High School Olympiads

Circumradius of 14-gon

Reply

Source: 0

Luis González

#1 Mar 3, 2009, 9:30 am

Let a be the side length of a regular 14-gon. Show synthetically that the radius R of its circumcircle is a real positive solution of the equation

$$(a+R)^3 = 4a^2R + 5aR^2$$

Luis González

#2 Mar 4, 2009, 1:30 am

Let O be the center of the 14-gon and B, C two consecutive vertices. Thus $\angle BOC = \frac{180^\circ}{7}$. There exists two points P, Q on OC, OB such that $BP = PQ = QO = a$. Draw parallels $QT = x$ and $PS = y$ to BC. Then $\triangle CBP$ and $\triangle QOT$ are congruent $\Longrightarrow PC = QT = x$. But $\triangle BCP$ and $\triangle OBC$ are similar

$$\Longrightarrow \frac{PC}{BC} = \frac{BC}{R} \Longrightarrow x = \frac{a^2}{R} \ (1)$$

$QTPS$ is a trapezoid with $PS = QS = y$ and since $\triangle OSP \sim \triangle OBC$, we get

$$\frac{SP}{BC} = \frac{OS}{OB} \Longrightarrow \frac{y}{a} = \frac{y+a}{R} \Longrightarrow y = \frac{a^2}{R-a} \ (2)$$

$$QS = TP = y \Longrightarrow TP + PC = OC - OT \Longrightarrow y + x = R - a \ (3)$$

Combining (1), (2) and (3) yields

$$\frac{a^2}{R-a} + \frac{a^2}{R} = R - a \Longrightarrow R^3 + a^3 = a^2R + 2aR^2$$

$$\Longrightarrow (a+R)^3 = 4a^2R + 5aR^2.$$

Quick Reply

High School Olympiads

Circles and tangent on equilateral triangle

Reply

Source: 0

Luis González

#1 Mar 2, 2009, 5:58 am

$\triangle ABC$ is equilateral with side-length a. Let (O,r) and (O,R) be the incircle and cirumcircle of $\triangle ABC$. P is a point on (O,r) and X,Y,Z are the projections of P onto BC,CA,AB. Circles $\mathcal{T}_1,\mathcal{T}_2$ and $\mathcal{T}_3$ are tangent to BC,CA,AB through X,Y,Z and tangent to (O,R) internally (their centers lie on different sides of BC,CA,AB WRT A,B,C). Prove that the sum of the lengths of the common external tangents of $\mathcal{T}_1,\mathcal{T}_2$ and $\mathcal{T}_3$ is a constant value equal to $\frac{35}{16}a$.

yetti

#2 Mar 3, 2009, 1:54 am

R is circumradius, $r=R/2$ inradius. X,Y,Z are feet of perpendiculars from $P\in(I)$ to BC,CA,AB. Area of the pedal triangle $\triangle XYZ$ is

$[\triangle XYX]=\dfrac{p(P,(O))}{4R^2}[\triangle ABC]=\dfrac{R^2-r^2}{4R^2}[\triangle ABC]=\frac{3}{16}[\triangle ABC]$. Then

$AY\cdot AZ+BZ\cdot BX+CX\cdot CY=\dfrac{2}{\sin 60^\circ}([\triangle ABC]-[\triangle XYZ])=\frac{13}{16}a^2.$

Let t_{23},t_{31},t_{12} be the external tangent lengths of the pairs $\mathcal{T}_2,\mathcal{T}_3$; $\mathcal{T}_3,\mathcal{T}_1$; $\mathcal{T}_1,\mathcal{T}_2$. Inversion with center A and power a^2 takes BC to (O) and the other way around, therefore it takes $\mathcal{T}_1$ to itself $\Longrightarrow$ $\mathcal{T}_1$ is perpendicular to the inversion circle $\Longrightarrow$ tangent length from A to $\mathcal{T}_1$ is a. By Casey theorem for points B,C and circles $\mathcal{T}_2,\mathcal{T}_3$, all tangent to (O),

$$a^2=BC\cdot t_{23}+CY\cdot BZ=a\cdot t_{23}+(a-AY)(a-AZ).$$

Summing this and two other equation obtained by cyclic exchange,

$$3a^2=a(t_{23}+t_{31}+t_{12})$$
$$+\,3a^2-a(AY+AZ+BZ+BX+CX+CY)+AY\cdot AZ+BZ\cdot BX+CX\cdot CY,$$

$$t_{23}+t_{31}+t_{12}=3a-\tfrac{13}{16}a=\tfrac{35}{16}a$$

Luis González

#3 Mar 3, 2009, 6:35 am

Thanks for your nice solution. Mine is almost the same

Denote δ_1 the tangent segment form A to ω_1. By Casey's theorem for (A,B,C,ω_1) we have $L\cdot BA'+L\cdot CA'=\delta_1\cdot L$ $\Longrightarrow\delta_1=L$. Similarly, we have $\delta_2=\delta_3=L$. By Euler's theorem for the pedal triangle $\triangle XYZ$ of P we get:

$[XYZ]=\dfrac{p(P,(O))}{4R^2}[ABC]=\dfrac{R^2-r^2}{4R^2}[ABC]=\frac{3}{16}[ABC]$. Therefore

$$AY\cdot AZ+BZ\cdot BX+CX\cdot CY=\frac{2}{\sin 60^\circ}([ABC]-[XYZ])=\tfrac{13}{16}L^2.\ (*)$$

By Casey's theorem for (B,C,ω_2,ω_3), we get

$$\delta_2\cdot\delta_3=L^2=BC\cdot\delta_{23}+CY\cdot BZ=L\cdot\delta_{23}+(L-AX)(L-AZ).$$

By cyclic exchange we have the expressions

$$L^2=L\cdot\delta_{31}+(L-BZ)(L-BX)\ ,\ L^2=L\cdot\delta_{12}+(L-CX)(L-CY)$$

Adding the three latter equations yields

$$3L^2=L(\delta_{23}+\delta_{31}+\delta_{12})+\ 3L^2-3L^2+AZ\cdot AY+BZ\cdot BX+CX\cdot CY$$

Combining with $(*)$ we obtain $\delta_{23}+\delta_{31}+\delta_{12}=3L-\frac{13}{16}L=\frac{35}{16}L.$

Quick Reply

High School Olympiads

Conics related to bicentric polygons

Reply

Source: 0

Luis González

#1 Feb 27, 2009, 11:58 am

1) Let $P_1P_2P_3....P_n$ be a bicentric polygon with incircle (I) and circumcircle (O). (I) touches the sides of the polygon through $A_1, A_2, A_3, ..., A_n$. Prove that lines $A_1A_2, A_2A_3, A_3A_4, ..., A_nA_1$ bound a polygon circumscribed in a conic.

2) Assume that $ABCD$ is a bicentric quadrilateral with incircle (I) and circumcircle (O). O_1, O_2, O_3 and O_4 denote the circumcenters of $\triangle OAB, \triangle OBC, \triangle OCD$ and $\triangle ODA$. Show that the parabola that passes trough O_1, O_2, O_3 and O_4 has focus O, if and only if the ratio between the areas of (I) and (O) is $2\varphi - 1$, where φ is the golden number.

Luis González

#2 Mar 2, 2009, 9:06 am

1) Lines A_1A_2, A_2A_3, A_3A_4, etc. are polars of P_1, P_2, P_3 etc WRT $(I) \Longrightarrow$ Sidelines of the polygon $A_1A_2A_3A_4...A_n$ are tangent to the polar conic $\mathcal{K}$ of (O) with respect to (I). The foci of $\mathcal{K}$ are the centers of the inverse (O') of (O) under the inversion WRT (I) and the center of the homothetic circle (O'') of (O') under the homothety with center I and coefficient $2 \Longrightarrow$ IO is the focal axis of $\mathcal{K}$.

Luis González

#3 Mar 2, 2009, 9:27 am

2) $\frac{r^2}{R^2} = 2\varphi - 1 \Longleftrightarrow (I)$ passes through O, due to Fuss theorem.

Inversion WRT (O) takes lines AB, BC, CD, AD into circles $\odot OAB, \odot OBC, \odot OCD, \odot ODA$ and (I) tangent to AB, BC, CD, AD into a tangent line τ to the circles $\odot OAB, \odot OBC, \odot OCD, \odot ODA \Longrightarrow$ Parabola $\mathcal{K}$ passing through O_1, O_2, O_3 and O_4 has focus O and directrix τ.

Quick Reply

High School Olympiads

Area of the triangle in terms of its medians

Reply

Source: 0

Luis González

#1 Feb 28, 2009, 8:11 am

Prove the following formula of the area of $\triangle ABC$ in terms of its medians

$$[\triangle ABC]^2=\tfrac{2}{9}({m_a}^2{m_b}^2+{m_a}^2{m_c}^2+{m_b}^2{m_c}^2)-\tfrac{1}{9}({m_a}^4+{m_b}^4+{m_c}^4)$$

arcsin1.01

#2 Feb 28, 2009, 4:57 pm

Use the identities $m_a=\dfrac{1}{4}(b^2+c^2-a^2)$, $m_b=\dfrac{1}{4}(a^2-b^2+c^2)$, $m_c=\dfrac{1}{4}(a^2+b^2-c^2)$ (which can be proved using Stewart's Theorem) and Heron's Formula.

Luis González

#3 Feb 28, 2009, 9:17 pm

We'll show that the area of the triangle formed by the lengths of the 3 medians of ABC equals 3/4 of the area [ABC], then the result follows by Heron formula. Let D,E,F be the midpoints of BC,CA,AB and G the centroid. Let G' the reflection of G' across D. It's easy to see that $GCG'B$ is a parallelogram such that $BG=\tfrac{2}{3}m_b, BG'=\tfrac{2}{3}m_c$ and $GG'=\tfrac{2}{3}m_a$. Since $CG'\parallel BG$, then we have $[\triangle BGG']=[\triangle BGC]=\tfrac{1}{3}[\triangle ABC]$.

SaYaT

#4 Mar 1, 2009, 8:29 pm

> *arcsin1.01 wrote:*
>
> Use the identities $m_a=\dfrac{1}{4}(b^2+c^2-a^2)$, $m_b=\dfrac{1}{4}(a^2-b^2+c^2)$, $m_c=\dfrac{1}{4}(a^2+b^2-c^2)$ (which can be proved using Stewart's Theorem) and Heron's Formula.

Your identity isn't right, try $a=b=c=2$

arcsin1.01

#5 Mar 1, 2009, 8:38 pm

Sorry, it should be $m_a^2=\dfrac{1}{4}(2b^2+2c^2-a^2)$, etc.

MeKnowsNothing

#6 Mar 2, 2009, 12:05 am

http://jwilson.coe.uga.edu/EMT725/Medians.Triangle/Area.Medians.Tri.html &
http://jwilson.coe.uga.edu/EMT725/Medians.Triangle/Details.html

Luis González

#7 Mar 2, 2009, 12:16 am

Another solution: Let M, N be the midpoints of $AC, AB.$ By Betschneider theorem for the trapezoid $BCMN,$ we get:

$$16 \cdot [BCMN]^2 = 4 \cdot BM^2 \cdot CN^2 - (BC^2 - CM^2 + MN^2 - BN^2)^2$$

Quick Reply

High School Olympiads

Acute triangle

Reply

Source: ABC

Ulanbek_Kyzylorda KTL
#1 Feb 28, 2009, 3:57 pm

In an acute triangle ABC, let H be intersection of its heights and D be midpoint of AC. Show that the line Dh passes through an intersection point of the circumcircle of ABC with the circle for which BH is a diameter

shobber
#2 Feb 28, 2009, 4:41 pm

> *Ulanbek_Kyzylorda KTL wrote:*
> In an acute triangle ABC, let H be intersection of its heights and D be midpoint of AC. Show that the line Dh passes through an intersection point of the circumcircle of ABC with the circle for which BH is a diameter

Reflect H with respect to AC. Suppose $H \to H'$, so $\angle AH'C = \angle AHC = 180^o - \angle ABC$. So H' is on the circumcircle of $\triangle ABC$.

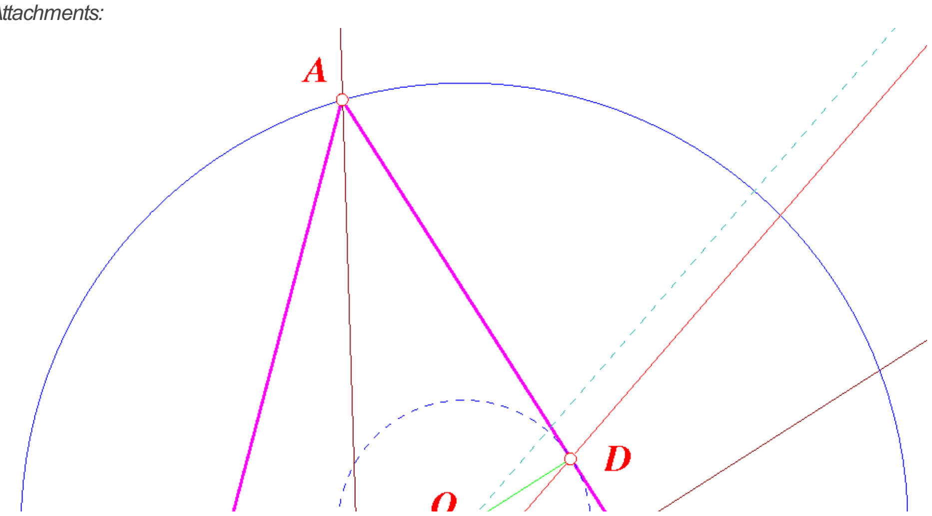
Let BO (O is the circumcenter of triangle ABC) meets the circumcircle at E, so $\angle AH'E = 90^o$. Hence $H'E \parallel AC$. Since H' and H are symmetric WRT AC, so we get that AC passes through the midpoint of HE. Since $AH \perp BC$ and $EC \perp BC$, so $AH \parallel EC$. Hence EH also passes through the midpoint of AC, which is D. So let the other intersection of DH with the circumcircle of $\triangle ABC$ be F, we get that $\angle BFH = 90^o$. Hence F is also on the circle with AH being the diameter.

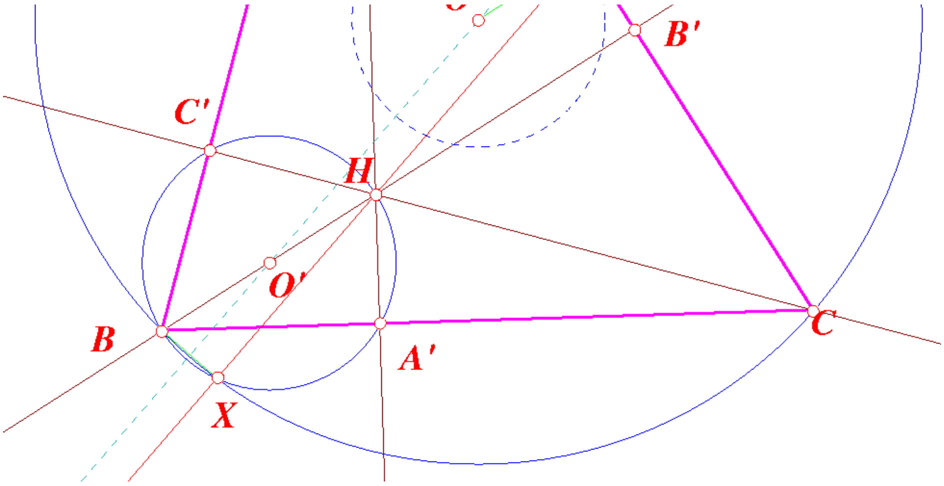
Moonmathpi496
#3 Feb 28, 2009, 8:56 pm

> *Ulanbek_Kyzylorda KTL wrote:*
> In an acute triangle ABC, let H be intersection of its heights and D be midpoint of AC. Show that the line Dh passes through an intersection point of the circumcircle of ABC with the circle for which BH is a diameter

We have $OD = O'H$ and also $OD \parallel OH$. So, $OO'HD$ is a parallelogram and $OO' \parallel DH$. Let $X = (O) \cap (O')$ and BX is the radical axis of (O). So, (O'). Also, $OO' \perp BX \implies DH \perp BX$. Let $BX \cap DH = X'$, $HX \perp BX$ (As $BXA'H$ concyclic) and $HX' \perp BX \implies X \equiv X'$ and we are done.

