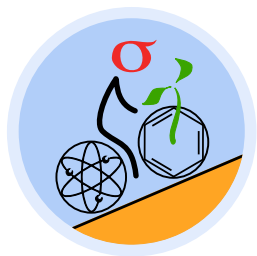**Collaborating with other applicants on QQ is prohibited.**

Using LLMs (ChatGPT, Claude, DeepSeek, etc.) or generative AI for QQ is also prohibited.

Violation of either of these rules will affect your admission.

SigmaCamp
Qualification Quiz 2025

This Qualification Quiz is only one part of your application to SigmaCamp. For full instructions, please check https://sigmacamp.org/2025/apply.

The Qualification Quiz contains two problems from each of the six main disciplines at Sigma – math, physics, chemistry, biology, computer science, and linguistics & applied sciences. The second problem in each category was designed to be more challenging than the first problem. **You are not expected to solve all the problems.** We will evaluate your quiz submission based on your approach to the problems and the quality of reasoning.

You can use the Internet, books and even help from someone (who is not another applicant), but **state precisely what sources you have used to solve each problem**. Note that you cannot post the problems to the Internet or other public forums and solicit help that way. **You are also not allowed to use any LLMs (ChatGPT, Claude, DeepSeek, etc.) to solve any of the problems.**

## You cannot collaborate with other applicants.

1. Your solutions should be submitted as `.pdf` files (except for Computer Science, which requires either `.py` or `.java` files).

2. Your solutions can be handwritten or typed. Handwritten solutions must be scanned as `.pdf` (not as `.jpg` or `.png`) files.

3. Submit at most one file per problem (at most two files per subject). Please don't combine the solutions for problems 1 and 2 of the same subject into one file, and also don't combine the solutions across subjects.

4. If you were accepted to SigmaCamp through the Problem of the Month contest (POM), you do not need to submit the QQ. **If you participated in POM, but were not admitted among the top scorers, your effort will not be forgotten: 35% of your total POM score will be added to your QQ score.**

The application deadline is April 15, 2025 – all your materials (Qualification Quiz, essay, letters of recommendation) must be submitted by that date. We will notify all applicants no later than May 5, 2025.

Good luck with your application!

Mathematics

For all mathematics problems, please provide full justification. **Do not include any code** in your submission — all code submissions will be awarded no points.
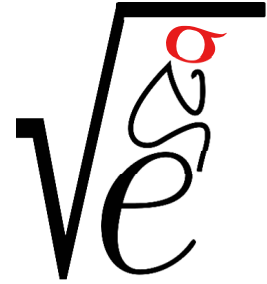
Problem 1 (5 points):

In a rectangular piece of grid paper of perimeter a units, there is a rectangular hole, cut along the grid lines, of perimeter b units. The hole does not touch the boundary of the paper. If this piece of paper is cut into stripes along all horizontal grid lines, there will be h stripes. If we instead cut along vertical grid lines, there will be v stripes. (A 1×1 square is a stripe.) An example with $a = 18$, $b = 6$, $h = 5$, $v = 7$ is shown below.
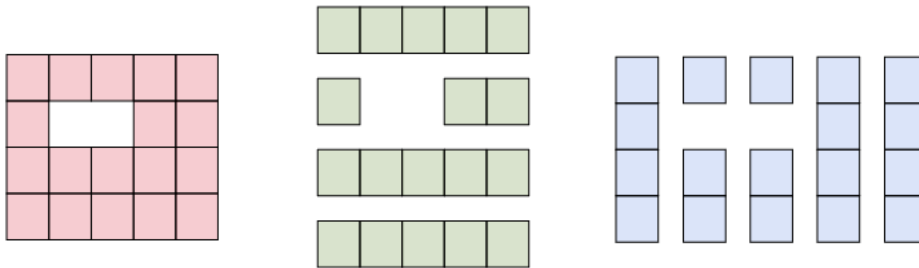
(a) Let $a = 50, b = 34$, and $h = 20$. What will v be? (Either a general proof or an example will be accepted as an answer.)

