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Bilingual Mathematics Education and Mathematical Olympiads

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Abstract

In July 2012, the U.S. team finished third in the 53rd International Mathematical Olympiad (IMO), after the South Korean team and the Chinese team. Greece won an individual gold medal for the 2nd consecutive year. In recent years, the U.S. IMO team has 50% of the first-generation or second-generation Asian (such as China, South Korea, India, Vietnam, etc.) or Europeans. These IMO team members are often bilingual and gifted students.
There has been a long history of mathematical competitions or challenges, starting in the ancient times. For example, around 300 B.C. in ancient Alexandria of Greece, Archimedes, in a letter to Eratosthenes, challenged him to solve the “Cattle Problem”.
Studying example problems of Mathematical Olympiads from different countries is not only to train problem solvers, but also to develop these young minds to become successful problem solvers in their future career challenges.

This paper will focus on the mathematics education in relation to the Mathematical Olympiads, and the discussion will include countries such as U.S., China, Russia, South Korea and Greece. China has won first place 17 times in the IMO, and Chinese IMO team members have won more than 100 individual gold medals. Because the author, Youyu Phillips, is bilingual in both English and Chinese, she translates and compares mathematics between Chinese and English. Sample problems of Chinese Mathematical Olympiads will be analyzed.

Keywords:
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Introduction

Many European countries mandate the teaching of two languages in high school. Although Spanish is a second language course in U.S. schools, less than half of U.S. middle and high schools offer other foreign language courses, e.g. Chinese, Korean, Japanese, Greek, Arabic, Portuguese, etc. Since 1994, there have been more than 300 Chinese language schools in the U.S. operating on Saturdays and Sundays with over 60,000 student enrollments per semester. Chinese language schools in the U.S. offer Chinese language classes as well as preparatory classes for standardized tests such as SAT mathematics, SAT Chinese and AP Chinese classes. Some American middle or high school students take both Chinese language classes and SAT mathematics classes. However, these students typically learn mathematics and sciences in English. The author, Youyu Phillips, has been teaching Mathematics at Keystone College since 2002, Mathematics throughout History at Keystone College since 2003, Mathematics Education and Methods at Keystone College since 2009. Dr. Phillips, is bilingual in both English and Chinese, thus she translates and compares mathematics between Chinese and English. Dr. Phillips has also taught SAT Mathematics at Guanghua Chinese School (Sundays) in 2010-2013, and Chinese Language and Culture at Guanghua Chinese School (Sundays) in 2003-2013.

Bilingual students may consider reading explanations of sample problems of Mathematical Olympiads in languages other than English: Chinese, Russian, Korean, Greek, as examples. This will help bilingual students understand the English meaning of original languages. An example of this is when an English/Chinese bilingual student first hears “Qiu Zhi” meaning evaluating; the student may confuse it with looking for a job because the two share the same pronunciation. In the Cartesian coordinate system, a quadrant in Chinese is “Xiang Xian”; a bilingual student may think it is associated to an elephant which is exactly the same writing and pronunciation.

History of Mathematical Olympiads

There have been mathematics competitions or challenges since ancient times. For example, in 200 B.C., Archimedes, the ancient Greek, wrote a letter addressed to Eratosthenes to solve the "Cattle Problem" as a challenge. The cattle problem was to find smallest number of bulls and cows under certain conditions. The problem remained unsolved for 2000 years and was finally solved in 1965 at the University of Waterloo in Canada (Devlin, 2004). Another example is the early sixteenth century Italian Tartaglia and Cardano’s student, Ferrari, competing on August 10, 1518 to solve the cubic equation, with Ferrari declared the winner. Cardano and Ferrari also worked out how to solve the quartic equations. However, they were not the first to solve such equations: the Chinese mathematician, Qin Jiushao, in his “Mathematical Treaties in Nine Sections” solved cubic and quartic equations as early as in

1245. Three years later, China's Li Ye solved cubic, quartic, quintic and even polynomial equations of 6^{th} degree in his "Sea Mirror of Circle Measurements" in 1248.

Mathematical Olympiad originated in Russia (then Soviet Union). From 1934 to 1935, the former Soviet Union started middle school mathematics competitions which were held in Leningrad and Moscow. These competitions were given the name Mathematical Olympiad in 1934 (Kenderov, 2009).

Later on, the first session of the International Mathematical Olympiad (IMO) was held in Bucharest, Romania, in 1959. After that first session, the IMO was held annually (except for 1980, as security issues in Mongolia canceled the IMOs). In the process of the competition, thousands of high school students first participate in National Mathematical Olympiad competitions within their own countries (about 100 countries), with six elected high school students representing each country in the International Mathematical Olympiad competition that year.