Attachments:





Luis González

#4 Feb 28, 2009, 9:34 pm

Let X, Y, Z be the feet of the altitudes issuing from $A, B, C.$ Inversion with pole H and power $\overline{AH} \cdot \overline{HX}$ takes 9-point circle passing through Y, D into the circumcircle (O) of $\overline{ABC}$ and sideline BC into the circle with diameter $\overline{BH} \Longrightarrow$ Second intersection P of (O) with the circle with diameter $\overline{BH}$ is the inverse of D under the referred inversion $\Longrightarrow$ Points D, H and P are collinear.

Moonmathpi496

#5 Feb 28, 2009, 11:15 pm

Actually the main idea behind my solution is also a transformation, that is, to translate the dotted circle to (O') :)

BTW I don't think that solutions that use inversion are quite elementary. ;)

Quick Reply

High School Olympiads

Very interesting property about concyclic:D

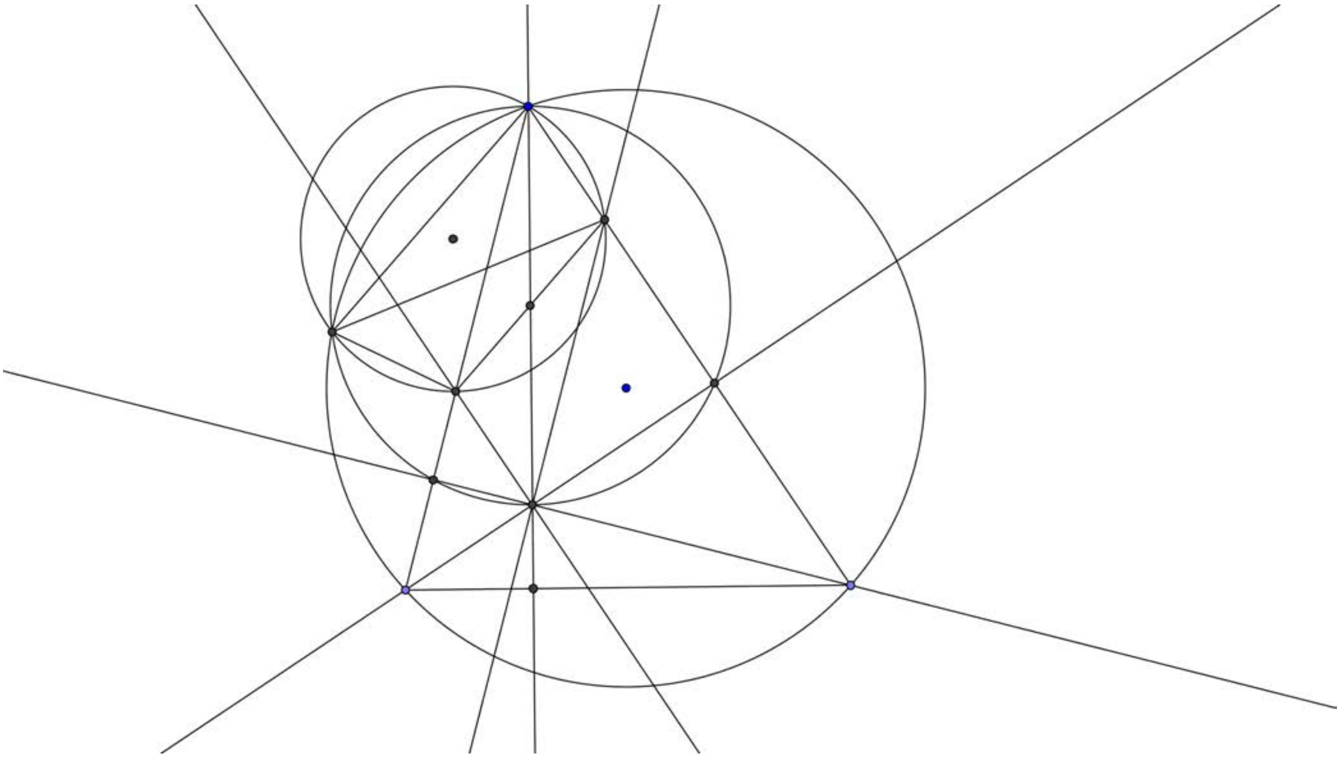
Reply

mathVNpro

#1 Feb 27, 2009, 9:16 pm

Let triangle ABC be the acute triangle inscribed in circumcircle (O). Let H be the orthocenter of triangle ABC. Through H, we draw line d, d' respectively parrallel to AB, AC, meets AB, AC at M, N. The circle that takes AH be its diameter intersects (O) at Q. Prove that A, M, N, Q are concyclic.

Attachments:



mathVNpro

#2 Feb 28, 2009, 5:19 am

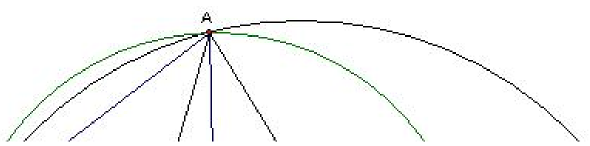
nobody can???What a pity

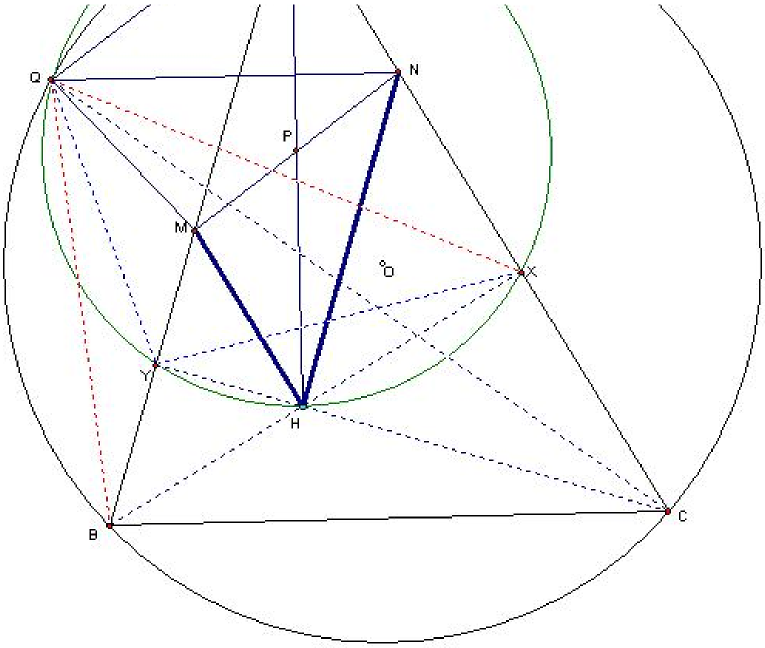
plane geometry

#3 Feb 28, 2009, 6:28 am • 2

That's too easy
MY/AY=YH/YC NX/AX=HX/BX
MY/NX=YH/YC*AY/AX*BX/HX notice BX/YC=AX/AY
MY/NX=YH/XH=AHsin□BAH/AHsin□CAH= sin□BAH/sin□CAH= BCsin□BAH/BCsin□CAH =BY/CX
□QBY□□QCX => BY/CX=QY/QX => MY/NX=QY/QX □QYA=□QXA => □QYM□□QXN
=> □YQX□□MQN => □MQN=□YQX=□YAX => M,Q,A,N are concyclic

Attachments:





yetti

#4 Feb 28, 2009, 7:04 am • 1

E, F are feet of the B-, C-altitudes. $(K), (P)$ are circles with diameters BC, AH, intersecting at E, F.
$\angle ENH = \angle FMH = \angle A \Longrightarrow \frac{\overline{MF}}{\overline{NE}} = \frac{\overline{FH}}{\overline{EH}} = \frac{\overline{FB}}{\overline{EC}}$. Ratio of powers of M to $(O), (P)$ is equal to ratio of powers of N to $(O), (P)$:

$$\frac{p(M,(O))}{p(M,(P))} = \frac{\overline{MA} \cdot \overline{MB}}{\overline{MA} \cdot \overline{MF}} = \frac{\overline{MB}}{\overline{MF}} = 1 + \frac{\overline{FB}}{\overline{MF}} = 1 + \frac{\overline{EC}}{\overline{NE}} = \frac{\overline{NC}}{\overline{NE}} = \frac{\overline{NA} \cdot \overline{NC}}{\overline{NA} \cdot \overline{NE}} = \frac{p(N,(O))}{p(N,(P))}.$$

Therefore, M, N are on the same circle coaxal with $(O), (P)$, i.e., passing through A, Q. :) :mad: :o :oops: :P :wink: :roll: :?: :!: :arrow: :idea: :rotfl: :| :ninja: :huh:

Luis González

#5 Feb 28, 2009, 7:49 am • 1

Let D, E, F the feet of the altitudes issuing from A, B, C. Negative inversion through pole H taking 9-point circle $\odot(DEF)$ into circumcircle (O) takes $\odot(AEHF)$ into line $BC \Longrightarrow$ Inverse of Q is the second intersection of BC with $\odot(DEF)$, i.e. the midpoint K of BC. The inverse of M and N are the reflections S and R of C and B about HM and HN. Thus, we need to show that K, D, R, S are concyclic. Indeed,

$$\angle RDS = \angle RHS + \angle HBD + \angle HCD = 2\angle BAC$$

If lines BR and CS meet at point P, then $HCPB$ is a parallelogram and $HSPR$ is cyclic with circumcenter $K \Longrightarrow$

$\angle RKS = 2\angle RHS = 2\angle BAC \Longrightarrow \angle RKS = \angle RDS \Longrightarrow DKSR$ is cyclic $\Longrightarrow APMN$ is also cyclic. $\square$

Moonmathpi496

#6 Feb 28, 2009, 10:52 am

> *yetti wrote:*
> Ratio of powers of M to $(O), (P)$ is equal to ratio of powers of N to $(O), (P)$:
> ....Therefore, M, N are on the same circle coaxal with $(O), (P)$, i.e., passing through A, Q.

I don't know why this is true. (I mean I haven't ever seen this theorem) Could you give me a reference where I can get a proof of this fact?

> *yetti wrote:*
> :o :oops: :P :wink: :roll: :?: :!: :arrow: :idea: :rotfl: :| :ninja: :huh:

But I don't understand why all these emoticons are for.... If it is a reply for two emoticons of mathVNpro, then I'd like to remind you that there about 100 more emot's in the "more emoticons" :spider:

yetti

#7 Feb 28, 2009, 11:37 am

(a) Read a more general proof then the posted problem at http://www.mathlinks.ro/viewtopic.php?t=121062.

(b) These are mixed emotions. I know how to get the spider.

Moonmathpi496

#8 Feb 28, 2009, 3:55 pm

Cool! (Both, your proof and the last emoticon)

Quick Reply

High School Olympiads

a line passing through the incenter

Reply

Source: bmo 1986

pohoatza

#1 Apr 24, 2007, 12:39 am • 1

A line passing through the incenter I of the triangle ABC intersect its incircle at D and E and its circumcircle at F and G, in such a way that the point D lies between I and F. Prove that:
$DF \cdot EG \geq r^2$.

This post has been edited 1 time. Last edited by pohoatza, Apr 24, 2007, 1:13 am

e.lopes

#2 Apr 24, 2007, 12:54 am • 1

$DF.EG = (IF - r)(IG - r) = IF.IG - r(IF + IG) + r^2 = (R^2 - OI^2) - r.FG + r^2 = 2Rr - r.FG + r^2 = r(2R - FG) + r^2$

but FG is one chord of the circuncircle, so, $2R \geq FG$, and the problem is solved!

crazyfehmy

#3 Feb 27, 2009, 11:34 pm

CI meets the circumcircle of triangle ABC at C'.

$|CI| = \dfrac{r}{sin\frac{C}{2}}$ and $|C'I| = 2Rsin\dfrac{C}{2}$.

$|GI|.|FI| = |CI|.|C'I| = 2Rr \implies$

$|DF|.|EG| + r^2 + r(|GF| - 2r) = 2Rr \implies$

$|DF|.|EG| = 2Rr - r^2 + 2r^2 - r.|GF| \geq 2Rr + r^2 - r.2R = r^2$ and solution is done.

$Remark$: Equality holds if and only if GF is passing through O.

Luis González

#4 Feb 28, 2009, 12:16 am

$IF \cdot IG = (r + FD)(r + EG) = r^2 + r(FG - 2r) + DF \cdot EG$

Substituting $IF \cdot IG = 2Rr$ (power of I with respect to the circumcircle) gives:

$DF \cdot EG = 2Rr + r^2 - r \cdot FG.$

$DF \cdot EG$ attains its minimum when FG is maximum $\Longleftrightarrow FG = 2R.$

$\Longrightarrow \quad DF \cdot EG \geq r^2.$

Quick Reply

High School Olympiads

Tangent circles

Reply

Source: 0

Luis González

#1 Feb 15, 2009, 8:23 pm

P and $\mathcal{C}$ are a fixed point and a fixed circle in the plane. A pencil of chords AA', BB', CC', DD', etc, pass through P. Circles C_1 and C_1' passing through P are tangent to $\mathcal{C}$ at A and A', respectively. These circles intersect at P and Q_1. Analogously, we defined the points Q_2, Q_3, Q_4, Q_i. Prove that all points Q_i lie on a same circle and find its diameter and center.

yetti

#2 Feb 27, 2009, 8:42 am

O, O_1, O_1' are centers of the circles $\mathcal{C}, \mathcal{C}_1, \mathcal{C}_1'$. Isosceles $\triangle AO_1P \sim \triangle AOA'$ and $\triangle A'O_1'P \sim \triangle A'OA$ are centrally similar with similarity centers A, A', respectively $\Longrightarrow PO_1OO_1'$ is a parallelogram, its diagonals cutting each other in half at M. $\mathcal{M}$ is a circle with diameter OP. $\mathcal{C}_1, \mathcal{C}_1', \mathcal{M}$ have collinear centers O_1, M, O_1' and all go through P, therefore they are coaxal and all go through the reflection Q_1 of P in the center line O_1O_1'.

Luis González

#3 Feb 27, 2009, 10:16 am

Inversion with pole P and power equal to the power of P WRT the circle $\mathcal{C}$ transforms C_1 into the tangent line p to $\mathcal{C}$ through A' and C_1' into the tangent line p' to $\mathcal{C}$ through A. Thus, lines p and p' meet at the inverse Q' of Q, but Q' lies on the polar τ of P with respect to $\mathcal{C}$. So, if Q' describes τ, then Q_1 describe the circle with diameter $\overline{OP}$.