(b) Let $a = 5294, b = 1816$, and $h = 2025$. What will v be? Justify your answer.

Problem 2 (10 points):

There are 1000 campers in TauCamp. In the camp, some campers know each other. If two campers know each other, they are either friends or enemies. Campers always know their friends, friends of their friends, etc. The campers in TauCamp are not very friendly — they only talk to their friends. Also, for every camper, any two of their friends are enemies, and any two of their enemies are friends.

Camp director Lily wants to inform all of the campers about the big party tomorrow. Any camper that hears about the party will tell all of their friends about it. Prove that Lily will have to talk to at least 200 campers.

Physics

Problem 1 (5 points):

Watch this video of a fighter jet performing at an airshow. Shortly after the 40 second mark, the jet executes a turn. Estimate the maximum acceleration, expressed as a multiple of Earth's surface gravity g, experienced by the pilot during this turn. You are expected to state any assumptions that you make.

The video is also available at this URL:

<div align="center">

https://www.youtube.com/watch?v=JQSNbeTmIsk

</div>
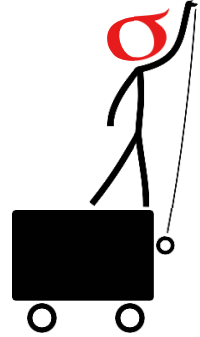
Problem 2 (10 points):

As shown in the picture below, a brick of mass $m_b = 1$ kg is situated on top of a wooden wedge of mass $m_w = 0.5$ kg and height $h = 50$ cm. Initially, the brick and the wedge are at rest, and there is no friction between the wedge and the horizontal surface and between the brick and the wedge.

(a) What is the velocity of the wedge right before the brick leaves the wedge?

(b) What is the angle of the brick's velocity relative to the horizontal line at that moment, if the angle at the base of the wedge is $\alpha = 30°$?
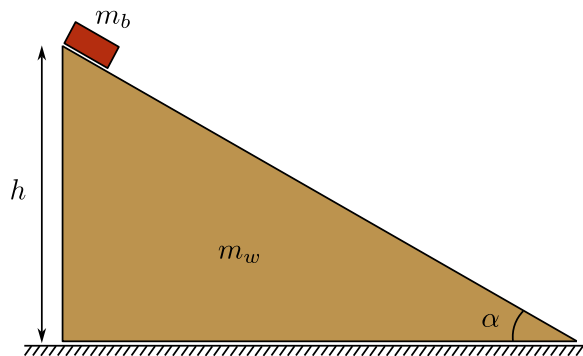
Chemistry

Problem 1 (5 points):

While preparing for a chemical experiment, a technician accidentally combined copper sulfate (blue crystals) and washing soda in an unknown ratio. To analyze the resulting mixture, he placed 6 grams of it into a porcelain crucible and heated it at 600°C for several hours. After the crucible returned to room temperature, the mass of the residue was 3.11 g. Calculate the initial composition of the mixture.
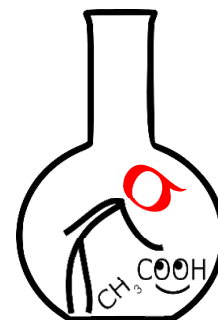
Problem 2 (10 points):

The metal X exhibits the following characteristics:

1. When heated in an excess of oxygen, it ignites, producing a white solid Y as a combustion product.

2. Solid Y is highly soluble in water, resulting in a solution that is strongly basic.

3. When heated, Y generates a gas that is used in medicine, along with a solid Z.

4. Solid Z is also highly soluble in water, leading to a basic solution.

Identify X, Y, and Z. (There is more than one possible answer.)

