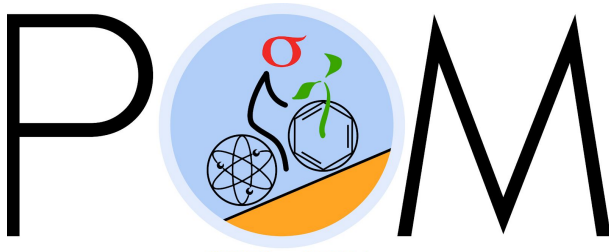
PROBLEM OF THE MONTH



November, 2020

2020 - 2021

MATHEMATICS

5 points:

Sophia said she knew a natural number such that the product of all of its divisors including 1 and the number itself is a number ending with exactly 42 zeros. Can she be right? If yes, give an example of such a number. If no, give proof that such numbers do not exist.

Hint: One gets 10 by multiplying 2 and 5.

10 points:

You are performing the following magic trick. You step out of the room and one of the spectators writes down a sequence of 101 digits on a blackboard. Your assistant, who is present in the room, then covers two subsequent digits in the sequence with a black square. After that you enter the room and, without communicating with anybody, brilliantly guess the two covered digits in the correct order. To be sure that the trick will work 100% of the time you gave precise instructions to your assistant before the show. What could those instructions have been?

Hint: By covering digits at places N and N+1 the assistant communicates the number N to the magician. The number N is a two-digit number and theoretically can be sufficient to encode two covered digits.

PHYSICS

5 points: Power 40 hp (horse-powers) is needed to drive a car at constant speed 60 mph on a horizontal road. How much power is needed to drive the same car at speed 90 mph, on the same road? Assume that the energy efficiency of the car stays the same and that most of the work done by the engine is against air drag.
(To get background information about drag force, check Wiki, or any other source, e.g. https://en.wikipedia.org/wiki/Drag_equation)

Hint: Note that power = force times speed.

10 points: Rotor (propeller) of Robinson R22 helicopter needs to spin at 600 RPMs (revolutions per minute) for it to lift from the ground. Suppose that you want to build a similar helicopter for use on Mars. The problem is, the density of the atmosphere on Mars is only 2% of that on Earth. Fortunately, gravitation acceleration there is $3.7 m/s^2$, rather than our $g = 9.8 m/s^2$. Engineers from your team managed to cut the mass of the helicopter by a factor of 2, leaving all its dimensions the same. Estimate how fast the rotor should spin for this helicopter to be able to lift from the surface of Mars.

Hint: gravity force should be balanced by lift force of the propeller. The latter is proportional to speed of rotation squared.

CHEMISTRY

This month, the topic is: **Electrochemistry**
IMPORTANT! In this PoM season, we do an experiment: each month, an online lecture will be given. This lecture may be helpful for those who want to solve Chemistry PoMs, although it is not supposed to provide direct hints.
This month, the lecture will be on Nov 22 morning. At 11:00, a Zoom conference will start where October PoM solutions will be discussed. After that, approximately at 11:30, the lecture starts.
To join the Zoom conference, use this link:
https://us02web.zoom.us/j/4817690592?pwd=T2djSjRETEpDSHFZdWJpYlBTYzdjQT09
Meeting ID: 481 769 0592
Passcode: 879615
If you are unable to connect, email to mark.lukin@gmail.com
The lecture recording is available in our youtube channel:
https://www.youtube.com/channel/UC7e5BDljoP5619Ula2fF4zQ/

5 points:

To test their ability to survive in the wild, a group of students decided to take a five-day hike through the Adirondack Mountains using only a printed map. As a precaution, they took only one smartphone, but agreed to use it just in a case of emergency. At the end of the fifth day, the guys realized that they were lost. They took out a smartphone, but it was completely discharged. They had a car charger, but it was useless because there was no car or even a 12V battery to plug it in.
Tom was the first to get up the next morning, and while the boys were starting the fire and the girls preparing breakfast, he gathered up empty cans and began to rub them with wet sand and cut them into small squares.
“Do you folks have coins? A penny is best. Girls, you definitely have cotton pads, I need a dozen of them."

Two hours later, the smartphone was charged, the students downloaded a map that quickly led them to the nearest town.
How did Tom manage to charge the phone?
What else did he have to use besides the items listed above?