Quick Reply

High School Olympiads

Inequality in bicentric quadrilateral

Reply

Source: 0

Luis González

#1 Feb 24, 2009, 11:07 am

Let I be the incenter of a bicentric quadrilateral $ABCD$ with diagonals AC and BD. Show that, if R, r denote its circumradius and inradius, then we have

$$2R^2 \geq IA \cdot IC + IB \cdot ID \geq 4r^2$$

Sergic Primazon

#2 Feb 26, 2009, 11:59 pm

$$\boxed{IA * IC + IB * ID = 4Rr^2(\frac{1}{AC} + \frac{1}{BD})}$$

1. $AC \leq 2R$ and $BD \leq 2R$ => $IA * IC + IB * ID \geq 4r^2$

2. Let $AB = a$, $BC = b$, $CD = c$, $DA = d$, $AC = d_1$, $BD = d_2$

$\boxed{4Rrs = \sqrt{d_1 d_2}\sqrt{(ab + cd)(bc + ad)}}$ (s - semiperimeter)

$$\frac{4Rrs}{\sqrt{d_1 d_2}} \leq \frac{(a + c)(b + d)}{2} = \frac{s^2}{2}$$

$$IA * IC + IB * ID = 4Rr^2 \frac{d_1 + d_2}{d_1 d_2} \leq \frac{s^2}{4} \leq 2R^2$$:)

Luis González

#3 Feb 27, 2009, 5:20 am

Let $(I, r), (O, R)$ be the incircle and circumcircle of $ABCD$. (I) touches its side-segments AB, BC, CD, DA at X, Y, Z, W. Simple angle chase gives $\angle XAI = \angle YIC$ and also $\angle BYI = \angle DIZ$. Rotate $\triangle AXI$ about I by angle $\angle XIY$ counterclokwise, thus $X \mapsto Y$ and we get a right triangle with legs $\overline{IA}$ and $\overline{IC}$. Similarly, rotating $\triangle IBY$ about I by angle $\angle YIZ$ we obtain a right triangle with legs $\overline{IB}$ and $\overline{ID}$. Thereby, area of $ABCD$ can be expresed as twice the sum of the areas of the two said right triangles. In other words, $[ABCB] = IA \cdot IC + IB \cdot ID$. Now, using the fact that in a fixed circle, the inscribed/circumscribed quadrilateral with maximum/minimum area is the square, it follows that

$$2R^2 \geq [ABCD] \geq 4r^2 \Longrightarrow 2R^2 \geq IA \cdot IC + IB \cdot ID \geq 4r^2.$$

Quick Reply

High School Olympiads

Spanish Sines Inradius Circumradius Inequality

Reply

Source: IMO LongList 1988, Spain 1, Problem 70 of ILL

orl

#1 Nov 10, 2005, 1:57 am

ABC is a triangle, with inradius r and circumradius R. Show that:

$$\sin\left(\frac{A}{2}\right)\cdot\sin\left(\frac{B}{2}\right)+\sin\left(\frac{B}{2}\right)\cdot\sin\left(\frac{C}{2}\right)+\sin\left(\frac{C}{2}\right)\cdot\sin\left(\frac{A}{2}\right)\leq\frac{5}{8}+\frac{r}{4\cdot R}.$$

Moonmathpi496

#2 Feb 24, 2009, 7:28 pm

> orl wrote:
> ABC is a triangle, with inradius r and circumradius R. Show that:
>
> $$\sin\left(\frac{A}{2}\right)\cdot\sin\left(\frac{B}{2}\right)+\sin\left(\frac{B}{2}\right)\cdot\sin\left(\frac{C}{2}\right)+\sin\left(\frac{C}{2}\right)\cdot\sin\left(\frac{A}{2}\right)\leq\frac{5}{8}+\frac{r}{4\cdot R}.$$

$$\begin{aligned}
&4\sum\sin\frac{A}{2}\sin\frac{B}{2}\leq\frac{3}{2}+1+\frac{r}{R}\\
\iff &4\sum\sin\frac{A}{2}\sin\frac{B}{2}\leq\frac{3}{2}+\sum\cos A\\
\iff &4\sum\sin\frac{A}{2}\sin\frac{B}{2}\leq\frac{3}{2}+\sum(1-2\sin^2\frac{A}{2})\\
\iff &4\sum\sin\frac{A}{2}\sin\frac{B}{2}+2\sum\sin^2\frac{A}{2}\leq\frac{9}{2}\\
\iff &2\left(\sum\sin\frac{A}{2}\right)^2\leq\frac{9}{2}\\
\iff &\left(\sum\sin\frac{A}{2}\right)^2\leq\frac{9}{4}
\end{aligned}$$

Using Jensen's Inequality on concave function $f(x)=\sin x$
We get,

$$\frac{1}{3}\sum\sin\frac{A}{2}\leq\sin\left(\frac{\sum\frac{A}{2}}{3}\right)=\sin\frac{\pi}{6}=\frac{1}{2}$$

And the conclusion follows. :)

I'd thank **Powerset** for giving hint to complete this solution.

This post has been edited 2 times. Last edited by Moonmathpi496, Feb 25, 2009, 9:48 am

$\{\emptyset\}$

Powerset

#3 Feb 25, 2009, 3:03 am

Moonmathpi, you are practically finished because of $4\sum\sin\frac{A}{2}\sin\frac{B}{2}+2\sum\sin^2\frac{A}{2}=2\left(\sum\sin\frac{A}{2}\right)^2$. Jensen kills the rest.

Moonmathpi496
#4 Feb 25, 2009, 9:36 am

> *Powerset wrote:*
> Moonmathpi, you are practically finished because of $4\sum\sin\frac{A}{2}\sin\frac{B}{2}+2\sum\sin^2\frac{A}{2}=2\left(\sum\sin\frac{A}{2}\right)^2$. Jensen kills the rest.

Ah...I see...I did not recognize that I need to square ...
By the way, thanks a lot!

Luis González
#5 Feb 26, 2009, 8:48 am

$$\frac{r}{R}=4\cdot\sin\frac{A}{2}\cdot\sin\frac{B}{2}\cdot\sin\frac{C}{2}$$

$$\sin\frac{A}{2}\cdot\sin\frac{B}{2}\cdot\sin\frac{C}{2}=\frac{1}{2}-\frac{1}{2}\left(\sin^2\frac{A}{2}+\sin^2\frac{B}{2}+\sin^2\frac{C}{2}\right)$$

$$\sum\sin\frac{A}{2}\cdot\sin\frac{B}{2}=\frac{1}{2}\left(\sin\frac{A}{2}+\sin\frac{B}{2}+\sin\frac{C}{2}\right)^2-\frac{1}{2}\sum\sin^2\frac{A}{2}$$

The desired inequality becomes $\sin\frac{A}{2}+\sin\frac{B}{2}+\sin\frac{C}{2}\le\frac{3}{2}$

Which is true by Jensen's inequality for the concave function $\sin x, \forall\ x\in(0,\pi)$

Quick Reply

High School Olympiads

Nice radical center:)

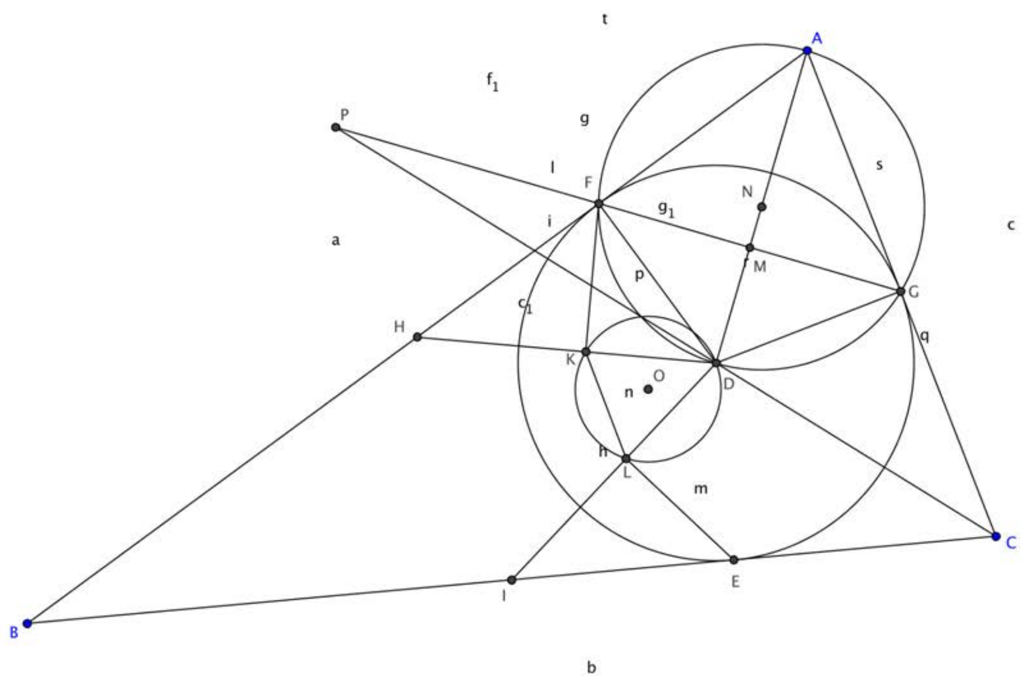
Reply

mathVNpro

#1 Feb 24, 2009, 10:58 pm

Let (D) be the incenter of triangle ABC. (D) touches AB, BC, CA respectively at F, E, G. Let H and I be the midpoints of AB, BC. K, L respectively be the projections of F, E onto OH, OI. CD intersects FG at P. Prove that P is the radical center of (D), (DKL), (DFG) .
MathVNPro

Attachments:



Luis González

#2 Feb 25, 2009, 12:26 am

Let Q be the reflection of A about PC. Line AQ is the polar of P WRT incircle ω, thus P and Q are harmonically separeted from the points where line CP intersects ω, i.e. $OQ \cdot OP = r^2 \ (*)$. On the other hand, it's clear that Q lies on the circle with diameter OA, thus we only need to prove that O, Q, K, L are concyclic. Inversion WRT ω transforms K into H and L into I, since $OE^2 = OF^2 = r^2 = OL \cdot OI = OK \cdot OH$. But according to $(*)$, this inversion takes Q into P. Now, since I, H, P are collinear $\Longrightarrow O, Q, K, L$ are concyclic.

mathVNpro

#3 Feb 25, 2009, 8:08 am

The main idea (maybe the most simple one) when I approach this problem is that I have to prove CD, HI, FG intersects at 1 point.
Here is my solution:
Let J be the intersection of FG and BC. As very well- known result, we have (JECB)=-1. On the other hand, because P, D, C are collinear. Therefore, P lies on the perpendicular bisector of GE. Then PC is the bisector of angle EPJ. Therefore PC perpendicular to PB. P belong to (I,BC/2).
By angle chasing, we can prove that PI parallel with AC. Besides, we also have HI parallel with AC.
=>P, H, I are collinear.
Invert around D with radius DE, DF, DG, we shall get the result

invert around D with radius DF=DE=DG, we shall get the result.

Luis González

#4 Feb 25, 2009, 8:35 am

I've seen an easier way. We already know that lines FG, CD and HI are concurrent (easy to prove with angle chasing), then just note that points H and I have equal powers with respect the incircle and the circle (DKL). Now, it means that IH is their radical axis and this completes the proof.

mathVNpro

#5 Feb 25, 2009, 9:32 am

Can you explain more about the detail: "points H and I have equal power respect the incircle and cirle DKL"???. Because I do not think so. Can you check again???

Quick Reply

High School Olympiads

Poland 1997

Reply

Source: Extracted from "Notes On Euclidean Geometry"

raf92

#1 Feb 23, 2009, 6:18 am

Let ABCDE a convex pentagon with CD=DE and /angle BCD = /angle DEA = 90^o. Let F be the point on side AB such that AF/FB=AE/BC. Show that /angle FCE = /angle FDE and /angle FEC = /angle BDC.

Sorry if I made double posting.

Luis González

#2 Feb 23, 2009, 7:12 am

> raf92 wrote:
> Let ABCDE a convex pentagon with CD=DE and /angle BCD = /angle DEA = 90^o. Let F be the point on side AB such that AF/FB=AE/BC. Show that /angle FCE = /angle FDE and /angle FEC = /angle BDC.

Are you sure that F lies on AB ?.

Luis González

#3 Feb 23, 2009, 7:26 am

Assume that $\angle FCE = \angle FDE \Longrightarrow$ quadrilateral $FCDE$ is cyclic. Then it follows that $\angle FEC = \angle FDC$, but we have $\angle FEC = \angle BDC \Longrightarrow \angle BDC = \angle FDC \Longrightarrow F \equiv B$, which is absurd.

P.S. raf92, may you write the reference of this problem?

raf92

#4 Feb 24, 2009, 11:13 pm

Yes, luis, I noticed some strange things in the question. I just copied from "Nots On Euclidean Geometry". Anyway, thank you for your remarks.

Luis González

#5 Feb 24, 2009, 11:17 pm

> raf92 wrote:
> I just copied from "Nots On Euclidean Geometry".

I just checked *"Nots on Euclidean Geometry"*, and the enunciation is indeed incorrect. The problem is proposed in section 4.3, when it's supposed to be proved by Pascal theorem

Quick Reply

High School Olympiads

Collinear points

Reply

Source: 0

Luis González

#1 Feb 23, 2009, 2:37 am

$\triangle ABC$ is scalene with circumcircle (O) and incircle (I). Let X, Y, Z be the midpoints of the arcs BC, CA, AB of (O). Show that the inverse lines of the circles with diameters IX, IY, IZ, under the inversion with respect to (I), cut the corresponding sidelines of the medial triangle of $\triangle ABC$ at three collinear points. Furthermore, show that this line also passes through the pole of the Euler line of $\triangle ABC$ WRT (I).

nsato

#2 Feb 24, 2009, 12:44 pm

After massive calculations, I found that all three points satisfy the equation

$$XI^2 - XG^2 = \frac{16Rr + r^2 - s^2}{9},$$

where I is the incenter and G is the centroid. Thus, all three points lie on a line that is perpendicular to GI. I don't think the pole of the Euler line lies on this line. It would be nice to see a synthetic solution.

Luis González

#3 Feb 24, 2009, 10:58 pm • 1

Thanks for your interest dear nsato, the problem is indeed correct.

Lemma 1. If M_c, M_b are midpoints of AB and AC, then the pole of M_bM_c WRT (I) is the orthocenter H_1 of $\triangle IBC$.

Lemma 2. Euler lines of $\triangle ABC, \triangle IBC, \triangle ICA, \triangle IAB$ concur at Shiffler's point of triangle $\triangle ABC$.

The inverse line p_a of the circle with diameter IX, under inversion WRT (I), is the polar of X WRT (I). The polar of H_1 WRT (I) is the A-midline M_bM_c of $\triangle ABC$. Therefore, $J_A \equiv M_bM_c \cap p_a$ is the pole of XH_1, the Euler line of $\triangle IBC$. Similarly, J_B, J_C are the poles of the Euler lines of $\triangle ICA, \triangle IAB \Longrightarrow J_A, J_B, J_C$ are collinear on the polar of the Schiffler's point of $\triangle ABC$ WRT $(I) \Longrightarrow J_AJ_BJ_C$ passes through the pole of the Euler line WRT (I), as desired.

nsato

#4 Feb 25, 2009, 10:42 am

First, I misread the question. But I still got three collinear points. :) I'll be posting it as another problem.

Second, thanks for your very nice problem and solution.