Biology

Problem 1 (5 points):

During the analysis of fossils of human ancestors, anthropologists found an interesting phenomenon: Fossils of ancient species, such as *Australopithecines*, show few signs of pathological transformations, diseases, or past injuries. However, remains from the Upper Paleolithic and more recent periods exhibit numerous marks of severe diseases and injuries. Is this associated with a change in living conditions or similar factors? Explain.
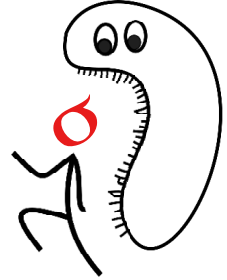
Problem 2 (10 points):

AD-Pyrexia is an exotic viral disease prevalent in the equatorial country of Brazigma. This disease primarily impacts individuals living in rural areas, particularly horse owners, stable workers, trainers, jockeys, and veterinarians. Infected individuals face severe consequences with a high risk of fatality. Interestingly, the virus's natural reservoir is not horses but large fruit-eating bats.

(a) A volunteer organization, largely composed of students from the University of Alphaheim (the capital of Brazigma), rescues and cares for injured fruit bats. Notably, throughout the history of this organization, none of its members have contracted AD-Pyrexia, despite many testing positive for antibodies to the virus. How can this be explained?

(b) Why do individuals in contact with horses continue to fall ill from this disease?

Linguistics & Applied Sciences

Problem 1 (5 points):

With the recent wildfires, you've probably seen a lot about AQI, or Air Quality Index, in the news. AQI is calculated based on the levels of O_3 (ozone), $PM_{2.5}$, PM_{10} (particulate matter less than 2.5 / 10 micrometers), CO (carbon monoxide), SO_2 (sulfur dioxide), and NO_2 (nitrogen dioxide) in the air. Choose one of the following locations: Atlanta, GA; Bozeman, MT; Champaign-Urbana, IL; Honolulu, HI; or Seattle, WA. Based on EPA guidelines, calculate the AQI in this location for each day of two different weeks: one in the winter, and one in the summer. If you're interested in learning more about these pollutants, check out epa.gov → Environmental Topics → Air.

The data you use should be in units of parts per million (ppm). Analyze and represent the data as you think best; include relevant charts and point out data trends. Are there any interesting differences between the summer and the winter weeks? Propose an explanation for the differences that you have found. Have fun with the data! Please clearly cite the air quality data that you used, and show your work, by including a scan of your calculations or a screenshot of your spreadsheet.

Problem 2 (10 points):

A language spoken in a fishing village uses the following terms for numbers and numbered items:

1. mumem	A. five men	
2. gamgmu	B. three men	
3. anithoqəsh	C. three villages	
4. ngahani	D. two boats	
5. muthom	E. ten reindeer	
6. hemarmenəng	F. fifteen	
7. tlanginyan	G. two men	
8. vochaqəsh	H. one berry	
9. minərvo	I. one reindeer	
10. qanəngmen	J. five boats	
11. hemarchakər	K. seven boats	
12. mhomeqrushk	L. five years	
13. mhothoqrushk	M. twelve	
14. mhotlangi	N. two dogs	
15. hemarthorəng	O. six years	
16. alsnyaqəsh	P. eight villages	

  a. Match the English words on the right with the foreign words on the left.

  b. Translate the following phrases into the target language:
- eight men
- three dogs
- eleven

Computer Science

- Your program should be written in Python-3 or Java. Python-3 programs should be submitted in a file with extension `.py`; Java programs should be submitted in a file with extension `.java`.

- No GUI should be used in your program (e.g. `easygui` in Python). Other common libraries (e.g. `numpy`, `scipy`) can be used, but **not** in a way that trivializes the problems.

- All the input and output should be done through files named as specified in the problem statement to receive full points.

- The use of generative AI (ChatGPT, Gemini, DeepSeek, etc.) is **prohibited**. **Any solutions suspected of using AI will not receive any points!**

Problem 1 (5 points):

The game "Crux" is played as follows: two people start with an empty $m \times n$ board. They take turns placing a tile (from a large pile of tiles) on a square on a board. The first person to create a 5-tile cross, like the one shown below, wins.

```
.X.
XXX
.X.
```

Here `X` denotes a tile, and `.` an empty square. Note that the cross does not have to be surrounded by empty squares, so from the position on the left a player can win by placing the tile on top, as shown on the right:

```
....        .X..
XXX.        XXX.
XXX.        XXX.
....        ....
```

Given a Crux board with some tiles already on it, you need to decide if a player can win on the next move and if so, what the winning move is.