Historically, mathematics competitions have been much more popular in Russia than in the U.S. The main difference of mathematics competition between Russia and the U.S. is the types of questions; the competitions in the U.S. are usually multiple choices, while Russian questions are mostly self produced (Formin and Kirchenko, 1994). In Russia (former Soviet Union), High School Mathematical Olympiad questions often combine algebra, geometry, and trigonometry. The following example was selected from the 14th former Soviet Union Mathematical Olympiad which was held in Belarus in 1964:(http://www.problems.ru/view_problem_details_new.php? id=109006)

A triangle has side lengths a, b, c and $m\angle A = 60^o$. Show that

$$\frac{3}{a+b+c} = \frac{1}{a+b} + \frac{1}{a+c}$$

Proof Using the law of cosines

$$a^2 = b^2 + c^2 - 2bc\cos A, \text{ and } \cos A = \cos 60^\circ = \frac{1}{2}.$$

Then $a^2 = b^2 + c^2 - 2bc\left(\frac{1}{2}\right) = b^2 + c^2 - bc$

$$a^2 + bc = b^2 + c^2$$

$$2a^2 + 3bc + 2ab + 2ac = (a+b+c)^2$$

$$3a^2 + 3bc + 3ab + 3ac = (a+b+c)^2 + a(a+b+c)$$

$$3a(a+b) + 3c(a+b) = (a+b+c)(2a+b+c)$$

$$\frac{3}{a+b+c} = \frac{2a+b+c}{(a+b)(a+c)} = \frac{a+c}{(a+b)(a+c)} + \frac{a+b}{(a+b)(a+c)}$$

$$Thus\ \frac{3}{a+b+c} = \frac{1}{a+b} + \frac{1}{a+c}$$

In fact, this is an algebra problem, despite being rooted in geometry. The given angle 60^o prompted the use of Trigonometry's special angle property. Students can deduce the result by using the law of Cosines. Learning this type of Mathematical Olympiad questions can help students understand that mathematics is a whole, and algebra, geometry, trigonometry, etc. are closely interrelated.

Mathematical Testing in China, U.S.A. Russia, and South Korea

China has a different mathematical education system than that of the U.S. Chinese primary school mathematics teachers are typically mathematics specialists (Phillips, 2008), while primary school teachers in the U.S. tend to teach all possible subjects. In Pennsylvania, primary school teachers are required to pass a PRAXIS I mathematics proficiency test which has only multiple-choice questions. Specializing specifically in mathematics, Chinese primary school teachers tend to be stronger in mathematics than their American counterparts. In Pennsylvania, secondary school teachers are required to pass PRAXIS II mathematics proficiency test which is a two hour long, 50 multiple-choice questions test. The majority of U.S. high school teachers often provide inadequate guide for the high school students to participate in the mathematical competitions.

Usually 5 questions in China's annual university entrance mathematics examinations are similar to the question types of the Mathematical Olympiad competitions (Olson, 2004), e.g. Proofs. However, the secondary level mathematics Scholastic Aptitude Test (SAT) in the U.S., has all multiple-choice questions as well. Although the general level of the SAT mathematics examination has 10 mathematics problems that require self-produced answers/grid-in, there are no questions involving proofs. China's primary and secondary Mathematical Olympiads combine the question types of the U.S. and Russia: multiple-choice and verbal reasoning questions.

Research (Colangelo, et al, 2004) shows that gifted students tend to have strong curiosity and thirst for knowledge. They have rich imagination and a keen interest in learning. In the U.S. from 1958 to the present, the specialized agencies in charge of culture and talented students have been established. Schools in the U.S. often have a separate division of the gifted students who would be given special attention and nurturing. Despite defects in some aspects of basic education in the U.S. (Desmond, et al, 2004), the U.S. is very successful in nurturing gifted students. Each year, about 250 high score achievers in the American Mathematics Examination (AIME) are invited to participate in the United States of America Mathematical Olympiad (USAMO). Mathematics Examinations transform dramatically into the International Mathematical Olympiad Examination style - only text proofs.

The International Mathematical Olympiad (IMO) for high school students is an examination of 6 word problems, each of varying difficulty, held each year, and the competition lasts for 9 hours over two days, 4.5 hours per day to solve 3 problems, so the average for each question is an hour and a half. Each question is worth 7 points, 42 points for 6 word problems. Students answer questions in their countries' official languages, so language skills are important in learning mathematics and in the Mathematical Olympiads. IMO Jury's official languages are English, German, French and Russian. Table at the end of this paper is a list of mathematical terms in English, Chinese, Greek, German, French, Russian and Korean.

