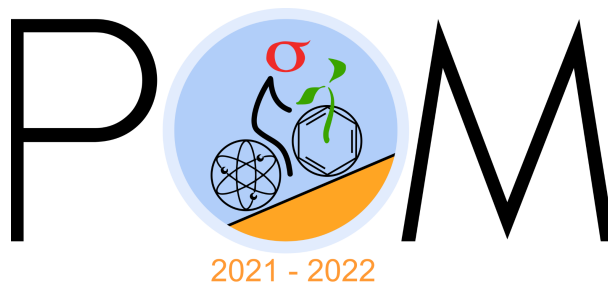


**PROBLEM OF THE
MONTH**



January, 2022

MATHEMATICS

5 points:

For this problem, a “word” is a string of English letters, even if it is gibberish. You type in “daisy” into Wordle (see computer science problems for more on Wordle) and get that *i* is green, *s* is brown, and the remaining letters are gray. How many 5-letter “words” are still possible?

10 points:

How many integers N satisfy the following three conditions?

1. N is divisible by 2020
2. N has exactly 2020 decimal digits
3. The decimal digits of N are a string of consecutive 1s followed by a string of consecutive 0s (e.g. 111111111100000000)

PHYSICS

5 points:

If a black hole was the size of a hydrogen atom, what would its mass be?

10 points:

Two weights attached to either end of a massless rigid rod are falling into a black hole such that one mass is 10 cm closer to the center of the black hole than the other. The weights are each 1 kg, the black hole has 5 solar masses, and the closer mass is 100 km from the black hole. What is the tension in the rod? Justify your calculation.

CHEMISTRY

5 points:

Silicon and carbon belong to the same group of the Periodic table, and they are similar in many aspects. Thus, both carbon and silicon burn in oxygen, and they both form oxides with the formula XO_2 . Like carbon, silicon forms a hydride (SiH_4), and this compound, silane, is a gas, and like methane (CH_4) it burns in oxygen, and the products of its combustion are water and silicon dioxide. Some other aspects of silicon chemistry closely resemble the chemistry of carbon too.

Do you think that life on some exoplanets may be based on silicon instead of carbon? More concretely, can some silicon based creatures exist on exoplanets with oxygen containing atmosphere? Are there any problems with production of biogenic oxygen by "silicon plants", and with usage of oxygen by "silicon animals" for aspiration?

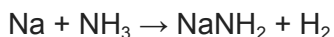
10 points:

Standard Chemistry textbooks describe ammonia as follows.

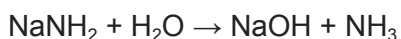
Ammonia is a gas with a boiling point of $-33^\circ C$. When mixed with water, ammonia becomes protonated, and ammonium and hydroxide ions form:



*which means **ammonia is a base**. When reacts with active metals (e.g. sodium), it form amides:*



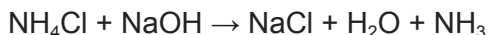
Sodium amide is a crystalline solid, which, upon dissolution in water, produces sodium hydroxide and ammonia:



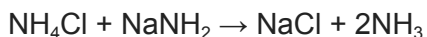
When reacts with acids, ammonia form salts:



When ammonium salts react with bases, such as NaOH, metal salts are free ammonia form:



Similar reaction with sodium amide yields ammonia and a sodium salt:



In a liquid state, ammonia is a polar liquid that is capable of dissolving many inorganic and some organic compounds, such as ammonium chloride (NH_4Cl) or sodium chloride ($NaCl$).

Since liquid ammonia in many aspects resembles water (like water, it is a polar liquid and a good solvent), it is theoretically possible that life on other planets may be based on ammonia

instead of water. Imagine that some civilization appeared on one of those planets, and their chemists wrote a textbook where a separate paragraph is devoted to water. What would this paragraph tell about properties of water? In your answer, assume that the paragraph was translated to English, and it was written in the same style as the above text (in blue).

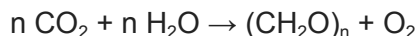
BIOLOGY

5 points:

Salt peter (sodium or potassium nitrate) is an essential component of gunpowder and a good fertilizer. One of the best sources of naturally occurring salt peter are Chilean and Indian deposits. Since nitrogen does not react with oxygen spontaneously, and taking into account that nitrates (in contrast to sulfates or phosphates) are unstable at elevated temperatures, the origin of naturally occurring salt peter deposits was unclear. Later, scientists figured out that naturally occurring salt peter deposits have a biogenic origin: they are produced from massive deposits of marine birds excrement by some bacteria. However, keeping in mind that nitrates are very energy rich compounds, its production requires a lot of energy. Explain, why do bacteria spend so much energy for production of nitrates?