Input specifications

Your program should read the input file `input.txt`, which contains a Crux board specification. The first line contains two space-separated integers, m and n. The following m lines each contain a sequence of n characters, `X`'s or periods, without any spaces, corresponding to tiles and empty squares of the board.

Output specifications

Your program should produce the file `output.txt`, which contains either the word `NONE` if there is no immediately winning move, or two numbers separated by a space, corresponding to the row and the column of the square for the winning move. The rows are numbered from 0 to $m - 1$, and the columns from 0 to $n - 1$. If there are several winning moves, the file should contain the lexicographically smallest of all possible winning moves (for example, if "4 3" and "5 2" are winning moves, output "4 3").

Examples

Sample Input 1:

```
3 3
...
XX.
XXX
```

Sample Output 1:

```
NONE
```

Sample Input 2:

```
6 5
.X...
.....
.XXXX
..XXX
X....
X..X.
```

Sample Output 2:

```
1 2
```

Sample Explanation 2:

Note that "4 3" and "1 3" are also winning moves, but "1 2" is lexicographically the smallest.

Problem 2 (10 points):

Tihs is rsaeonlbay esay to raed! In fcat, it amsolt deos not mettar waht oedrr the lrettes in a wrod are. This observation led to some interesting ideas about how we learn to read and perceive written text.

In this problem, you will be given a file with a short text. In each word, the letters are in a random order, except for the first and the last letter, which are in their proper places. (This means that all two- and three-letter words appear correctly; why?)

Your task is to write a file with the same text, but with all the words spelled correctly. You should use this list of English words (to download, press Ctrl-S on Windows, or Command-S on Mac).

Input specifications

Your program should read the input file `input.txt`, which contains scrambled text on a single line. The first letter of each word may be capitalized (but not the subsequent letters), and punctuation may be used, consisting of the following symbols: ".", ",", "!", "?".

Output specifications

Your program should produce the file `output.txt`, which contains the unscrambled text on a single line. The capitalization and punctuation should stay consistent.

If there is a misspelled word that may have multiple possible spellings, correct to the one that is lexicographically the smallest: for example, "aertls" should be corrected to "alerts" rather than "alters".

Example

```
Tihs is rsaeonlbay esay to raed! In fcat, it amsolt does not mettar waht
    oedrr the lrettes in a wrod are.
```

```
This is reasonably easy to read! In fact, it almost does not matter what
    order the letters in a word are.
```

Input/Output in Python

In this section, we briefly describe how to read and write to a `.txt` file using Python. You can also check out this cheatsheet for reading/writing to Python files, or search for more guides on Google. For input/output in Java, you can refer to this online guide.

Reading from a file

To read from a text file in Python, use the `open()` function with the `"r"` (read) setting:

```python
1  with open("input.txt", "r") as file:  # Open in read mode
2      line = file.readline() # Read the first line
3      print(line)
4      line = file.readline() # Read the second line
5      print(line)
```

Suppose your `input.txt` file consists of a single line of space-separated integers, such as "1 3 5". You can read these numbers and put them into a list as follows:

```python
1  with open("input.txt", "r") as file:  # Open in read mode
2      line = [int(x) for x in file.readline().strip().split()]
3      print(line)
```

The function `strip()` will remove any white-space, `split()` will break the string up into a list using the spaces as dividers, and `int()` will convert them from strings to integers.

Writing to a file

To write to a text file in Python, use the `open()` function with the `"w"` (write) setting, and use the `write()` function:

```python
1  with open("output.txt", "w") as f:
2      f.write("Hello World!")
```

Suppose you have a list of numbers `ints = [1, 5, 6, 2, 3]`, and you want to write them to `output.txt` in one line, separated by spaces. Here is how you would do this:

```python
1  with open("output.txt", "w") as f:
2      f.write(" ".join([str(x) for x in ints]))
```

On the second line, `[str(x) for x in ints]` converts each element in the array from integers to their string representations, and `" ".join([...])` converts the array into a single string, separating each element of the array by a space.