The U.S. had not participated in the International Mathematical Olympiad Contests until 1974. Since then, the U.S. team had been the first place winner four times (1977, 1981, 1986, and 1994). The U.S. team members have also won many individual gold medals; some American students have won the IMO individual gold medal for two consecutive years or many years. The 53rd International Mathematical Olympiad Competition was held in Mar del Plata, Argentina, on July 16, 2012. South Korea surpassed frequently triumphant China and won first place. The top winner was from the Seoul Science School (Oh, 2012). The U.S. team was the third, and Greece won an individual gold medal for the 2nd consecutive year, a Silver and three Bronze medals as well as an honorable mention.

Mathematics Competitions in China

The ancient Chinese imperial examination system lasted about one thousand three hundred years from Emperor Wudi of the Han Dynasty (165 B.C.) to Emperor Guangxu of the Qing Dynasty (1901). Mathematics competitions continue China's examination tradition every year (Bin and Lee, 2007-2008). China has won first place 17 times in the IMO, and Chinese IMO team members have won more than 100 individual gold medals. The following question was selected from China's Mathematical Olympiad National Contests for high school juniors (equivalent to U.S. Grade 9):

Suppose a quadratic equation $ax^2 + (a+2)x + 9a = 0$ has two unequal real roots, x_1, x_2, and $x_1 < 1 < x_2$, the the values of a must be (   ).

(A) $-\frac{2}{7} < a < \frac{2}{5}$ (B) $a > \frac{2}{5}$ (C) $a < -\frac{2}{7}$ (D) $-\frac{2}{11} < a < 0$

<u>Solution</u>

Use $(a+2)^2 - 4a(9a) > 0, (a+2)^2 - 36a^2 > 0, (a+2+6a)(a+2-6a) > 0;$ simp lify to

$$(7a+2)(2-5a) > 0; \text{ then } -\frac{2}{7} < a < \frac{2}{5}.$$ However, if one considers

$$x_1 + x_2 = -\frac{a+2}{a} = -1 - \frac{2}{a},\ x_1x_2 = \frac{9a}{a} = 9, \text{and } x_1 < 1 < x_2, \text{then } a < 0, \text{so (D)}$$

but this is not so persuasive. Below is a better way (Zhang, 2008) to reach the correct answer.

$a \neq 0$, the original equation can be changed to $x^2 + \left(1 + \frac{2}{a}\right)x + 9 = 0$, then the parabola opens upward.

Because $x_1 < 1 < x_2$, then when $x = 1$, $y < 0$, i.e. $1^2 + \left(1 + \frac{2}{a}\right)(1) + 9 < 0$,

so $-\frac{2}{11} < a < 0$, so (D).

Being able to read the Chinese explanation (or in a different language), students can connect languages and applications and thus appreciate the importance of language learning which benefits mathematics skill learning as well.

The following question was selected from the Wuhan CASIO Cup competition (Zhang, 2008) with the author's, i.e. Youyu Phillips' translation and explanation: Given that the graph of the linear function y = ax + b passes Quadrants I, II and III, and intersects the x-axis at (–2, 0), then the solution set of the inequality ax > b is (   ).

(A) x > –2   (B) x < –2   (C) x > 2   (D) x <2

<u>Solution</u> ∵ a > 0, 0 = a(–2) + b, b = 2a, ∴ the solution set ax > b is x > 2. Therefore the correct answer choice is (C). American students usually get to x > 0, and will choose (C) as well, but if students could truly understand the substitution x = –2 and y = 0 and continue further analysis, then their problem-solving skills would greatly improve.

The following Chinese Mathematical Olympiad example was selected from the 7th "Hope Cup" National Invitational Mathematics Competition exam (Zhang, 2008) with the author's, i.e. Youyu Phillips' translation and explanation: If $a > b$, and c < 0, then there exits the inequality below.

① $a + c > b + c$ ② $ac > bc$ ③ $-\frac{a}{c} > -\frac{b}{c}$ ④ $ac^2 < bc^2$

The number of correct inequalities is (   ).

(A) 1   (B) 2   (C) 3   (D) 4

<u>Solution</u> From the properties of inequalities, ① and ③ are correct. So choose (B).