Quick Reply

High School Olympiads

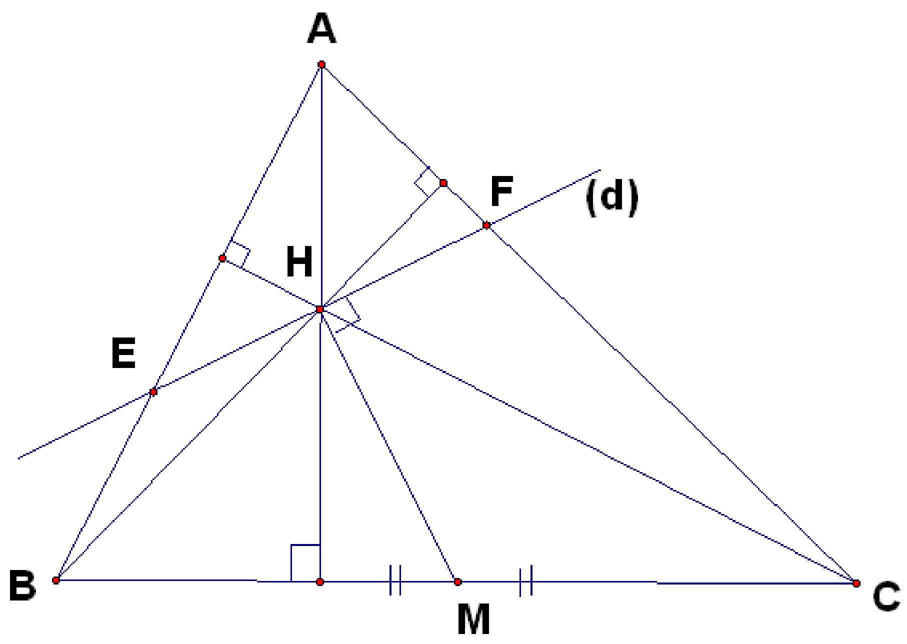
Prove HE = HF

Reply

thanhnam2902
#1 Feb 23, 2009, 10:40 pm

Let ABC is a triangle, let H is orthocenter of $\triangle ABC$, let M is midpoint of BC. Let (d) is a line perpendicular with HM at point H. Let (d) meet AB, AC at E, F respectively. Prove that $HE = HF$.

Attachments:



K_Er_Tus
#2 Feb 23, 2009, 10:52 pm

This is actually a particular case of the Butterfly Theorem.

mstoenescu
#3 Feb 24, 2009, 1:30 am

http://www.cut-the-knot.org/pythagoras/Butterfly.shtml

K_Er_Tus's solution is correct !Thank you !
Click to reveal hidden text

vittasko
#4 Feb 24, 2009, 3:16 am • 1

Let $K,\ L$ be, the orthogonal projections of $B,\ C$ respectively, on the line segment EF and we denote the points $X\equiv BC\cap AH,\ Y\equiv AC\cap BH,\ Z\equiv AB\cap CH.$

It is easy to show that $HK = HL,$ from $MB = MC$ and $BK\parallel MH\parallel CL$ and then, the points $B'\equiv CL\cap BH$ and $C'\equiv BK\cap CH,$ are the reflexions of $B,\ C$ respectively, with respect to $H.$

We have now, the configuration of two congruent triangles $\triangle HBC$, $\triangle H'B'C'$, with E, F as their orthocenters respectively and so, their distances from their homologous vertices, are equal.

Hence, we conclude that $EH = FH$ and the proof is completed.

Kostas Vittas.

Attachments:
t=260415.pdf (4kb)

mstoenescu
#5 Feb 24, 2009, 3:37 am

Great vittasko !

thanhnam2902
#6 Feb 24, 2009, 6:03 am

Thank you very much. I like this problem. It's easy but we can solve it by many ways. Use Butter fly Theorem is a nice example.

Luis González
#7 Feb 24, 2009, 6:32 am • 1

> *K_Er_Tus wrote:*
> This is actually a particular case of the Butterfly Theorem.

> *thanhnam2902 wrote:*
> Thank you very much. I like this problem. It's easy but we can solve it by many ways. Use Butter fly Theorem is a nice example.

Can someone explain to me what Butterfly theorem is?

thanhnam2902
#8 Feb 24, 2009, 7:43 am

oh! It is very famous Theorem. I have posted it at this forum.

thanhnam2902
#9 Feb 24, 2009, 7:54 am

You see it at here:
http://www.cut-the-knot.org/pythagoras/Butterfly.shtml

Luis González
#10 Feb 24, 2009, 8:00 am • 1

Thank you so much!. I realized that it is a particular case of a more general result:

AB is a chord of a circle (O) and P is a point on AB. Two distintc chords MN and RS pass through P. MS and RN cut AB at X, Y, respectively. Then we have

$$\frac{1}{PA} - \frac{1}{PX} = \frac{1}{PB} - \frac{1}{PY}$$

Nemion
#11 Feb 24, 2009, 8:40 am

Let M' the diametrically oposite point of A in the circumcircle of $\triangle ABC$. H, M, M' are collinear since by angle chasing

$BHCM'$ is a parallelogram. Also, $EHM'B$ and $HFCM'$ are both cyclic (opposite angles equal $\frac{\pi}{2}$, sum π. Since $\angle HBE = \angle HCF$ this implies HM is angle bisector of $EM'F$ then $EH = HF$.

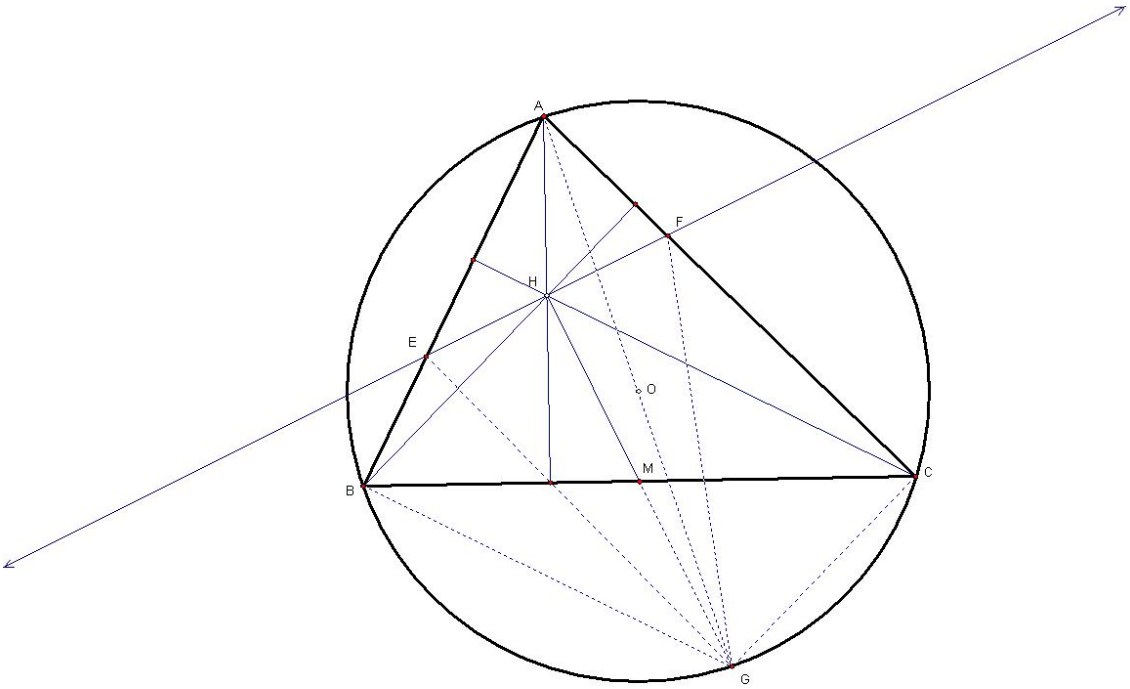
plane geometry

#12 Feb 24, 2009, 10:03 am

> *Nemion wrote:*
> Let M' the diametrically oposite point of A in the circumcircle of $\triangle ABC$. H, M, M' are collinear since by angle chasing $BHCM'$ is a parallelogram. Also, $EHM'B$ and $HFCM'$ are both cyclic (opposite angles equal $\frac{\pi}{2}$, sum π. Since $\angle HBE = \angle HCF$ this implies HM is angle bisector of $EM'F$ then $EH = HF$.

This is exactly what I am thinking about

Attachments:



jayme

#13 Feb 25, 2009, 10:36 am

Dear Mathlinkers,
for the butterfly theorem you can see a nice article written by Darij Grinberg
http://www.cip.ifi.lmu.de/~grinberg/ On cyclic quadrilaterals and the butterfly theorem
Sincerely
Jean-Louis

armpist

#14 Feb 26, 2009, 7:23 am • 1

Two orthogonal lines through orthocenter is the signature of Droz-Farny configuration.

The required equality of segments follows immediately.

M.T.

sunken rock

#15 Nov 4, 2009, 7:26 pm

If N=BH∩AC and P=CH∩AB, then BCNP is cyclic, M is it's excenter and, from butterfly theorem, EH = FH.

Best regards,
sunken rock

Quick Reply

High School Olympiads

Tangential hexagon and Nagel point

Reply

Source: 0

Luis González

#1 Feb 23, 2009, 3:40 am

Let N be the Nagel point of $\triangle ABC.$ Its incircle (I) touches BC at X and line AN intersects (I) at Y (closer to BC). H is the foot of the A-altitude $AH.$ Draw through H a tangent to (I) which touches it at $P.$ Define lines $s_a \equiv XY$ and $r_a \equiv XP.$ Similarly, define the pairs of lines s_b, r_b and $s_c, r_c.$ Prove that $s_a, s_b, s_c, r_a, r_b, r_c$ bound a hexagon circumscribed in a conic.

yetti

#2 Mar 2, 2009, 1:00 pm

The said lines are obviously polars WRT the incircle (I) of the altitude feet and midpoints of the triangle sides, all on the 9-point circle (N). They are tangent to a conic with one focus I and pedal circle (N'), the inversion image of (N) in (I).

Quick Reply

High School Olympiads

collinear

Reply

Source: bulgaria 97

ishfaq420haque
#1 Feb 22, 2009, 10:57 pm

let $ABCD$ be a convex quadrilateral such that $< DAB =< ABC =< BCD$ .let H and O be the orthocenter and cicumcenter of ABC.prove that D,O,H collinear

Luis González
#2 Feb 23, 2009, 12:44 am

We can use barycentric coordinates WRT ABC, though I believe there must be an easier approach. Using Conway formula for $\theta=\alpha-\beta$ and $\phi=\alpha-\gamma$, we compute the coordinates of D WRT $\triangle ABC$. Then we verify that D satisfies the equation of the Euler line e of $\triangle ABC$, namely

$e \equiv S_A(S_B-S_C)x+S_B(S_C-S_A)y+S_C(S_A-S_B)z=0$

This post has been edited 1 time. Last edited by Luis González, Feb 23, 2009, 12:59 am

NextPeace
#3 Feb 23, 2009, 12:56 am

What is conway's formula? Can you explan it to me, please?

Luis González
#4 Feb 23, 2009, 1:03 am

The Conway formula gives the barycentric coordinates of a point P defined by the *balanced angles* $\angle PBC=\theta$ and $\angle PCB=\varphi$. Keeping in mind the notation $S_{\theta}=S\cot\theta$

$$P \equiv (-a^2:S_C+S_{\varphi}:S_B+S_{\theta})$$

yetti
#5 Feb 23, 2009, 1:18 am

Let K,M be midpoints of BC,AB and $G\equiv AK\cap CM$ centroid of $\triangle ABC$ and OGH its Euler line. CD is reflection of AB in the perpendicular bisector OK of BC. Similarly, AD is a reflection of BC is the perpendicular bisector OM of AB. AB,CD intersect at $X\in OK$ and AD,BC intersect at $Y\in OM$. By Pappus theorem for the lines XAM,YCK, the intersections $O\equiv XK\cap YM, G\equiv AK\cap CM, D\equiv AY\cap CX$ are collinear.

Quick Reply

High School Olympiads

Another interesting property of the incircle

Reply

Source: 0

Luis González

#1 Feb 22, 2009, 6:38 am

Show that a point P lies on the incircle (I) of $\triangle ABC$ if and only if

$$a \cdot PA^2 + b \cdot PB^2 + c \cdot PC^2 = (4R + 2r)[\triangle ABC]$$

R, r denote the inradius and circumradius of $\triangle ABC$ and $[\triangle ABC]$ stands for its area.

SaYaT

#2 Feb 22, 2009, 4:11 pm

This problem based on that identity(i will try to post proof later):
$\sum_{cyclic} XA^2 \cdot a = XI^2 \sum_{cyclic} a + abc$

so if P is a point in the inscribed cirumference of a $\triangle ABC$ then we have:
$aPA^2 + bPB^2 + cPC^2 = r^2(a+b+c) + abc = 2r[ABC] + 4[ABC]R = (4R+2r)[ABC]$

if we have:
$aPA^2 + bPB^2 + cPC^2 = (4R+2r)[ABC]$
$\leftrightarrow$
$PI^2(a+b+c) + abc = 4R[ABC] + 2r[ABC]$
$\leftrightarrow$
$PI^2(a+b+c) + abc = abc + r^2(a+b+c)$
$\leftrightarrow$
$PI = r$
So point P is in the inscribed circumference of $\triangle ABC$

Quick Reply

High School Olympiads

Equilateral Triangle

Reply

Source: Bulgarian Mathematical Olympiad 2008: Regional Round

Moonmathpi496

#1 Feb 21, 2009, 12:33 am

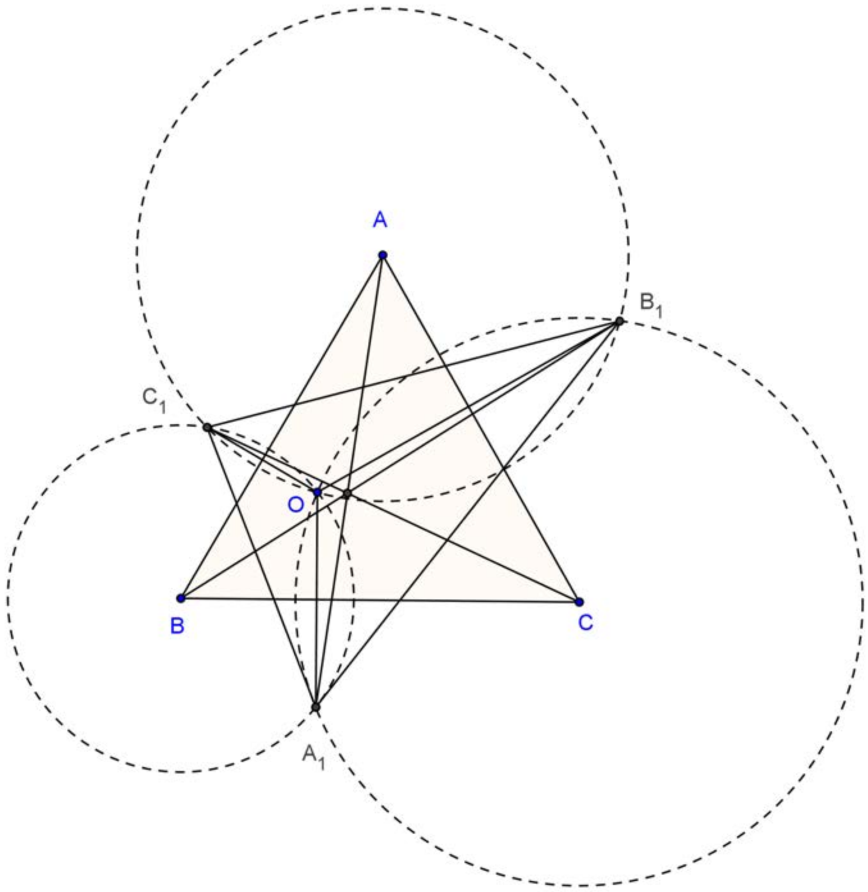
In the equilateral triangle ABC is chosen a point O. Its symmetric point with respect to the sides BC, CA and AB are denoted respectively with A_1, B_1 and C_1. Prove that the lines AA_1, BB_1 and CC_1 intersects at a common point.