10 points:

We all know that life on our Earth exists because of two main processes: In the first process (photosynthesis), plants use the energy of the Sun to produce organic matter from carbon dioxide and water, and oxygen is formed as a byproduct. The overall process occurs according to the scheme:



where $(\text{CH}_2\text{O})_n$ is some sugar, usually, glucose ($n = 6$). In this process, the energy of the Sun is used to convert low energy substances (carbon dioxide and water) into high energy substances (oxygen and sugar).

The second process (aspiration) is production of energy from organic materials and oxygen: we all are breathing, and we inhale oxygen and exhale carbon dioxide and water, which are produced in our body when organic materials “burn” in our cells. This process is spontaneous, and, therefore, it liberates the energy that was captured by plants during photosynthesis.

The combination of photosynthesis and aspiration forms the main carbon cycle in the biosphere.

However, some organisms exist that seem not to fit into this cycle. Thus, deep water in the Black Sea is populated by strange microorganisms that do not need oxygen for aspiration, and oxygen is even toxic to them. In addition, they do not produce water during aspiration, and hydrogen sulfide is produced instead. Moreover, since they live in an aphotic zone (in absolute darkness), their participation in photosynthesis is also impossible..

Does it mean that Black Sea ecosystem (and similar deep water ecosystems) form a totally autonomous system that does not depend on external sources of energy? If it is not the case, where do they take energy?

LINGUISTICS

5 points:

An additive numerical system is a system in which the numerals sum to the value of the number which they represent. For example, if we wish to represent the number 29, we would put the symbol for 20 and the symbol for 9 next to one another.

The following ancient numerical system has symbols representing the numbers 1-19 and the base symbols for 20, 30, 40, 50, 60, 70, 80, 90, and 100. As the numbers increase, the symbols build off of the previous ones and grow more complex.

Fill in the remainder of the table with the twelve symbols below.

1	2	3	4	5	6	7	8	9	10
1			k		u				
11	12	13	14	15					

Similarly, fill in the chart of the following base symbols.

20	30	40	50	60	70	80	90	100
oT				ho		to	oT	

o oT T ho o

Finally, write the numbers 21, 115, 48, and 700.

10 points:

Here is a list of every semilab that took place in 2021:

https://docs.google.com/document/d/1VR17RFol0D_JkRkpuFb18vXM3lupq5DJBZvT50OLgDM/edit?usp=sharing

Each semilab has been run through the SigmaNamer algorithm to produce the following alphabetical list of every semilab at SigmaCamp 2021:

asone, ayono, beso, beve, dese, eyino, eyive, hase, hovo, iyane, kano, kose, lane, laso, mive, mivo, nurvo, oyose, oyoso, piso, pive, tese, teso, xase, xxuvo, yavo, yuve, zevo

1. Match each course encoding to a semilab. Example: *Light: Classical and Quantum* → dese, *Modeling with Julia* → hovo.

2. Identify the purpose of each letter used in the course encodings. Explain what purpose the SigmaNamer could serve, and why it may be helpful for SigmaCamp staff.

COMPUTER SCIENCE

- Your program should be written in Java or Python-3
- No GUI should be used in your program: eg., easygui in Python
- All the input and output should be via files named as 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 .pdf, .doc, .docx, etc! Programs submitted in incorrect format will not receive any points!**

WORDLE!

You may have recently encountered Wordle - a daily word game that got very popular lately. For the uninitiated: every day Wordle conceives a 5-letter “secret” word, which you need to figure out in 6 or less guesses. After each guess (which should be a valid word), you are given the feedback showing which letters are not in the target word, which letter you guessed correctly, but not correctly placed, and finally correctly guessed and placed letters. The Wordle site is here: <https://www.powerlanguage.co.uk/wordle/>. Have fun playing!

In the meantime, our problems this month are influenced by Wordle. Your program will be getting an input in the file **input.txt**, each line of which will reflect a previously made guess and its score markup. The markup contains 5 characters, where X means incorrectly guessed letter, 0 means correctly guessed letter but placed in the wrong spot, and 1 means correctly guessed letter in the correct spot. The guessed word and associated markup are space-separated. For example:

```
BLACK XX1X0  
STAKE 10101  
SKATE 11111
```

would represent the won Wordle game.

Your program should use file **words.txt** as an official dictionary of allowed words (you can download it here: <https://raw.githubusercontent.com/redbo/scrabble/master/dictionary.txt> and use it for your testing).

5 points:

Given the guesses from the input file, your program should print all 5-letter words from the dictionary that would satisfy the markup and print them, one word per line, to the **output.txt** file. In the example above, the input file contains the first two presented lines you would write a single word SKATE to the output file.

10 points:

Assume that the secret word is chosen uniformly at random from the five-letter words in the dictionary file (words.txt). Given a list of guesses made so far and their markup (from the input file, as per above), find the next guess that will minimize the expected size of the remaining set of words (after the next feedback is received) and print it to the **output.txt** file.