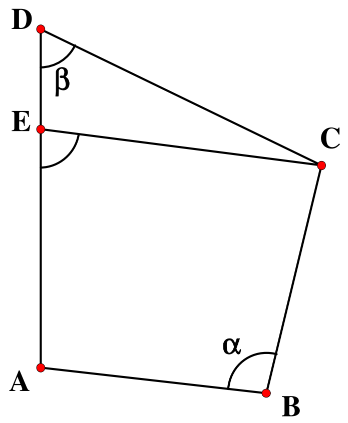


In the figure,
if $\alpha + \beta = 180°$, then
A, B, C, D are concyclic.
Abbreviation: **opp. ∠s supp.**

Proof: Assume that any 3 points are not collinear. Draw a circle which passes through A, B and C. There are 3 different cases:

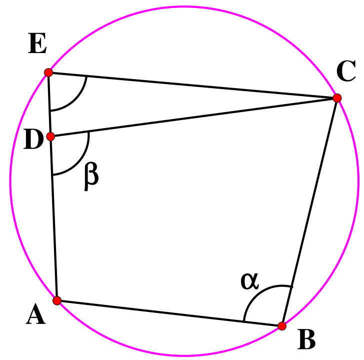
Case 1 D lies outside the circle

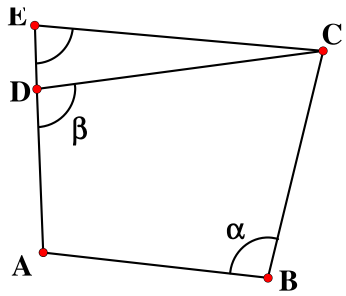




∴ Case 1 is impossible.

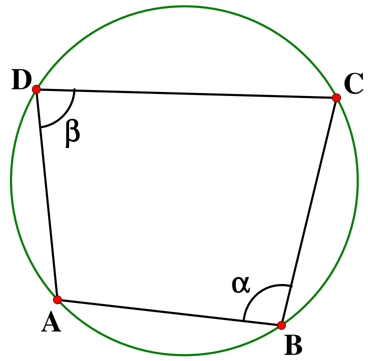
Case 2 D lies inside the circle





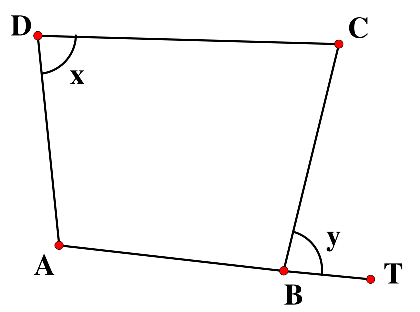
∴ Case 2 is impossible.

Case 3 D lies on the circle ABC.



∴ A, B, C, D are concyclic.

Test for Concyclic points: Exterior angle = interior opposite angle



In the figure, if $x = y$, then A, B, C, D are concyclic

Proof: $\angle ABC = 180° - y$ (adj. $\angle$s on st. line)

$\angle ABC + \angle ADC = x + 180° - y$

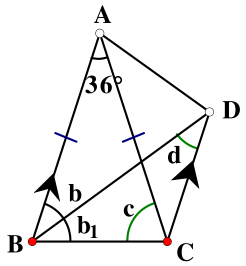
$= 180°$

$\therefore$ A, B, C, D are concyclic (opp. $\angle$s supp.)

The theorem is proved.

Abbreviation: **ext. $\angle$ = int. opp. $\angle$**

Example 1



In the figure, Given ΔABC, $AB = AC$, $\angle BAC = 36°$, the line bisecting $\angle ABC$ meets the line through C parallel to BA at D. To prove: A, B, C, D are concyclic.

Proof: $\angle ABC = \angle ACB$ (base $\angle$s isos. Δ)

$= \dfrac{180^\circ - 36^\circ}{2} = 72°$ ($\angle$ sum of Δ)

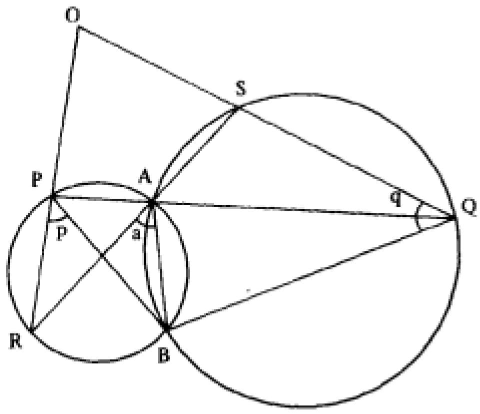
$b = b_1 = \dfrac{72^\circ}{2} = 36°$ ($\angle$ bisector)

$d = b = 36°$ (alt. $\angle$s, AB // DC)

$\therefore \angle A = \angle D$

$\therefore$ A, B, C, D are concyclic (converse, $\angle$s in the same segment)

Example 2



In the figure, 2 circles $APRB$, $ASQB$ intersect at A and B. PAQ, RAS are straight lines, RP and QS are produced to meet at O. To prove: O, P, B, Q are concyclic.