Luis González

#2 Feb 21, 2009, 10:06 am

$\triangle ABC$ becomes a Napoleon triangle (either internal or external) of $\triangle A_1B_1C_1$, so the lines AA_1, BB_1, CC_1 concur at a Napoleon point of $\triangle A_1B_1C_1$.

Attachments:



Moonmathpi496

#3 Feb 21, 2009, 11:10 pm

> *Luis González wrote:*
> $\triangle ABC$ becomes a Napoleon triangle (either internal or external) of $\triangle A_1B_1C_1$, so the lines AA_1, BB_1, CC_1 concur at a Napoleon point of $\triangle A_1B_1C_1$.

1st of all, what's the proof of this? I mean ABC may be just homothetic to the Napoleon's triangle of $A_1B_1C_1$....

And the concurrency here is not so well know as far as I know, (and I also think that this problem is true for not for the reflected points but also for the glide reflected points)

Luis González

#4 Feb 21, 2009, 11:23 pm

Dear it's the celebrated Jacobi's theorem: In a $\triangle ABC,$ points X, Y, Z are constructed, all outside or all inside, such that $\angle BCX = \angle ACY, \angle CAY = \angle BAZ$ and $\angle ABZ = \angle CBX.$ Then the lines AX, BY, CZ concur.

For a proof try a search, it has been posted before.

Quick Reply

High School Olympiads

rectangular hyperbola

Reply

Leonhard Euler
#1 Feb 21, 2009, 5:16 pm

Let ABC be a triangle and g be the line passing through the circumcenter of triangle ABC. Prvoe that isogonal conjugate of g is rectangular hyperbola.

Luis González
#2 Feb 21, 2009, 10:17 pm

Let us consider barycentric coordinates WRT $\triangle ABC.$ $px+qy+rz=0$ is the equation of a line $\ell.$ Isogonal conjugation $\mathcal{I}:(x:y:z) \mapsto \left(\frac{a^2}{x}:\frac{b^2}{y}:\frac{c^2}{z}\right)$ takes ℓ into a curve $\mathcal{L}$ with equation $\mathcal{L} \equiv pa^2yz+qb^2zx+rc^2xy=0,$ i.e the equation of a homogeneous polynomial of secong degree.

Thus, $\mathcal{L}$ represents a conic passing through the vertices of $\triangle ABC.$ Since the isogonal conjugate of the circumcircle (O) of $\triangle ABC$ is the line at infinity, we conclude that $\mathcal{L}$ is either hyperbola, parabola or ellipse if ℓ has either two, one or any common point with $(O).$ However, I don't know how to prove that $O \in \ell \Longleftrightarrow \mathcal{L}$ is a rectangular hyperbola.

¬[ƒ(Gabriel)³²¹º]¼
#3 Feb 22, 2009, 1:47 am

a short proof: the isogonal of a line is an gyperbola from A,B,C so we have to prove that an hyperbola from A,B,C,H i rectangular. Let the conics from A,B,C,H, on this bunch there exist 2 equilateral hyperbola than all the conics of the bunch are equilateral hyperbola.

yetti
#4 Feb 23, 2009, 12:51 am

Gabriel, you did not even show that isogonal conjugate of a line is a conic, not to mention a hyperbola.

Anyway, I put it down at http://www.mathlinks.ro/viewtopic.php?t=129699, click on "Show details".

Leonhard Euler
#5 Feb 23, 2009, 5:07 pm

Thank you for your help. Could you explain easily about lemma in Show details? What is parallel projection?

yetti
#6 Feb 26, 2009, 12:13 am

Parallel projection is a central projection from a point P^* at infinity. Just like central projection, parallel projection takes points to points, lines to lines, and conics to conics. Suppose it carries points $A, B, ...$ to points $A', B', ...$ Since all rays $P^*AA', P^*BB', ...$ concur at a point P^* at infinity, they are all parallel. It has the same invariant as central projection (it preserves cross ratios) and additional invariants: It preserves ratios of line segments on the same line and ratios of areas. Therefore, all points at infinity remain at infinity and parallel lines go to parallel lines. Parallel projection can also be defined as an affine transformation, i.e., the composition of a linear transformation and a translation.

Quick Reply

High School Olympiads

Nice Geometry

Reply

Source: Bulgarian Mathematical Olympiad 2008: Regional Round

Moonmathpi496

#1 Feb 21, 2009, 12:36 am

The points A, B and C are situated on the circumference k in such a way that the tangents to k at the points A and B intersects at the point P and C lies on the bigger arc AB. Let the line through C which is perpendicular to PC intersects the line AB at the point Q.
Prove that:

(a) if the lines PC and QC intersects k for second time at the points M and N then the angles $\angle CQP$ and $\angle CMN$ are equal.

(b) If S is the middle point of PQ then SC is tangent to k.

Luis González

#2 Feb 21, 2009, 11:30 am

Lines MN and PC cut QB at X and Y, respectively. $R \equiv MN \cap PQ$. AB is the polar of P WRT $\mathcal{K} \Longrightarrow P, M, Y, C$ are harmonically separeted $\Longrightarrow R, M, X, N$ are also harmonically separeted, since (R, M, X, N) is a section of the pencil $Q(P, M, Y, C)$. Therefore, we have $XN \cdot XM = r^2 = OX \cdot OR \Longrightarrow R$ lies in the inverse of YB under inversion $(O, r^2) \Longrightarrow \angle XRQ = 90^\circ \Longrightarrow \angle NMC = \angle PQC$.

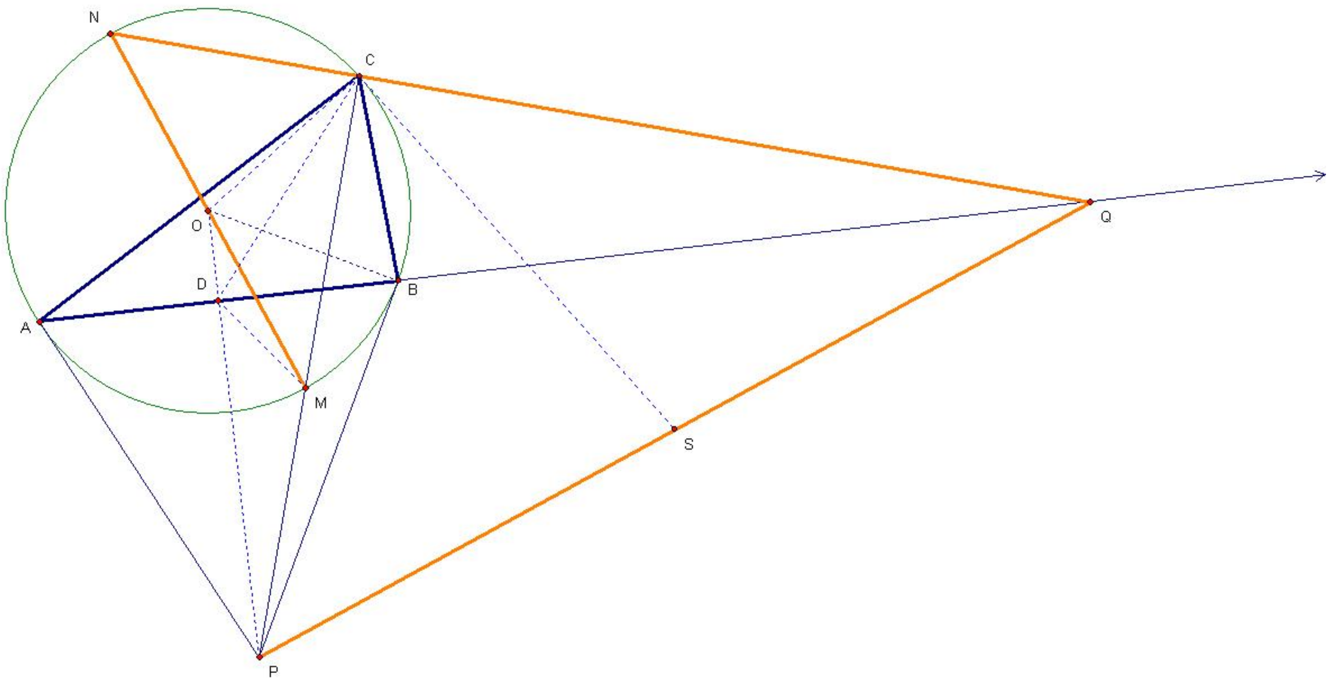
This post has been edited 1 time. Last edited by Luis González, Feb 21, 2009, 9:52 pm

plane geometry

#3 Feb 21, 2009, 1:42 pm • 1

Denote D is the midpoint of AB then we have P,D,C,Q are concyclic
Notice M,C,O,D are concyclic =>
□CMN=□ODC => □ODC=□CMN
□PCS=□CPS=□CDB=□CNM => CS is tangent to □O

Attachments:



Quick Reply

High School Olympiads

Point inside a regular polygon

Reply

Rijul saini
#1 Feb 21, 2009, 12:29 am

Let P be any point inside a regular polygon.
if d_i is the distance of P from the i^{th} side of the polygon, prove that
$d_1+d_2+....+d_n$ is constant
where n is the number of sides of the polygon

Luis González
#2 Feb 21, 2009, 9:33 am

Let Δ denote the area of the n-gon and L the lentgh of its side. Then

$$\Delta=\frac{L(d_1+d_2+d_3+...+d_n)}{2} \Longrightarrow d_1+d_2+d_3+...+d_n=\frac{2\cdot\Delta}{L}=\text{const}$$

Rijul saini
#3 Feb 21, 2009, 8:48 pm

Hey i think youre wrong
its not necessary that all the areas together will form the area of the ngon as the altitude can be on the produced side too!

somebody help

Rijul saini
#5 Feb 21, 2009, 10:09 pm

now i understand
i dont know what happened to me that time...

thanx.

Quick Reply

High School Olympiads

inequality of altitude

Source: INMO 2009 Problem 5

skand

#1 Jan 18, 2009, 7:16 pm

Let ABC be an acute angled triangle and let H be its ortho centre. Let h_{max} denote the largest altitude of the triangle ABC. Prove that:

$AH + BH + CH \leq 2h_{max}$

befuddlers

#2 Jan 18, 2009, 10:43 pm

This is a very nice question.

$AH + BH + CH$ is the same as $2RcosA + 2RcosB + 2RcosC$

Let b be the smallest side without loss of generality.

Then $2h_max = 4area/b$

But we know $4area = abc/R$

So we need to prove that $ac/R >= 2R(cosA + cosB + cosC)$

So we need to prove $ac >= 2R^2((cosA + cosB + cosC)$

But from sine rule we know that $ac = 4R^2 sinAsinC$

So we need to prove that $2sinAsinC >= (cosA + cosB + cosC)$

But since b is the smallest side we know that both A and C are greater than or equal to 60.

So LHS is greater than or equal to 3/2 with equality for equilateral triangle

And RHS is lesser than or equal to 3/2 by jensen's with equality for equilateral triangle.

And so we are done.

QED

Befuddlers

EDit: i am also trying to prove the case when one of the angles is obtuse.

gauravpatil

#3 Jan 19, 2009, 9:32 am

try the ptolemys theorem it can be done in a very small place (small thing to write)
shall post solution tommorow at #:00 pm

TRAN THAI HUNG

#4 Jan 19, 2009, 10:34 am

Assume that $h_c = h_{\max}$ so $c = \min\{a, b, c\}$
Let (O) is circumscribed ABC.
$(O) \cap CH = KA$
$2h_c - AH - BH - CH = CK - AH - BH = CK - AK - BK \geq 0$ (Q.E.D) Is that right?

antiparticle
#5 Jan 19, 2009, 2:44 pm

> *befuddlers wrote:*
> So we need to prove that $2sinAsinC >= (cosA + cosB + cosC)$
>
> But since b is the smallest side we know that both A and C are greater than or equal to 60.

Both A and C need not be greater than 60.

e.g. A=80, C=55, => B=45

I too got to the same inequality as you have but coudn't proceed further.

LEE TAE HUN
#6 Jan 31, 2009, 10:53 am

$D = AH \cap BC$
E, F is same define
$$\frac{S - \triangle BCH}{S} = \frac{AH}{AD}$$
$$AH + BH + CH = \frac{(S - \triangle BCH)AD}{S} + \frac{(S - \triangle CAH)BE}{S} + \frac{(S - \triangle ABH)CF}{S}$$
$$\leq \frac{(S - \triangle BCH)h_{max}}{S} + \frac{(S - \triangle CAH)h_{max}}{S} + \frac{(S - \triangle ABH)h_{max}}{S}$$
$$= \frac{(3S - S)h_{max}}{S} = 2h_{max}$$

gauravpatil
#7 Jan 31, 2009, 3:43 pm

Let the largest altitude(h_a) meet the circumcircle at H' as $h_a > h_b, h_c \implies a < b, c$
by ptolemy's theorem,
$$a \cdot AH' = BH' \cdot c + CH' \cdot b$$
$$\implies AH' = BH' \cdot \frac{c}{a} + CH' \cdot \frac{b}{a}$$
$$\implies AH' > BH' + CH'$$
as $BH' = BH$ and $CH' = CH$
adding AH to both sides we get $2h_a > AH + BH + CH$

campos
#8 Feb 5, 2009, 12:13 am • 1

as posted before, assuming $C \leq A, B$, the inequality is equivalent to
$$2\sin A \sin B \geq \cos A + \cos B + \cos C = 1 + 4\sin\frac{A}{2}\sin\frac{B}{2}\sin\frac{C}{2}...$$

so, we have to prove that

$$4\sin\frac{A}{2}\sin\frac{B}{2}\left(2\cos\frac{A}{2}\cos\frac{B}{2} - \sin\frac{C}{2}\right) = 2\left(\cos\frac{A-B}{2} - \sin\frac{C}{2}\right)\cos\frac{A-B}{2} \geq 1$$

suppose wlog that $A \geq B$ and consider two cases:

i) $C \geq 45$.. it's clear that $180 - 3C \geq A - B$, so we have that

$2\left(\cos\frac{A-B}{2}-\sin\frac{C}{2}\right)\cos\frac{A-B}{2}\geq 2\left(\sin\frac{3C}{2}-\sin\frac{C}{2}\right)\sin\frac{3C}{2}$...

if we let $a=\sin^2\frac{C}{2}$, the inequality $2\left(\sin\frac{3C}{2}-\sin\frac{C}{2}\right)\sin\frac{3C}{2}\geq 1$ is equivalent to $(1-4a)(8a(1-a)-1)\geq 0$..

using that $8a(1-a)-1=2\sin^2 C-1$ and that $45\leq C\leq 60$ shows that the last inequality is true and we're done for this case...

ii) $C\leq 45$.. it's clear that $C\geq A-B$, so we have that
$2\left(\cos\frac{A-B}{2}-\sin\frac{C}{2}\right)\cos\frac{A-B}{2}\geq 2\left(\cos\frac{C}{2}-\sin\frac{C}{2}\right)\cos\frac{C}{2}$...

the inequality $2\left(\cos\frac{C}{2}-\sin\frac{C}{2}\right)\cos\frac{C}{2}\geq 1$ is equivalent to $\cos C\geq\sin C$, which is true and we're done...