Hint:

The hint is “Voltaic pile”

10 points:

To demonstrate that some metals react with acids, whereas others do not, a teacher put an iron nail and a piece of copper wire into the same glass beaker and poured 10% aqueous HCl into it (the iron nail and copper wire didn't touch each other, and their tips were protruding from the beaker). Bubbles of the hydrogen gas began to form at the nail's surface, and the nail immediately began to "dissolve", whereas the copper surface remained unchanged, and no gas formation was observed.

Look, if I leave this setup for several hours, the iron nail will "dissolve" nearly completely. However, it is possible to affect the outcome of this reaction. I can do that without adding any extra chemicals to the solution in the beaker. First, I can make the iron nail to react even faster; Second, I can stop the reaction of the naIl with HCl; Third, I can invert the reaction, so the nail will remain unchanged, whereas the copper wire will start to react with HCl. I am going to do that just by doing something with the tips of the iron nail and copper wire that are protruding from the beaker."

How can the teacher do that? Will it be accompanied by some additional visual effects?

Hint:

What if a teacher allows electrical current to flow freely from one piece of metal to another, or forces the current to flow in an opposite direction?

BIOLOGY

As we predicted during the Sigma-Opening ceremony in 2018, the developers of CRISPR-Cas9 technology got the Nobel prize, although that happened just one month ago. To celebrate this event, we declare this month a **CRISPR-Cas9 month**. Both problems are related to this subject.
IMPORTANT! To help you solve these problems, there will be a Biology PoM lecture.
This month, the lecture will be on Nov 21 at 11:00 AM via Zoom conference.
To join the Zoom conference, use this link:
https://us02web.zoom.us/j/4817690592?pwd=T2djSjRETEpDSHFZdWJpYlBTYzdjQT09
Meeting ID: 481 769 0592
Passcode: 879615
If you are unable to connect, email to mark.lukin@gmail.com
The lecture recording is available in our youtube channel:
https://www.youtube.com/channel/UC7e5BDljoP5619Ula2fF4zQ/

5 points:

A bioinformatic researcher performed analysis of a genome of some newly discovered bacteria, whose genes had virtually nothing in common with any other bacteria. In this genome, the researcher found strange segments with repeating motifs:

Sequence 1:

...TGGGTTTGAACCCGTCGTTGCGGGTTGAAGA(...)TGATTTAACCCGTGCTATGCGGGTTGAGCT
...

Sequence 2:

...AAAGTCCGACGGACTTATCCGACGGAATC(...)ATATCCCGACGGGCTAGTCCGACGGAAGC…

Sequence 3:

...GGACTCTTTGGCTTACTTTGGCAATC(...)ACACCCTTTGGCCTAGTCACTTTGGCTTTGGC…

The researcher concluded that all these repeats are the CRISPR cassettes. Is this conclusion correct for each of those sequences?

Hint:

For a CRISPR cassette to work, its non-variable parts must form so called stem-loop (a.k.a. hairpin) structures. What is needed for that?

10 points:

As we know, the CRISPR-Cas9 technology, which was awarded the Nobel prize one month ago, allows genome editing directly in a living organism. That creates excellent opportunities for treatment of various diseases caused by defects in genomic DNA. Which diseases listed below can be treated with CRISPR-Cas9 technology?

1. Sickle cell anemia;
2. Beta-thalassemia;
3. Huntington disease;
4. Hemophilia;
5. Down's syndrome;
6. MELAS syndrome;
7. Cancer.

Explain your answers.

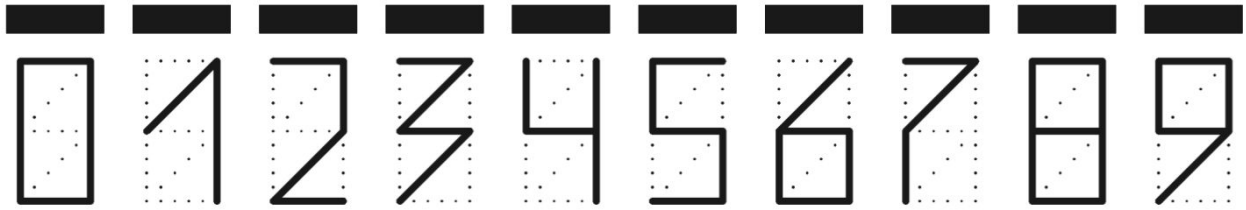
Hint:

Currently the CRISPR-Cas9 technology is capable of fixing (or changing) some single gene in some fraction of all cells in an organism or a tissue.

