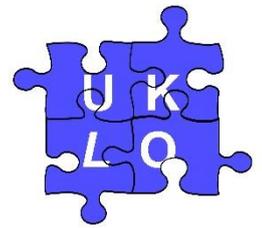


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Round 2 Problem 5. Magic Yup'ik

Central Alaskan Yup'ik belongs to the Eskimo-Aleut language family. It is spoken in western and southwestern Alaska by around 20,000 speakers. Yup'ik people have an interesting approach to counting: the words for the numbers can be broken down into meaningful parts which may be related to their body parts. For example, the word for five, *talliman*, means *one arm* and the word for six, *arvinlegen*, means *cross over*, as you need to change hand to go on counting.

Another interesting fact about the Yup'ik people is that their parkas often include geometrical patterns such as the 3x3 square shown below.

	1	2	3
a			
b			
c			

This problem is about an imaginary 'magic square' based on this pattern. In a magic square with nine cells, like this one, every cell contains one of the digits 1 to 9, every one of these digits is found in just one cell, and the sum of all the digits in every row, column, and diagonal is the same. In our magic square, the middle cell of the top row (i.e. cell 2a) contains the digit 9.

The clues in the next table will help you fill in the rest of the cells by defining each row and each column as a three-digit number which could also be defined in words as a complex number-phrase. For example the sequence of digits 1-2-3 defines the number 123, which can also be given in English by the number-phrase "One hundred and twenty three". The only snag is that the number-phrases in the table are in Yup'ik. HINT: The Yup'ik name for the number 294 is "yuinaat qula cetaman qula cetaman".

Across		Down	
a	Yuinaat yuinaq cetaman qula malruk	1	Yuinaat yuinaq atauciq akimiaq pingayun
b	Yuinaat akimiaq malruk akimiaq malruk	2	Yuinaat yuinaak malruk yuinaat malrunglegen qula atauciq
c	Yuinaat yuinaak malruk akimiaq atauciq	3	Yuinaat qula pingayun akimiaq atauciq

Q.5.1. Fill in the magic square on your answer sheet.

Q.5.2. Give the Yup'ik number-phrase for the number defined by the diagonal of cells 1a-2b-3c.

Q.5.3. Explain your answers.

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Problem 2.5 Magic Yup'ik (answer blank)

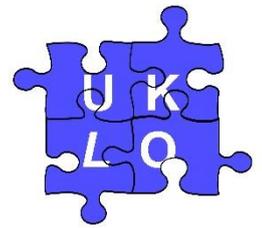
Q.5.1

	1	2	3
a		9	
b			
c			

Q.5.2 $1a + 2b + 3c =$

Q.5.3 Explanation (if you need more paper, ask for it – don't write on the back of this sheet!)

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Solution and marking.

Scoring (max 31)

- 5.1: 2 points for every correctly-filled cell. (max 16)
- 5.2: 1 point for every correct Yup'ik word. (max 5)
- 5.3: (max 10)
 - 3 points for a mathematical explanation of the magic square.
 - 5 points for a linguistic explanation of the Yup'ik number system.
 - 2 points for an explanation of how the clue numbers lead to the solution.

5.1

	1	2	3
a	4	9	2
b	3	5	7
c	8	1	6

5.2 Yuinaat yuinaq malruk akimiaq atauciq.

5.3 Explanation: see the commentary.

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Commentary (by the problem's author, Kai Low Rui Hao)

Candidates should recognize this as a mathematics problem and take into consideration the possibility of the spelling of numbers being represented in a different base (for example, in French, 99 is *quatre-vingt dix neuf*, which translates to $4 \times 20 + 10 + 9$).

There is only one possible type of 3-by-3 magic square, although there are 8 distinct configurations that stems from the one type due to rotation and reflection. These permutations are avoided due to the presence of the Yup'ik cross-number puzzle clues.

Since there are 9 digits, the numbers can be arranged via this formula

N-1	N+4	N-3
N-2	N	N+2
N+3	N-4	N+1

This formula takes into consideration 9 consecutive numbers, as well as the fact that the sum of every row, columns, and diagonals is the same – $3n$. Since the sum of each column is $3n$, the sum of three columns is $9n$. The sum from 1 to 9 is 45. Hence $9n = 45$, leaving us with $n=5$.

The answer to Task 1 is as above. Candidates may in the process arrive at the other 7 possible combinations. These permutations will be eliminated when checked against the yup'ik hints.

Since the question provided 2Down as a 3-digit number that starts with 9, and all numbers in the clues are 3-digit, and all Yup'ik numbers begin with Yuinaat, candidates have to consider that Yup'ik may be using a base larger than 10. The most common, in fact, is the Vigesimal system, which is base 20. This is also practical based on the background provided in the question – Yup'ik people based their concept of counting on body parts (20 fingers + toes).

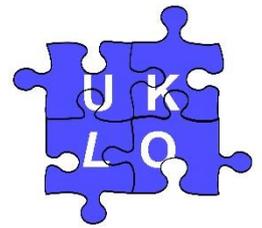
Despite the various permutations, candidates should be able to arrive at 2D, which is 951. Further attempts at solving the spelling will reveal that $951 = (20 \times 20 \times 2) + (20 \times 7) + (10 + 1)$. This is true to the base 20 system. Arriving at this conclusion will reveal:

1. Suffix -k: multiply by 2/double/to do with two (a dual number)
2. Suffix -t: multiply by more than 2 (a plural number)
3. Suffix -q: the root suffix.

If the word ends in suffix -q, it signifies to the candidate that the subsequent number should be an addition and not a multiplication.

Candidates can then work on 3Across, which is the next biggest number with $20 \times 20 \times 2$. Hence, the number, which is the second biggest after one starting with "9", should start with "8". This will lead to 3A being 816. Candidates can then associate *akimiaq atauciq* to 16. From the 2D, *atauciq* = 1, hence *akimiaq* is 15. This is a reasonable and valid guess since Yup'ik people pay attentions to numbers based on the hands and feet.

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Next, refer to 3D where candidates can make out $(20 \times (10+?)) + 16$. Given that diagonals also sum up to 15, we can gather 2 and then 7 from it being the remaining cell in 3D. Hence 3D is 276 and it is $(20 \times (10+3)) + 16$.

Knowing that *qula* = 10, *akimiaq* = 15, and that *malruk* = 2, *pingayun* = 3, we will be able to solve most of the magic square. The other number not mentioned is *cetaman* = 4.

Task 2: Yuinaat yuinaq malruk akimiaq atauciq.

The diagonal 1a-2b-3c is 456 and can be expressed in Yup'ik spelling as $(20 \times 20) + (20 \times 2) + 16$. However, notice from other clues that numbers below 800 are not phrased in this manner but more of $(20 \times 22) + 16$. Hence the number will be expressed as $(20 \times (20 + 2)) + 16$.