Rijul saini

#9 Feb 21, 2009, 1:15 am

My answer is quite similar to gaurav patil's answer

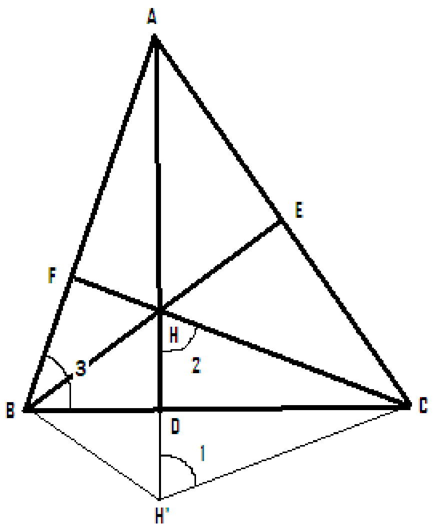
Let the greatest altitude be AH
Therefore $BC\leq AB$ as well as AC

Now produce HD to H' such that $HD=H'D$
Therefore H' is the reflection of H
So $CH=CH'$ and $BH=BH'$
This implies that $\angle 1=\angle 2$
$=\angle 3$ (since $\angle 2$ is the exterior angle of cyclic quad $BDHF$)
So $ACH'B$ are cyclic

Applying Ptolemy's theorem we get
$AH'\cdot BC=AB\cdot CH'+AC\cdot BH'$
This implies that $AD+DH=(AB/BC)\cdot CH+(AC/BC)\cdot BH$
Since each of the fractions is less than or equal to 1
$AD+DH\geq CH+BH$
Adding AH to both sides the result follows.
$Q.E.D.$

EDIT: the figure will appear black coloured--click on the figure to see it

Attachments:



This post has been edited 2 times. Last edited by Rijul saini, Dec 29, 2011, 3:39 am

Luis González

#10 Feb 21, 2009, 9:19 am

Let O be the circumcenter of $\triangle ABC$ and D,E,F the projections of O on BC,CA,AB (midpoints of the corresponding sides). Parallel through O to BC cuts AC,AB at U,V and cuts the A-altitude AP at K. Since $AP=h_a$ is the longest altitude of $\triangle ABC$ we can assume WLOG that $AC\geq AB\geq BC\longrightarrow AU\geq AV$

altitude of $\triangle ABC$, we can assume WLOG that $AC \geq AB \geq BC \Longrightarrow AU \geq AV$.

If L is the projection of U on AB and M is the projection of O on UL, then $OMLF$ is clearly a rectangle $\Longrightarrow OF = ML$ and $OM \parallel FL \Longrightarrow \angle MOU = \angle AVU$. But since $AU \geq AV \Longrightarrow \angle MOU \geq \angle EUO \Longrightarrow UM \geq OE \Longrightarrow OE + OF \leq UL \leq AK \Longrightarrow h_a = AK + KP \geq OD + OE + OF = \frac{1}{2}(HA + HB + HC)$.

Agr_94_Math

#11 Feb 21, 2009, 2:45 pm

Rijul Saini, your proof is correct but already posted before.
And $\angle 3$ wrong.

Rijul saini

#12 Feb 22, 2009, 12:04 pm

hey i've posted the correct figure

@aravind

Ulanbek_Kyzylorda KTL

#13 Mar 23, 2009, 12:40 pm

For gauravpatil

From here you made mistake because you don't correctly use Ptolemey's theorem but it doesn't matter. For gauravpatil

Rijul saini

#14 Nov 18, 2009, 12:47 am • 2

Using the Gergonne-Euler theorem it's just a one-liner

$$\frac{AH}{AD} + \frac{BH}{BE} + \frac{CH}{CF} = 2$$

$$\Longrightarrow \frac{AH + BH + CH}{h_{max}} \leq 2$$

$$\Longrightarrow AH + BH + CH \leq 2h_{max}$$

Attachments:
GergonneEuler.pdf (86kb)

Maharjun

#15 Jan 15, 2010, 3:15 pm • 1

Solution using P.T and elementary side inequalities

Rijul saini

#16 Dec 29, 2011, 4:01 am • 1

We have $\triangle ABC$ acute. Therefore, a^2, b^2, c^2 are sides of some triangle. Therefore, we can let $a^2 = y + z,\ b^2 = z + x,\ c^2 = x + y$ for some positive reals x, y, z. Also, let x be the largest among x, y, z so that a is the smallest side, and therefore, h_a the largest altitude.
We have,

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc} = \frac{x}{\sqrt{(x+y)(x+z)}}$$

and therefore

and therefore,

$$\sin A = \sqrt{\frac{xy+yz+zx}{(x+y)(x+z)}}$$

Thus, we have,

$$R = \frac{a}{2\sin A} = \sqrt{\frac{(x+y)(y+z)(z+x)}{2(xy+yz+zx)}}$$

Also,

$$\cos A + \cos B + \cos C = \frac{\sum x\sqrt{(y+z)}}{\sqrt{(x+y)(y+z)(z+x)}}$$

Now, let us state the problem in terms of x, y, z. We have to prove,
$2h_{max} = 2h_a = 4R\sin B\sin C \geq AH + BH + CH = 2R(\cos A + \cos B + \cos C)$
$\iff (2\sin B\sin C)^2 \geq (\cos A + \cos B + \cos C)^2$

$$\iff 4 \cdot \frac{(xy+yz+zx)^2}{(x+y)(x+z)(y+z)^2} \geq \frac{(\sum x\sqrt{(y+z)})^2}{(x+y)(y+z)(z+x)}$$

$$\iff 4(xy+yz+zx)^2 \geq (\sum x\sqrt{(y+z)})^2(y+z)$$

Now, we have by Cauchy Schwarz Inequality,
$(\sum x\sqrt{(y+z)})^2 \leq (\sum x(y+z))(\sum x) = 2(xy+yz+zx)(x+y+z)$
Therefore, it suffices to prove $2(xy+yz+zx) \geq (x+y+z)(y+z) = xy+zx+y^2+z^2+2yz$
Thus, we only have to prove $xy+xz \geq y^2+z^2$, which is true since we have x as the largest among x, y, z. ($xy \geq x^2$ and $xz \geq z^2$)
We are through.

Dranzer
#17 Dec 29, 2011, 11:00 am

@Rijul Saini: Awesome.I just noticed you have posted 3 different proofs to this particular problem.

tc1729
#18 Apr 30, 2012, 2:23 am

Let AD, BE, CF be the altitudes and H be the orthocenter. Observe that we have

$$\frac{AH}{AD} = \frac{[AHB]}{[ADB]} = \frac{[AHC]}{[ADC]}.$$

This gives

$$\frac{AH}{AD} = \frac{[AHB]+[AHC]}{[ADB]+[ADC]} = 1 - \frac{[BHC]}{[ABC]}.$$

Similar expressions for the ratios $\frac{BH}{BE}$ and $\frac{CH}{CF}$ may be obtained. Adding we obtain

$$\frac{AH}{AD} + \frac{BH}{BE} + \frac{CH}{CF} = 2.$$

WLOG assume that AD is the largest altitude. Hence, we get

$$\frac{AH+BH+CH}{AD} \leq \frac{AH}{AD} + \frac{BH}{BE} + \frac{CH}{CF} = 2.$$

We are done. $\square$

We are done. $\square$

War-Hammer

#19 May 16, 2013, 3:19 pm

Hi ;

It prove very beautiful by Ptolemy's Theorem :)

Best Regard

leader

#20 May 16, 2013, 6:22 pm

> War-Hammer wrote:
>
> Hi ;
>
> It prove very beautiful by Ptolemy's Theorem :)
>
> Best Regard

yes i solved it too by Ptolemy's theorem
WLOG BC is the smallest side than let D be symmetric of A wrt BC than $DCHB$ is cyclic so
$DH * BC = CH * BD + BH * CD = CH * BA + BH * AC \geq CH * BC + BH * BC$ giving
$DH \geq BH + CH$ now adding AH to both sides finishes the problem.

War-Hammer

#21 May 16, 2013, 10:58 pm

Hi ;

This is my solution and figure :)
http://www.uploadtak.com/images/e594_201302261781.jpg
http://www.uploadtak.com/images/p313_201302261780.jpg

Best Regard

Quick Reply

High School Olympiads

Sum of altitudes in the acute triangle

Reply

Source: 0

Luis González

#1 Feb 19, 2009, 12:06 am

$\triangle ABC$ is acute with altitudes h_a, h_b, h_c. R, r, r_0 denote the radii of its circumcircle, incircle and incircle of its orthic triangle. Prove synthetically the relation

$$h_a + h_b + h_c = 2R + 4r + r_0 + \frac{r^2}{R}$$

Luis González

#2 Feb 20, 2009, 6:36 am

Hint: If H is the orthocenter, show that $HA + HB + HC = 2(R + r)$. Also, keep in mind that $\odot(HBC), \odot(HCA), \odot(HAB)$ are congruent to $\odot(ABC)$.

Hint for a trigonometric solution: Use the identity $r_0 = 2R\cos A\cos B\cos C$.

Virgil Nicula

#3 Feb 22, 2009, 5:35 am

$$\| \sum h_a = 2R + 4r + r_o + \frac{r^2}{R} \| \odot\ 2R \Longleftrightarrow \| \left(\begin{array}{c} \sum bc = 4R^2 + 8Rr + 2Rr_0 + 2r^2 \\ bc + ca + ab = p^2 + r^2 + 4Rr \\ r_0 = 2R\cos A\cos B\cos C \end{array} \right) \| \Longleftrightarrow$$

$\boxed{p^2 = (2R + r)^2 + 2Rr_0} \Longleftrightarrow \cos A\cos B\cos C = \frac{p^2 - (2R + r)^2}{4R^2}$. **Nice relation !**

Virgil Nicula

#4 Feb 23, 2009, 5:18 pm

$$\| \sum h_a = 2R + 4r + r_o + \frac{r^2}{R} \| \odot\ 2R \Longleftrightarrow \| \left(\begin{array}{c} \sum bc = 4R^2 + 8Rr + 2Rr_0 + 2r^2 \\ bc + ca + ab = p^2 + r^2 + 4Rr \\ r_0 = 2R\cos A\cos B\cos C \end{array} \right) \| \Longleftrightarrow$$

$\boxed{p^2 = (2R + r)^2 + 2Rr_0} \Longleftrightarrow \cos A\cos B\cos C = \frac{p^2 - (2R + r)^2}{4R^2}$, what is truly.

Remark. A triangle ABC is nonobtuse $\Longleftrightarrow\ \sum \sin A\ \ge\ 1 + \sum \cos A\ \Longleftrightarrow\ p\ \ge\ 2R + r$.

Quick Reply

High School Olympiads

Nice geometry problem

Reply

Source: Hope for a nice inversive solution!

Mashimaru

#1 Feb 15, 2009, 5:06 pm

Let $ABCD$ be a trapezium where $AB//CD$ and F be the point on AB such that $FC = FD$. AC intersects BD at E. Prove that EF is the radical axis of (FAD) and (FBC), where (XYZ) stands for the circumcircle of $\triangle XYZ$.

yetti

#2 Feb 16, 2009, 2:10 am

$(P), (Q)$ are the circumcircles $\odot(FAD), \odot(FBC)$. They cut AC at A, C and again at U, V, respectively. Power of A to (Q) is $\overline{AV}\cdot\overline{AC} = \overline{AF}\cdot\overline{AB}$ and $\frac{\overline{EA}}{\overline{EC}} = \frac{\overline{AB}}{\overline{CD}} \Longrightarrow$

$$\frac{\overline{EV}}{\overline{EA}} = 1 - \frac{\overline{VA}}{\overline{EA}} = 1 - \frac{\overline{AF}\cdot\overline{AB}}{\overline{CA}}\cdot\frac{\overline{AB}+\overline{DC}}{\overline{CA}\cdot\overline{AB}} = 1 - \frac{\overline{AF}\cdot(\overline{AB}+\overline{DC})}{\overline{CA}^2}.$$

(P) cuts CD at D and again at X. $AFDX$ is cyclic trapezoid, isosceles $\Longrightarrow AX = FD = FC \Longrightarrow AFCX$ is a parallelogram $\Longrightarrow$ power of C to (P) is $\overline{CU}\cdot\overline{CA} = \overline{CD}\cdot\overline{CX} = \overline{CD}\cdot\overline{FA} \Longrightarrow$

$$\frac{\overline{EU}}{\overline{EC}} = 1 - \frac{\overline{UC}}{\overline{EC}} = 1 - \frac{\overline{CD}\cdot\overline{FA}}{\overline{AC}}\cdot\frac{\overline{BA}+\overline{CD}}{\overline{AC}\cdot\overline{CD}} = 1 - \frac{\overline{FA}\cdot(\overline{BA}+\overline{CD})}{\overline{AC}^2}.$$

As a result, $\frac{\overline{EV}}{\overline{EA}} = \frac{\overline{EU}}{\overline{EC}}$ or $\overline{EV}\cdot\overline{EC} = \overline{EU}\cdot\overline{EA}$, powers of E to $(P), (Q)$ are equal, E is on their radical axis.

vittasko

#3 Feb 18, 2009, 2:36 am

LEMMA. – Through the vertex A of a given isosceles triangle $\triangle ABC$, we draw a line parallel to its base BC and let $D,\ E$ two arbitrary points on it, from both sides of A. We denote as K, the intersection point of the circucircles $(O_1),\ (O_2)$, of the triangles $\triangle ABD,\ \triangle ACE$ respectively, the other than A and let be the points $M\equiv DE\cap CK$ (between $A,\ D$) and $N\equiv DE\cap BK$. Prove that $\frac{AM}{MD} = \frac{AN}{NE}$.

PROOF OF THE PROPOSED PROBLEM. - Let $(O_1),\ (O_2)$ be, the circucircles of the triangles $\triangle FAD,\ \triangle FBC$ respectively and let K be, their intersection point, the other than F.

We denote as $M,\ N$, the intersection points of the side-segment AD of the given trapezium $ABCD$, from the line segments $CK,\ DK$ respectively and it is enough to prove that the points $F,\ K,\ E$, are collinear.

• We consider the pencil $C.FMAD$ which is intersected from the line segment $FA \parallel CD$ and so, we have $(C.FMAD) = (F, M, A)$, (1) as well.

Similarly, because of the pencil $D.FNBC$ is intersected from the line segment $FB \parallel DC, \Longrightarrow (D.FNBC) = (F, N, B)$, (2)

Based on the above **Lemma**, we have that $(F, M, A) = (F, N, B)$, (3)

From $(1), (2), (3) \Longrightarrow (C.FMAD) = (D.FNBC)$, (4)

From (4) and because of the pencils $C.FMAD,\ D.FNBC$, have the line segment CD as their common ray, we conclude that the points $F \equiv CF \cap DF,\ K \equiv CM \cap DN$ and $E \equiv CA \cap DB$, are collinear and the proof is completed.

• This proof is dedicated to **Mihalis Lambrou.**

kostas Vittas.

PS. I will post here later the proof of the above **Lemma** I have in mind.