The above examples do not have any figures, just letters, so that the students really understand the inequality terms multiplied or divided by a negative number, the inequality will change its direction (Phillips, 2012). The following example shows geometry (circular and triangular shapes), and the trigonometry are interrelated.

In the Figure at the end of this paper, in ΔABC, ∠BAC is an obtuse angle (Zhang, 2008), O is the orthocenter, AO=BC, then the value of cos∠BOF is (   ).

(A) $\frac{\sqrt{2}}{2}$ (B) $\frac{\sqrt{2}}{3}$ (C) $\frac{\sqrt{3}}{2}$ (D) $\frac{1}{2}$

Solution ∵ ΔABC is an obtuse triangle, ∴ orthocenter O is external of ΔABC.

∵ B, D, F, O are concyclic, ∴∠ CBF = ∠ AOF.

In ΔAOF and ΔCBF, ∠AOF = ∠CBF, ∠OFA = ∠ BFC = 90^o, OA = BC,

ΔAOF ≅ ΔCBF. $\overline{OF} = \overline{BF}$, ∠BOF = 45^o, ∴cos ∠BOF = $\frac{\sqrt{2}}{2}$.

Thus (A) is the correct answer.

Difficult mathematical problems tend to just be an amalgamation of mathematical concepts, unusual phrasing of the question, or hidden information that requires analysis. The ability to read the questions from the original language and understand the meaning of the keywords in the text is of great help for problem-solving (Phillips' Book Review, 2012). Students capable of abstract thinking and logical reasoning are very important for mathematical success, as well as lifelong success.

The following example was provided by Donghua University Graduate student, Ren Jia, indirectly.

(1) Prove the squares of odd natural numbers divided by 8 has a remainder 1.

(2) Prove 2006 cannot be expressed as the sum of the square of ten odd natural numbers.

Proof:

(1) Method 1.

Odd natural numbers are 2n +1, n is any natural number, then

$(2n+1)^2 = 4n^2 + 4n + 1 = 4n(n+1)+1 = 2n(2n+1)+1$.

2n and 2n +2 are two consecutive even natural numbers.

When n = 1, 2 and 4 are the two consecutive even natural numbers, 2 (4) +1 = 8 +1 divided by 8, the remainder is 1.

When n = 2, 4 and 6 are two consecutive even natural numbers, 4 (6) +1 = 3 (8) +1 divided by 8, the remainder is 1.

Suppose when n = k, $(2k+1)^2 = 2k(2k+2) + 1$ divided by 8, the remainder is 1, then when n = k +1,

$(2(k+1)+1)^2 = 2(k+1))(2(k+1)+2)+1 = (2k+2)(2k+4)+1 =$
$2k(2k+2)+4(2k+2)+1$

$=2k (2k + 2) + 8(k +1) +1$, and $2k(2k+2) + 1$ divided by 8, the remainder is 1,and so, when the squares of odd natural numbers are divided by 8, the remainder is 1.

The above method is Proof by Induction. China's junior high school students often use the following simple way to prove it instead.

Method 2.

The odd natural number is (2k +1)

The squares of the odd natural numbers are $(2k +1)^2 = 4k^2 + 4k + 1 = 4k(k +1) + 1$

If k is odd natural number, then k +1 is an even natural number, so 4k(k +1) +1 is divisible by 8, and the remainder is 1.

If k is an even natural number, then k +1 is an odd natural number, so 4k(k +1) +1 is also divisible by 8, and the remainder is 1.

$\therefore$ The square of an odd natural number is divisible by 8, and the remainder is 1.

(2) Ten odd numbers are 2(k+1) +1, 2(k+2) +1, 2(k+3) +1, 2(k+4) +1, 2(k+5) +1,

2(k+6) +1, 2(k+7) +1, 2(k+8) +1, 2(k+9) +1, 2(k+10) +1.