LINGUISTICS

5 points:

In some of the countries in Europe the numbers in zip-codes used to be written according to the following template in order to allow for automatic recognition:



The system checked one of the 9 intervals (2 diagonal, 6 on the outside of the box, 1 horizontal interval inside the box) to determine whether it is filled out or not. In order to determine which digit is written, the system had to be programmed to check a certain set of these intervals, and based on the result of these checks, it had to determine which digit was written.

Question 1: What is the minimum number of intervals that had to be checked to determine the digit?
Question 2: If the digits 2, 3, 6, and 9 had the following way of writing, what would be the minimal number of checks?

10 points:

Below is a list of translated words from a language in northeast Asia. Each word below uses the concept of **stress**, where one syllable in a word is emphasized over the others. In the examples below, the stressed syllable is **bolded**. (The symbol **ə** below indicates a **short vowel** that occurs for example in English at the beginning of the word *about*, or is represented by *e* in the word *taken*.),

Original	English	Original	English
tatul	fox	**pun**ta	liver
nət**gəl**qin	hot	qe**tum**gən	relative
nu**ra**qin	far	**piw**tak	(to) pour
gəlgən	skin	nə**mit**qin	handy
neqəqin	fast	**tum**gətum	friend

nə**səq**qin	cold	**tət**ka	walrus
tap**la**ngətkən	he sews shoes	**kət**til	forehead
kəmgətək	(to) curl up	qal**pu**qal	rainbow
itək	(to) be	kə**pi**rik	hold (a child) in one's hands
pa**qət**kuk	(to) gallop	tə**vi**tatətkən	I work
nilgəqinat	white (pl.)	**pin**təvəlngək	to attack (someone)

Using this information, set the proper stress mark on the following words. You may bold, italicise, or set an accent mark to indicate stress on a syllable.

Original	English
sawat	lasso
pantawwi	fur boots
nəktəqin	sturdy
gətgan	late autumn
nəminəm	soup stock
nirvəqin	spicy
puygən	spear
tilmətil	eagle
wiruwir	salmon
wintatək	(to) help
nəmalqin	good
yaqyaq	seagull
yatək	(to) show up
tavitətkən	I will work
pintətkən	He is attacking (someone)
tayəsqəngki	in the evening

COMPUTER SCIENCE

- Your program should be written in Java or Python-3
- No GUI should be used in your program: eg., easy gui in Python
- All the input and output should be via files with specified in the problem statement
- Java programs should be submitted in a file with extension .java; Python-3 programs should be submitted in a file with extension .py.
  No .txt, .dat, .pdf, .doc, .docx, etc. Programs submitted in incorrect format will not receive any points!

Introduction:

Consider the game of Connect4 (see rules in https://en.m.wikipedia.org/wiki/Connect_Four).

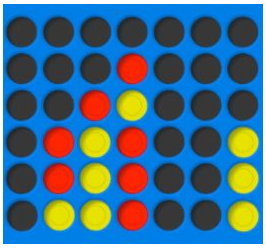
In this assignment as an input you will be given a position in the Connect4 game where Red goes next.

Input:

- The input of your program is a file **input.txt**
- The file contains 6 lines, each line being 7 characters long with the position of Connect4 board.
- The character is one of the following:
  - Letter O: Empty space
  - Letter R: Red disk
  - Letter Y: Yellow disk
- The first line represents the top of the board. The last line represents the bottom of the board.

For example, file input.txt containing below text represents the game position in the picture on the right:

```
OOOOOOO
OOOROOO
OORYOOO
ORYROOY
ORYROOY
OYYROOY
```



Output:

- The output of your program is a file **output.txt**
- A move in the game is specified by the number that represents the column where a Red disk will be dropped
- 1 represents the left-most column, 7 represents the right-most column

5 points:

Write a program that given a position in input.txt finds the move that brings an immediate win to the Red.

Output should contain:

- number 1-7, corresponding to the move
- X - if the win for Red in one move is not possible
- Z - if position is such that the one of the sides has already won

10 points:

Write a program that given a position in input.txt finds the move that either brings an immediate win to the Red or leads to a win in the next move, while avoiding a loss in the next move by Yellow.

Output should contain:

- number 1-7, corresponding to the move
- X - if the win for Red in one or two moves is not possible
- Y - if a loss for Red in unavoidable
- Z - if position is such that the one of the sides has already won