Attachments:
t=258337.pdf (5kb)

vittasko

#4 Feb 18, 2009, 11:32 pm

> *vittasko wrote:*
> **LEMMA. – Through the vertex A of a given isosceles triangle $\triangle ABC$, we draw a line parallel to its base BC and let $D,\ E$ two arbitrary points on it, from both sides of A. We denote as K, the intersection point of the the circucircles $(O_1),\ (O_2)$, of the triangles $\triangle ABD,\ \triangle ACE$ respectively, the other than A and let be the points $M \equiv DE \cap CK$ (between $A,\ D$) and $N \equiv DE \cap BK$. Prove that $\frac{AM}{MD} = \frac{AN}{NE}$.**

PROOF OF THE LEMMA. - Let be the points $B' \equiv (O_1) \cap BC$ and $C' \equiv (O_2) \cap BC$ and $P \equiv DB' \cap EC'$.

It is easy to show that the triangle $\triangle PED$ is isosceles, because of $\angle DEP = \angle ACB = \angle ABC = \angle EDP$, (1)

So, we have that the trapezium $DB'C'E$ is isosceles and hence, it is cyclic with circumcircle so be it (O).

We conclude now, that the line segment AK, passes through the point P, as the radical center of the circles $(O),\ (O_1),\ (O_2)$ and let be the point $X \equiv BC \cap AKP$.

• From (1) and because of $\angle ABC = \angle BAD$, we have that $PE \parallel AB$ and similarly, $PD \parallel AC$.

From $BC \parallel DE \Longrightarrow \frac{AM}{AN} = \frac{XC}{XB}$, (2)

From the similar triangles $\triangle ABC,\ \triangle PED$ and because of $\angle BAX = \angle EPA$ and $\angle XAC = \angle APD$, we conclude that $\frac{XC}{XB} = \frac{AD}{AE}$, (3)

From $(2), (3) \Longrightarrow \frac{AM}{AN} = \frac{AD}{AE} \Longrightarrow \frac{AM}{MD} = \frac{AN}{NE}$, (4) and the proof is completed.

Kostas Vittas.

Attachments:
t=258337(a).pdf (11kb)

Luis González

#5 Feb 20, 2009, 1:02 am

We define rectangular coordinates as follow

$A : (b, h)$, $F : (0, h)$, $B : (c, h)$, $C : (a, 0)$, $D : (-a, 0)$

Coordinates of the circumcenters O_1 and O_2 of $\triangle AFB$ and $\triangle BFC$ are given by

$$O_1\left(\frac{b}{2}\ ,\ -\frac{a(a+b)}{2h} + \frac{h}{2}\right)\ ,\ O_2\left(\frac{c}{2}\ ,\ \frac{a(c-a)}{2h} + \frac{h}{2}\right)$$

$$\Longrightarrow \delta\overline{O_1O_2} = \frac{a(b+c)}{h(c-b)}$$

Lines AC and BD intersect at $P\left(\frac{a(b+c)}{c-b+2a}\ ,\ \frac{2ah}{c-b+2a}\right)$

$$\Longrightarrow \delta\overline{FP} = \frac{\ldots}{a(a+b)} \Longrightarrow \delta\overline{O_1O_2} \cdot \delta\overline{FP} = -1,$$

which means that $O_1O_2 \perp FP \Longrightarrow FP$ is radical axis of $\odot(AMB), \odot(BMC)$

sunken rock

#6 Nov 4, 2009, 7:37 pm

Let (ADF) cuts AC at A and M while (BCF) cuts it at C and N. From CF = DF we get $\angle BFC = \angle AFD, hence \angle BNC = \angle AMD$ (1), i.e. BN || DM, consequently $\frac{NE}{ME} = \frac{BE}{DE}$ (2), but $\frac{BE}{DE} = \frac{AE}{CE}$ (3), that is, $\frac{NE}{ME} = \frac{AE}{CE}$ (4). The relation (4) shows that E belongs to the radical axis of the subject circles.

Best regards,
sunken rock

Quick Reply

High School Olympiads

m,k,d,h

Reply

stvs_f

#1 Feb 18, 2009, 1:20 am

Let AM,AH,AD are median, height and bisector of ABC triangle. Consider AK is symmetry of AM toward AD. Prove that:

$$\frac{MH}{AM}\cdot\frac{\sin BAK}{\sin KAM}=\frac{AB}{BC}$$

stvs_f

#2 Feb 19, 2009, 9:23 am

any solution????

Luis González

#3 Feb 19, 2009, 10:24 am

Let the tangents of the circumcircle $\odot(ABC)$ at B, C meet at P. $AP \equiv AK$ is the A-symmedian of $\triangle ABC$.

Substituting $\frac{BK}{KM}=\frac{\sin \widehat{BAK}}{\sin \widehat{KAM}}\cdot\frac{AB}{AM}$ and $\frac{MH}{KM}=\frac{PA}{PK}\Longrightarrow\frac{PA}{PK}=\frac{AB^2}{BC\cdot BK}\ (\star)$.

On the other hand, we get $\frac{PA}{PK}=\frac{AC}{CK}\cdot\frac{\sin \widehat{PCA}}{\sin \widehat{PCK}}=\frac{AC}{CK}\cdot\frac{\sin \widehat{B}}{\sin \widehat{A}}=\frac{AC^2}{CK\cdot BC}$.

Hence, combining with the expression $(\star)$ gives $\frac{CK}{BK}=\frac{AC^2}{AB^2}$, which is well-known identity of the A-symmedian.

Quick Reply

High School Olympiads

Ineq about sum of the medians in triangle

Reply

SUPERMAN2
#1 Feb 18, 2009, 9:43 pm

I think it is not difficult(only use some theorems),try it now!
Given triangle ABC.m_a, m_b, m_c is the length of the medians from vertex A,B,C.
Prove that $m_a + m_b + m_c$≤4R+r

Dr Sonnhard Graubner
#2 Feb 19, 2009, 2:55 am

hello, let d_a, d_b and d_c be the distance of the circmcentre from the sides BC, CA and AB respectively we have
$m_a \le R + d_a$
$m_b \le R + d_b$
$m_c \le R + d_c$
adding these three inequalities we have
$m_a + m_b + m_c \le 3R + d_a + d_b + d_c$ (1)
Further we get $d_a + d_b + d_c = R(\cos(\alpha) + \cos(\beta) + \cos(\gamma)) = R(1 + \frac{r}{R})$ (2)
Inserting (2) in (1) we get $m_a + m_b + m_c \le 4R + r$, this was to prove.
Sonnhard.

Luis González
#3 Feb 19, 2009, 7:41 am

I found another interesting result (for acute triangles ABC)

$$\sqrt{6\sqrt{3}rp + \frac{3}{2}(p^2 - r^2) - 6Rr} \le m_a + m_b + m_c \le 4R + r$$

Luis González
#4 Feb 19, 2009, 8:51 am

> *Dr Sonnhard Graubner wrote:*
> $d_a + d_b + d_c = R(\cos(\alpha) + \cos(\beta) + \cos(\gamma)) = R(1 + \frac{r}{R})$

This is only true for acute triangles.

Quick Reply

High School Olympiads

P>2D

Reply

Source: Baltic Way 1992 #18

gwen01

#1 Feb 18, 2009, 8:09 pm

Show that in a non-obtuse triangle the perimeter of the triangle is always greater than two times the diameter of the circumcircle.

Luis González

#2 Feb 18, 2009, 11:15 pm

When $\triangle ABC$ is right-angled, the inequality is trivial, thus we assume that $\triangle ABC$ is acute. Let D,E,F denote the midpoints of $BC,CA,AB.$ Since O becomes orthocenter of $\triangle DEF$ (also acute) then O is inside of it $\Longrightarrow O$ is inside the quadrilateral $BFEC,$ thus $BF+FE+EC>BO+OC \Longrightarrow a+b+c>4R \Longrightarrow$ perimeter of $\triangle ABC$ is greater than two times its circumcircle diameter.

Quick Reply

High School Olympiads

Very interesting collinear problem:)

Reply

mathVNpro

#1 Feb 17, 2009, 1:52 pm

Let ABC be the acute triangle. M is its medians' intersection, H is its orthocenter. The lines perpendicular to MA, MB, MC by A, B, C intersects each other at A1, B1, C1. G is A1B1C1's medians' intersection. Prove that H, G, M are collinear.

mathVNpro

#2 Feb 18, 2009, 7:15 pm

Nobody can!! What a pity:D

limsk1

#3 Feb 18, 2009, 9:44 pm

I solved it by complex number but too long

Luis González

#4 Feb 18, 2009, 10:52 pm

We basically have to prove that the symmedian point is the centroid of its pedal triangle. Thus, let us prove the following lemma

Lemma: Let P be a point in the plane of $\triangle ABC$ and $\triangle XYZ$ its pedal triangle. $X \in BC, Y \in CA, Z \in AB.$ Then P is the centroid of $\triangle XYZ,$ if and only if P coincides with the symmedian point of $\triangle ABC.$

$$\frac{[\triangle PXY]}{[\triangle ABC]} = \frac{PX \cdot PY}{BC \cdot CA} \ , \ \frac{[\triangle PXZ]}{[\triangle ABC]} = \frac{PX \cdot PZ}{BC \cdot AB}$$

Thus, $[\triangle PXY] = [\triangle PXZ] \Longleftrightarrow \frac{PY}{PZ} = \frac{CA}{BA} \Longleftrightarrow P$ moves of the A-symmedian of $\triangle ABC.$ By similar reasoning, loci of points P such that $[\triangle PYZ] = [\triangle PYX]$ and $[\triangle PZY] = [\triangle PZX]$ are the B- and C- symmedian of $\triangle ABC.$ Consequently, the symmedian point K of $\triangle ABC$ is the unique point that satisfies

$[\triangle KXY] = [\triangle KYZ] = [\triangle KZX] \Longrightarrow K$ is the centroid of $\triangle XYZ.$

Mashimaru

#5 Feb 18, 2009, 11:02 pm

Consider $\triangle A_1B_1C_1$ and point M, we have ABC is the pedal triangle of M wrt $\triangle A_1B_1C_1$ and M is the centroid of $\triangle ABC$, i.e., M is the Lemoine's point (or the sym-median point) of $\triangle A_1B_1C_1$. Thus, if O is the circumcenter of $\triangle ABC$, we deduce, by the property of Lemoine's point, that O is the midpoint of MG.

With this, the problem is solved.

P/S: In order to prove the properties of the Lemoine's point of $\triangle ABC$, you can also apply its bary-centric ratios, but there is of course a synthetic proof for them.

plane geometry

#6 Feb 19, 2009, 6:21 am

with http://www.mathlinks.ro/viewtopic.php?t=228911 we conclude G=O,where O is the circumcenter of triangle ABC , thus we are done

PS:
Hi,Mashimaru:
Are you sure about that?
I think O=G,but not O is the midpoint of MG

No Reason

#7 Feb 19, 2009, 10:20 pm

No,Mashimaru was right.Because Lemoine point and centroid of $A_1B_1C_1$ are isogonal conjugate wrt $A_1B_1C_1$ then the midpoint O' of them pass through vertices of their pedal triangles.Obviously $O' \equiv O$

Quick Reply

High School Olympiads

a nice problem!

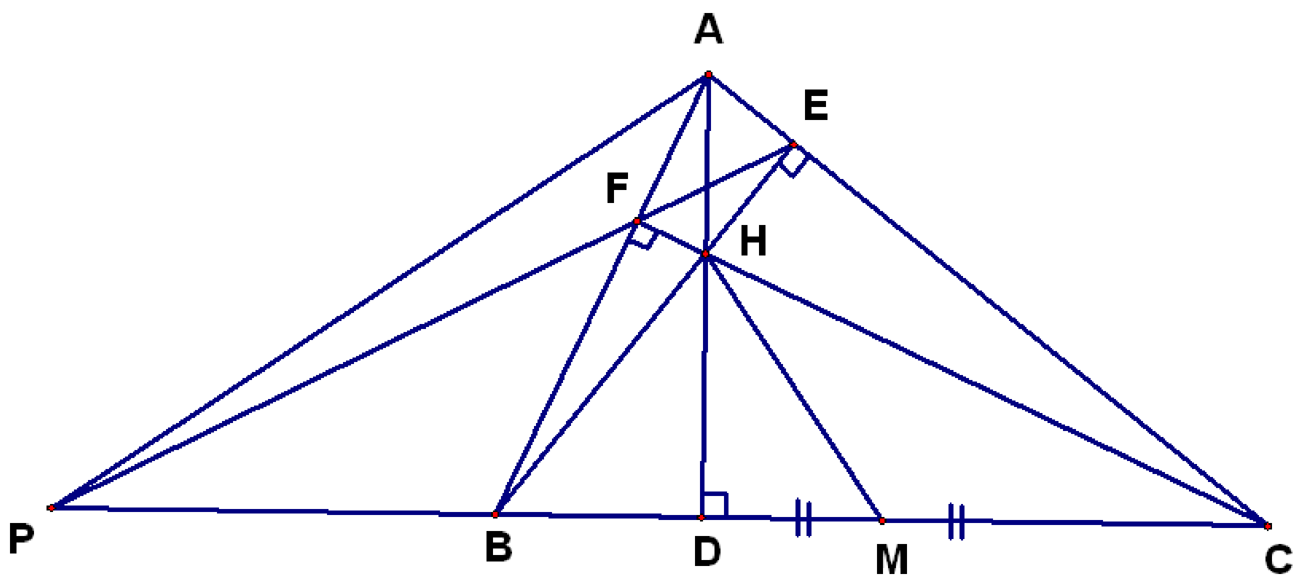
Reply

thanhnam2902

#1 Feb 17, 2009, 8:53 pm

Let ABC is a triangle. Let D is a point on BC and $AD \perp BC$, let E is a point on CA and $BE \perp CA$, let F is a point on AB and $CF \perp AB$. Let H is orthocenter of ABC triangle. Let M is midpoint of BC. Let EF meet BC at P. Prove that $MH \perp AP$.