The sum of the squares of the ten odd natural numbers is $(2(k+1)+1)^2 + (2(k+2)+1)^2 + (2(k+3)+1)^2 + (2(k+4)+1)^2 + (2(k+5)+1)^2 + (2(k+6)+1)^2 + (2(k+7)+1)^2 + (2(k+8)+1)^2 + (2(k+9)+1)^2 + (2(k+10)+1)^2$ = 2k(2k + 2) + 8(k +1) +1 + 2(k+1)(2(k+1) + 2) + 8((k+1) +1) +1 + 2(k+2)(2(k+2) + 2) + 8(k+2) +1 + 2(k+3)(2(k+3) + 2) + 8((k+3)+1)+1 + 2(k+4)(2(k+4) + 2) + 8(k +4) +1 + 2(k+5)(2(k+5)+ 2) + 8((k+5) +1) +1 + 2(k+6)(2(k+6) + 2) + 8(k+6) +1+2(k+7)(2(k+7)+2) + 8((k+7) +1) +1 +2(k+8)(2(k+8)+2) + 8((k+8) +1) +1 + 2(k+9)(2(k+9)+2) + 8((k+9) +1) +1 (from Part 1, $(2(k+1)+1)^2$ = 2k (2k + 2) + 8(k +1) +1, divided by 8, the remainder is 1). Then the sum of the squares of the ten odd natural numbers divided by 8, the remainder is 10 (10×1=10), and 10 divided by 8, the remainder is 2. Thus the sum of the squares of the ten odd natural numbers divided by 8, the remainder is 2. However, 2006 divided by 8, the remainder is 6.

$\therefore$ 2006 cannot be expressed as the sum of the square of ten odd natural numbers.

Another example involving Proof is as follows.

(Tianjin Competition Question) There is (are) ________ natural number(s), n, which make(s) 2n(n+1)(n+2)(n+3)+12 able to be expressed as the sum of two squares of positive integers.

(A) none existed
(B) 1
(C) 2
(D) infinitely many

Solution:

$2(n^2+3n)(n^2+3n+2) + 12 = 2(n^2+3n+1-1)(n^2+3n+1+1) + 12 = 2(t-1)(t+1) + 12$

$=2(t^2-1)+12=2t^2+10=2(t^2+5) = 2((2k+1)^2+5)=2(4k^2+4k+6) = 4(2k^2+2k+3)$

where $t = n^2+3n+1$ and is an odd integer 2k +1, if it is the sum of two squares $x^2+y^2 = 4(2k^2+2k+3)$, then both x and y are even integers, u and v are odd integers.

x =2u, y =2v. $x^2+y^2=4(u^2+v^2)$, $u^2+v^2=\frac{x^2+y^2}{4}$ $=2k^2+2k+3$ which is an odd integer, but it cannot be odd, as u^2+v^2= odd + odd = even. There is a contradiction. Thus (A) none existed.

Mathematics is the Language of Science

Mathematical proofs reflect the practice of the students' overall understanding of mathematics and creativity. When students struggle to find the solution of mathematical problems, it is often because these students' mathematical foundation is not solid and these students often do not even understand what the problem asked exactly. The difficult issue is that studying some skills for mathematics tests is not equal to fully comprehending basic skills such as arithmetic and algebra. The knowledge of the basic skills in mathematics should be completely mastered.

Mathematics is a universal language. Mathematics is known to be the language of sciences. Language is not just ability, it is an art. Answering Mathematical Olympiad problems does not only require the mechanical memorization of formulas, and questions do not simply require substitution the values into the formula. Answering Mathematical Olympiad problems requires speculation and skillful mathematical manipulation. The student not only needs to possess patience, calmness, and persistence, but also needs to possess the inquisition to want to explore new domains. In our competitive society, the ability to rebound from failure and frustration to continue to progress is the start on the road to success.

Success in the Mathematical Olympiad is definitely not the only measure of success. The competition serves not mostly as an indicator of success, but actually as training for the students' visionary and abstract thinking. A person's creativity may be generated from any of the following: words, images, equations, situations, senses, dreams, inspirations, imaginations, feelings, and so on. Genius is a combination of talent, hard work, and opportunity. The success of many scientists, mathematicians, composers, painters, athletes, entrepreneurs, musicians and actors, in addition to the fact that they were found and received recognition, is because of hard work. They know how to devote themselves to study or long-term training, but also know how to relax their minds to rest physically and mentally, learning and absorbing new knowledge or new ideas or new methods. Accumulation of experience is an important part of the road to success. With open-minded attitude for new problems, new knowledge, and new methods, learning broadly will achieve more than before.

The research results show that innovative awareness and ability are first for all students. It is important to protect the students' curiosity and imagination. The 19th century German mathematician Gauss said, "Mathematics is the queen of all sciences". Young people may cultivate self-confidence in mathematics through learning and preparing for mathematics Olympiad. Applying and connecting mathematics to other subjects can broaden students' problem-solving aptitude which will stimulate their interest in mathematics, physics, and chemistry. One example of connections helping students in such manner is the logarithmic application for physics and chemistry.