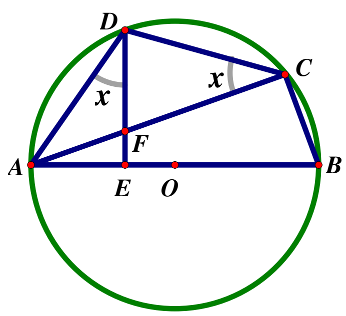
Proof: $p = a$ ($\angle$s in the same segment)

$a = q$ ($\angle$ sum of Δ)

$\therefore p = q$

$\therefore$ O, P, B, Q are concyclic. (ext. $\angle$ = int. opp. $\angle$)

Example 3



In the figure, O is the centre of the circle. AOB is a diameter. AC intersects DE at F. If $\angle ADE = \angle DCA = x$, prove that $FEBC$ is a cyclic quadrilateral.

$\angle ACB = 90°$ ($\angle$ in semi-circle)

$\angle DAE = 180° - \angle BCD$ (opp. $\angle$ cyclic quad.)

$= 180° - (90° + x) = 90° - x$

$\angle AED = 180° - (90° - x) - x = 90°$ ($\angle$ sum of Δ)

$\therefore \angle ACB = 90° = \angle AED$

B, C, F, E are concyclic (ext. $\angle$ = int. opp. $\angle$)

Orthocentre

Example 4

The **three altitudes** of a **triangle** are **concurrent** at a point called the "**orthocentre**". (Figure 1)

In ΔABC, $AD \perp BC$, $BE \perp AC$, $CF \perp AB$.

Then AD, BE, CF are **concurrent** at H.

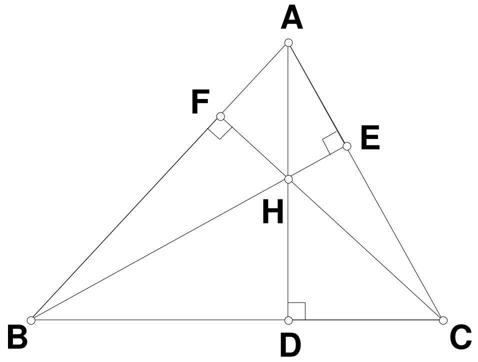


Figure 1

Proof: Let the **altitudes** BE and CF meet at H.

Join AH and produce it to meet BC at D.

Try **to show** that $AD \perp BC$. (Figure 2)

$\angle AFH + \angle AEH = 180°$

A, F, H, E are concyclic. (opp. $\angle$ supp.)

$\angle BFC = \angle BEC$

B, C, E, F are concyclic. (converse, $\angle$s in the same seg.)

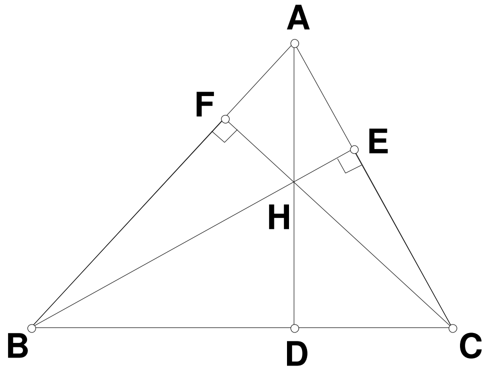


Figure 2

In **Figure 3**, let $\angle BAD = x$, $\angle AHF = y$.

$\angle FEH = x$ ($\angle$s in the same seg.)

$\angle BCF = \angle BEF$ ($\angle$s in the same seg.)

$= x$

$\angle CHD = y$ (vert. opp. $\angle$s.)

In ΔAFH, $x + y = 90°$ ($\angle$ sum of Δ)

In ΔCDH, $x + y + \angle CDH = 180°$ ($\angle$ sum of Δ)

$\therefore$ $\angle CDH = 90°$

The **theorem is proved.**

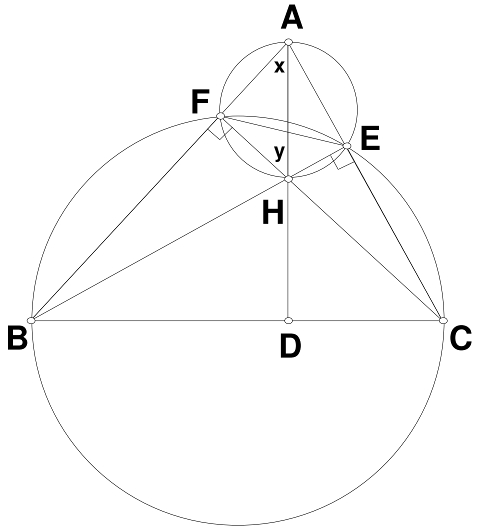


Figure 3