Attachments:



shobber

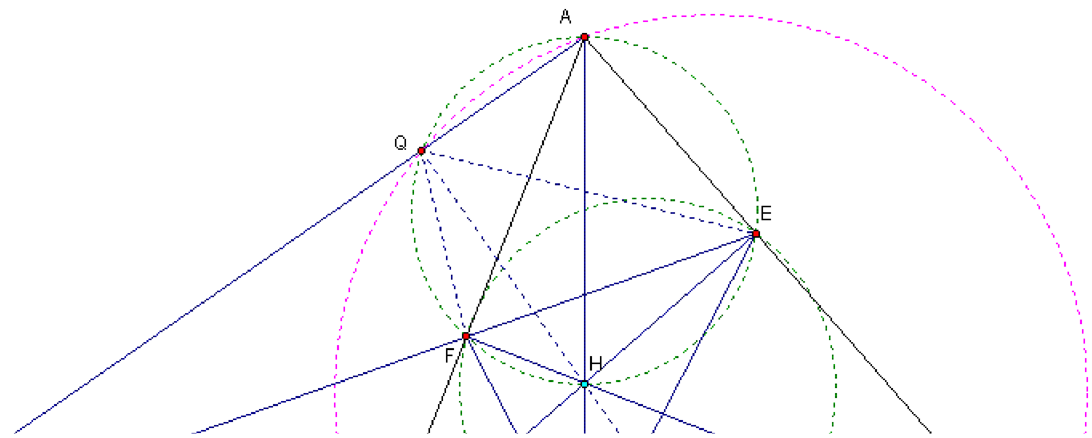
#2 Feb 17, 2009, 9:28 pm

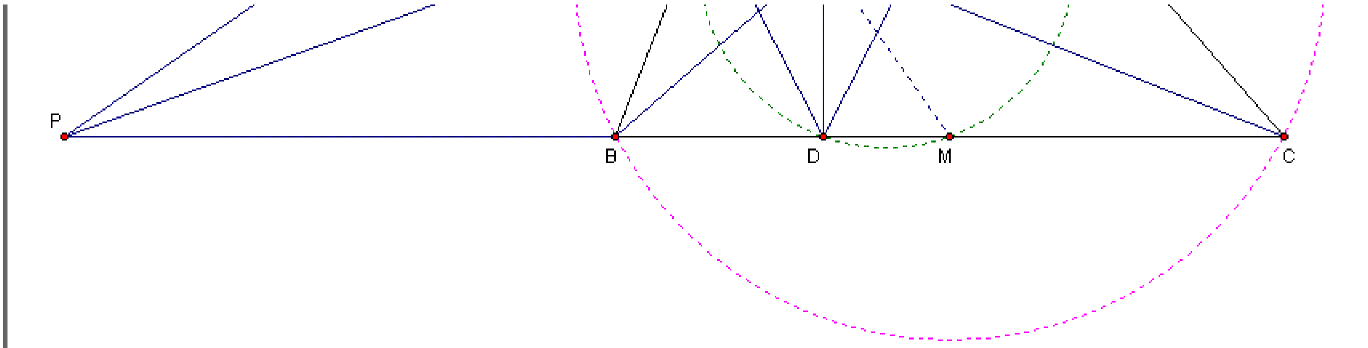
Let Q be the intersection of AP and the circumcircle of $\triangle ABC$.

$PQ \cdot PA = PB \cdot PC = PF \cdot PE$, so A, Q, F and E are concyclic. Since H is on the circumcircle of $\triangle AEF$, so A, Q, H and E are concyclic, which gives $AQ \perp HQ$.

By the Nine Point Circle theorem, M is on the circumcircle of $\triangle EFD$. So $PD \cdot PM = PF \cdot PE = PQ \cdot PA$. Hence A, Q, D and M are concyclic. So $MQ \perp AQ$. Hence Q, H and M are collinear, which means $HM \perp AP$.

Attachments:





thanhnam2902

#3 Feb 17, 2009, 9:45 pm

Thank you very much. Your solution very nice, I think we can be done this problem by ues harmonic. So it's a nice proof.

Luis González

#4 Feb 18, 2009, 12:49 am

Since the pencils $A(B,C,H,P)$ and $P(C,E,H,A)$ are obviously harmonic, it follows that line AP is the polar of the intersection H of the diagonals of the quadrilateral $BCEF$. Now, it's well known that the line connecting the center of the circle and the pole is perpendicular to the polar $\Longrightarrow MH \perp AP$, as desired.

P.S. An alternate way is using barycentric coordinates.

thanhnam2902

#5 Feb 18, 2009, 11:20 am

Yes. I proved this problem by barycentric coordinates because it's easy. But it's for only hight school of VietNam. So I want find other way to prove this problem.

Quick Reply

High School Olympiads

Prove APRQ a Parallelogram

Source: IMO Shortlist 1983: BEL 5

Moonmathpi496
#1 Feb 16, 2009, 12:17 am

On the sides of the triangle ABC, three similar isosceles triangles $ABP\,(AP = PB)$, $AQC\,(AQ = QC)$, and $BRC\,(BR = RC)$ are constructed.
The first two are constructed externally to the triangle ABC, but the third is placed in the same half-plane determined by the line BC as the triangle ABC.
Prove that $APRQ$ is a parallelogram.

SaYaT
#2 Feb 16, 2009, 6:34 pm

> *Moonmathpi496 wrote:*
> On the sides of the triangle ABC, three similar isosceles triangles $ABP\,(AP = PB)$, $AQC\,(AQ = QC)$, and $BRC\,(BR = RC)$ are constructed.
> The first two are constructed externally to the triangle ABC, but the third is placed in the same half-plane determined by the line BC as the triangle ABC.
> Prove that $APRQ$ is a parallelogram.

Let's $\angle BAC = \alpha$, $\angle ABC = \beta$, $\angle ACB = \gamma$, $\angle RCB = x$, $BC = a$, $AC = b$, $AB = c$
We have that
$\angle QCR = \gamma$
$\angle PBR = \beta$
$AQ = CQ = \dfrac{b}{2cos(x)}$
$AP = BP = \dfrac{c}{2cos(x)}$
$CR = BR = \dfrac{a}{2cos(x)}$
$QR = \sqrt{\dfrac{a^2 + b^2 - 2ab\cdot cos(\gamma)}{4cos^2(x)}} = \dfrac{c}{2cos(x)} = AP$
$PR = \sqrt{\dfrac{a^2 + c^2 - 2ac\cdot cos(\beta)}{4cos^2(x)}} = \dfrac{b}{2cos(x)} = AQ$
So $\triangle QRC$ and $\triangle PBR$ equal to each other and similiar to $\triangle ABC$
here we have few cases(depending on situation of points A,R), but in both cases we have that $\angle QAC = \angle QRC$ and equal to $2x + \alpha$ or $180 + \beta + \gamma - 2x$
Finally we have $QR = AP$, $AQ = PR$ and $\angle QAP = \angle QRP$, so therefore $APRQ$ is a parallelogram.

Mashimaru
#3 Feb 16, 2009, 9:08 pm

We can solve this problem in a more synthetic way:

We have: $\widehat{PBR} = \widehat{RBC} + \widehat{PBR} = \widehat{ABC}$

And: $\dfrac{BP}{BA} = \dfrac{BR}{BC}$ (<---- At here, why can't I see the LaTeX equation???)

So, we deduce that $\triangle BPR \sim \triangle BAC$
$\Rightarrow \frac{PR}{AC} = \frac{BR}{BC} = \frac{CR}{BC} = \frac{CQ}{AC} \Rightarrow PR = AQ$.

Similarly, $QR = AP$. Thus, $APRQ$ is a parallelogram and we are done.

Luis González

#4 Feb 16, 2009, 11:42 pm

$\angle PBA = \angle RBC$ and $\frac{BP}{BR} = \frac{BA}{BC} \Longrightarrow \triangle BRP \sim \triangle BCA$

$\Longrightarrow \frac{RP}{AC} = \frac{BP}{AB} = \frac{AQ}{AC} \Longrightarrow RP = AQ$

Similar reasoning yields $RQ = AP \Longrightarrow APRQ$ is a parallelogram.

sunken rock

#5 Mar 18, 2009, 4:26 pm

The property holds for any APB, CRB and CQA similar triangles, not necessarily isosceles. If the angles PAB, RCB and ACQ are equal, then the triangles QRC and ABC are spirally similar, which gives AP and QR equal and parallel.

Note: this is quite an ancient problem!

Best regards,
sunken rock

yetti

#6 Mar 18, 2009, 7:58 pm

This is special case of http://www.mathlinks.ro/viewtopic.php?t=109435 for quadrilateral ABCD degenerated to triangle ABC by A = D.

vittasko

#7 Mar 20, 2009, 4:46 am

GENERAL PROBLEM. – A triangle $\triangle ABC$ is given and let $\triangle PAB,\ \triangle QCA,\ \triangle RCB$ be, three similar triangles, with $\angle PAB = \angle QCA = \angle RCB = \angle\omega$ and $\angle P = \angle Q = \angle R = \angle\varphi$, erected on $AB,\ AC,\ BC$ respectively, such that $\triangle PAB,\ \triangle QCA$ to be outwardly to $\triangle ABC$ and $\triangle RCB$, inwardly to it. Prove that the quadrilateral $APRQ$, is a parallelogram.

PROOF. – Let (O_1) be, the circumcircle of the triangles $\triangle RCB$, and we denote the point $K \equiv AB \cap (O_1)$.

From $\angle BKC = \angle BRC = \angle AQC = \angle\varphi$, we have that the quadrilateral $AKQC$ is cyclic with circumcircle so be it (O_2) and then, from $\angle RKB = \angle RCB = \angle QCA = \angle\omega$, we conclude that the points $R,\ K,\ Q$, are collinear.

We draw the line through the point C and parallel to AB, which intersects the circles $(O_1),\ (O_2)$, at points $X,\ Y$, respectively.

We denote the point S on RX, such that $QS \parallel AB$ and we will prove that $QS \parallel = AB$.

• It is easy to show that the quadrilateral $QSXY$ is a parallelogram, from $QS \parallel XY$ and $\angle RXC = \angle CKQ = \angle QYY'$ $\Longrightarrow SX \parallel QY$.

So, we have that $QS \parallel = XY$, (1)

Similarly, it is easy to show that the quadrilateral $ABXY$ is a parallelogram, from $AB \parallel XY$ and from $BX = KC = AY$ (from the trapeziums $BXCK$ and $ACYK$) and $\angle AYX = \angle AKC = \angle ABX$, (2)

So, we have $AB \parallel = XY$, (3)

From $(1),\ (3) \Longrightarrow QS \parallel = AB$, (4)

• Because of now $\angle RBX = \angle KBC$, (5) (from $RX = KC$) we conclude that $\angle SRQ = \angle RBC = \angle\varphi$ and then

● Because of now, $\angle BKX = \angle KKC$, (5) (from $BX = KC$), we conclude that $\angle SKQ = \angle BKC = \angle\varphi$ and then, because of $\angle PAB = \angle RQS = \angle\omega$ (from $\angle RKB = \angle\omega$ and $QS \parallel AB$), we have also, $\angle PBA = \angle RSQ$, (6)

Hence, because of $AB \parallel= QS,$ we conclude that the triangles $\triangle PAB,\ \triangle RQS$ are congruent, with their homologous side-segments, parallel each other.

That is, we have that $AP \parallel= QR$, (7)

From (7) we conclude that the quadrilateral $APRQ$ is a parallelogram and the proof is completed.

REMARK. – As an interesting remark, we can say that from the similar triangles $\triangle RQS,\ \triangle QCA,$ we have that $\dfrac{QR}{QS} = \dfrac{QC}{QA} = u$, (8)

From $(8) \Longrightarrow QR = u\cdot QS = u\cdot AB = constant$, (9)

That is, if we consider AB as a fixed segment and $C,$ as a mobile point in the plane then, for the similar triangles $\triangle QCA,\ \triangle RCB,$ with $\angle QAC = \angle RCB = \angle\omega$ and $\angle Q = \angle R = \angle\varphi,$ where $\angle\omega,\ \angle\varphi$ are constant, erected on $AC,\ BC$ rerspectively, such that the triangle $\triangle QCA$ to be outwardly to $\triangle ABC$ and the triangle $\triangle RCB$ to be inwardly to it, it is true always the result of $QR = u\cdot AB,$ where $u = \dfrac{QC}{AC} = \dfrac{RC}{BC}$ and the angle formed by the line segments $QR,\ AB,$ is equal to $\angle\omega.$

● As a direct application of this interesting result, we can have an easy proof of the problem Prove that it is parallelogram.

Kostas Vittas.

Attachments:
t=258422.pdf (9kb)

Quick Reply

High School Olympiads

Triangle inequality

Reply

Source: 0

Luis González

#1 Feb 14, 2009, 12:08 pm

Prove for any triangle $\triangle ABC$ with inradius r and semiperimeter p, the following inequality:

$$1225\left(\frac{p}{r}\right)^2+729\left(\frac{r}{p}\right)^2\ge 33102$$

Luis González

#2 Feb 15, 2009, 10:56 am

Ok, here is my solution:

From $2p^2\ge 27Rr$ and Weitzenbock $p^2+4Rr+r^2\ge 4\sqrt{3}p^2$, we have

$$\frac{27}{4}p^2+27Rr+\frac{27}{4}r^2+2p^2\ge 27\sqrt{3}rp+27Rr$$

$$\Longrightarrow\ 35\cdot\frac{p}{r}+27\cdot\frac{r}{p}\ge 108\sqrt{3}$$

$$\Longrightarrow\ 1225\left(\frac{p}{r}\right)^2+729\left(\frac{r}{p}\right)^2\ge 33102.$$

encyclopedia

#3 Feb 24, 2009, 10:12 am

I think it is not nice,

we have $p\ge 3\sqrt{3}r, p^2\ge 27r^2$ so

$$1225\left(\frac{p}{r}\right)^2+729\left(\frac{r}{p}\right)^2=1224\frac{p^2}{r^2}+\frac{p^2}{r^2}+27^2\frac{r^2}{p^2}\ge 1224.27+2\sqrt{\frac{p^2}{r^2}27^2\frac{r^2}{p^2}}=33048+2.27=33102$$

we are done.

Quick Reply

High School Olympiads

A property of polars and circles

Reply

Source: 0

Luis González

#1 Feb 15, 2009, 7:18 am

Prove synthetically the following theorem:

Two fixed circles $\mathcal{K}$ and $\mathcal{K}'$ are given in the plane. The polar of all points lying on $\mathcal{K}$ with respect to $\mathcal{K}'$ are tangent to a single conic $\mathcal{H}$. Such a conic is known as polar conic of $\mathcal{K}$ with respect to $\mathcal{K}'$.

yetti

#2 Mar 2, 2009, 1:13 pm

Let a be polar of $A \in (P)$ WRT (O). Foot of perpendicular from O to a is on the inversion image (P') of (P) WRT (O), therefore a is tangent to a conic with one focus O and pedal circle (P'). In addition, the pole T of a tangent t of (P) at A is the tangency point of the polar a with this conic. One directrix of this conic is polar p of the circle center P WRT (O).

See Yaglom's Geometric Transformation III, p. 75 (English translation).

Quick Reply

High School Olympiads

Sum of radii in a triangle

Source: 0

Luis González

#1 Feb 15, 2009, 6:35 am

Let $\triangle ABC$ be an acute-angled triangle with perimeter $2s$. r_a, r_b, r_c denote the radii of its excircles against A, B, C. H is the orthocenter of $\triangle ABC$ and $\sigma_a, \sigma_b, \sigma_c$ denote the radii of the incircles of $\triangle HBC, \triangle HCA, \triangle HAB$. Prove synthetically the relation

$$\sigma_a + \sigma_b + \sigma_c + r_a + r_b + r_c = 2s$$

yetti

#2 Mar 3, 2009, 5:15 am

$a = BC, b = CA, c = AB$. R is circumradius, r inradius, r_a, r_b, r_c the A-, B-, C-exradii, and s semiperimeter of $\triangle ABC$. $\varrho_a, \varrho_b, \varrho_c$ are inradii and $\sigma_a, \sigma_b, \sigma_c$ semiperimeters of $\triangle HBC, \triangle HCA, \triangle HAB$.

$$R(\cos A + \cos B + \cos C) = R + r,$$
$$R(\cos A - \cos B - \cos C) = R - r_a.$$

Using these equations yields

$$\sigma_a = \frac{2R(\cos B + \cos C) + a}{2} = \frac{r_a + r + a}{2},$$
$$\varrho_a = (\sigma_a - a)\tan\frac{\widehat{CHB}}{2} = \frac{r_a + r - a}{2\tan\frac{A}{2}} = \frac{2s - a - 4R\cos^2\frac{A}{2}}{2} = s - \frac{a}{2} - R(1 + \cos A).$$

Cyclic sum is

$$\sum_{\odot} \varrho_a = 3s - s - 3R - R\sum_{\odot} \cos A = 2s - \sum_{\odot} r_a.$$

Links

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