Young students should receive their education in all possible subjects, (languages, mathematics, culture, history, geography, sports, dance, sciences, music, art…) so students will be developed in all aspects, and well developed in his or her most favorable subject. No matter what kind of job a young student grows up to hold, hope that he or she will be both beneficial and useful for a family and a society.

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Table. *Mathematical Terms in 7 Languages*

English	Chinese	Greek	German	French	Russian	Korean
Solve for the value	求值	Λύσει για την αξία	Lösen Sie für den Wert	Résoudre pour la valeur	Решите для значений	평가
Quadrant	象限	Τεταρτοκύκλι ο	quart de rond	QUART de Cercle	квадрант	사분면
Function	函数	λειτουργία	Funktion	fonction	функция	기능
System of Equations	方程组	Σύστημα των Εξισώσεων	System von Gleichungen	Système d'équations	Система уравнений	방정식의 시스템
Linear Functions	线性函数	γραμμικές συναρτήσει	lineare Funktionen	Les fonctions linéaires	Линейные функции	선형 함수
Quadratic Functions	二次函数	Τετραγωνικές Λειτουργίες	quadratische Funktionen	Fonctions du second degré	квадратичной функции	이차 함수
Straight Lines	直线	τ ευθεία	Gerade	ligne droite	Прямые линии	일직선
Parabolas	抛物线	παραβολή	Parabel	parabole	парабола	포물선
Real Number Solution /Root/Zero	实数根	Ρεάλ ρίζες	Wirklichen Wurzeln	Racines réelles	Реальные корни	실제 뿌리
Point of Intersection	交点	σημείο τομής	Schnittpunkt	point d'intersection	точка пересечения	교차로 지점
Increase	增大	Οι αυξήσεις	erhöht	augmente	Увеличивает	증가
Decrease	减小	Μειώσεις	verringert	diminue	Уменьшает	감소
Abscissa	横坐标	τετμημένη	Abszisse	abscisse	абсцисса	횡좌표
Ordinate	纵坐标	τεταγμένη	Ordinate	coordonner	ордината	종좌표
Integer	整数	ακέραιος αριθμός	ganze Zahl	entier	целое	정수
Odd Integer	奇数	περιττός ακέραιος	ungerade Ganzzahl	entier impair	нечетное число	이상한 정수
Even Integer	偶数	Ακόμα και Ακέραιοι	selbst Integer	même Entier	Даже Integer	도 정수
x-intercept	x轴截距	χ-τομής	x-Achsenabschni tt	abscisse à l'origine	Х-перехват	X-절편
y-intercept	y轴截距	y-τομής	y-Achsenabschni tt	ordonnée à l'origine	у-перехват	Y-절편
Pythagorean Theorem	勾股定理	Πυθαγόρειο Θεώρημα	Satz des Pythagoras	Théorème de Pythagore	теоремы Пифагора	피타고라스의 정리
Hypotenuse	斜边	υποτείνουσα	hipotenüs	hypoténuse	гипотенуза	빗변
Right Angle	直角	ορθή γωνία	rechter Winkel	angle droit	прямой угол	직각
Acute Angle	锐角	οξεία γωνία	spitzer Winkel	angle aigu	острый угол	예각
Obtuse Angle	钝角	αμβλεία γωνία	stumpfen Winkel	Angle obtus	тупой угол	둔각
Circle	圆	Κύκλος	Kreis	cercle	круг	원
Diameter	直径	Διάμετρος	Durchmesser	diamètre	диаметр	직경
Radius	半径	Ακτίνα	Halbmesser	rayon	радиус	반지름
Chord	弦	Χορδή	Akkord	corde	аккорд	현
Positive Number	正数	Θετική αριθμός	Positiv Zahl	nombre positif	Положительное число	정수
Negative Number	负数	Αρνητική αριθμός	Negative Zahl	nombre négatif	Отрицательные числа	음수

Trigonometric Function	三角函数	Τριγωνομετρικές Λειτουργία	Trigonometrische Funktion	Fonction trigonométrique	тригонометрические функции	삼각 함수
Sine	正弦	Ημίτονο	Sinus	sinus	синус	사인
Cosine	余弦	Συνημίτονο	Kosinus	cosinus	косинус	코사인
Tangent	正切	Εφαπτομένη	Tangente	tangente	касательный	접선
Cotangent	余切	Συνεφαπτομένη	Kotangens	cotangente	котангенс	코탄젠트
Secant	正割	Διατέμνων	Sekante	sécante	секущий	시컨트
Cosecant	余割	Συντεμνούσα	Kosekans	cosécante	косеканс	코시컨트

Figure. *ΔABC with orthocenter O*