MATHEMATICS

5 points:

After a math class on the blackboard there remained the graph of $y = \frac{k}{x}$ and five lines, parallel to $y = 2kx \ (k \neq 0)$. Find the product of the x-coordinates of all 10 intersection points.

10 points:

Every bus has passengers, and not always the same amount. Every passenger has co-passengers. Two passengers are co-passengers if they are riding the same bus (every passenger is also his own co-passenger). At any given time, what is greater, the average number of passengers per bus or the average number of co-passengers per passenger?

You can start by considering 3 buses, with 3, 5, and 7 passengers. Then, consider the general case of n buses with $a_1, a_2, \ldots, a_n$ passengers.

PHYSICS

5 points:

Tokyo Skytree is the second tallest structure in the world. Shuttle elevators servicing its Tembo Observation Deck have a maximum speed of 10m/s, making them the fastest large-capacity elevators in Japan. It takes only 50 seconds for an elevator to travel 350m to the Observation Deck. Find the time during which the elevator moves with its maximum speed, assuming that it first reaches this speed by moving up with a constant acceleration, and that at the end of the trip it slows down with a constant deceleration.

Hint: The average velocity of the elevator during acceleration and deceleration is 5 m/s.

10 points:

The UFO is moving in deep space with velocity V_0. The pilot of UFO would like to change the velocity of UFO so that it is the same in absolute value but turned by an angle of 90^0. The acceleration of the UFO cannot exceed a_0 in its absolute value. What is the shortest time needed for such a turn? Prove that this time is indeed the minimal. How far from its initial position the UFO will be after the completion of the maneuver?

Hint: Think of the velocity difference as of a vector. What should be the direction of the acceleration during the optimal maneuver?

CHEMISTRY

5 points:

Experiments with oxygen are very spectacular, but its preparation require either expensive equipment or dangerous chemicals. Nevertheless, it is quite possible to prepare oxygen using only the materials that you can freely buy at Stop&Shop. Imagine you have $50. What should you buy at Stop&Shop (or another supermarket if you are living not in the US) for that money to prepare as much oxygen as possible?

Hint:

To obtain one of those chemicals, you should break apart some stuff that you can buy at every convenience store. Another reactant can be found in the medicine section.

10 points:

Imagine that by the 5th day of Sigma, the only remaining chemicals in Mark's lab were:
1. Sulfuric acid
2. Hydrogen peroxide
3. Copper sulfate
4. Manganese sulfate
5. Luminol
6. Potassium ferrocyanide
7. Ammonium thiocyanate
8. Malonic acid
9. Sodium hydroxide
10. Potassium iodate
11. Ferric chloride

Which spectacular chemical reactions our counselors would do using the chemicals from this list? What additional demonstrations will they be able to do if they come to the camp's kitchen and take some stuff there?

Hint:

Usually, one can find starch at any kitchen.
The name "luminol" has the same root as "lumos".

BIOLOGY

A sensory deprivation chamber is an environment, usually a large tub of saline water carefully calibrated to be at body temperature, and in a sealed room, in which all sensory inputs (ambient light, sound, tactile stimuli) are eliminated. In this environment, individuals report having no sensation of time and are often quite off in terms of their estimation of how much time has passed (they think hours have passed when they have been there only minutes, and vice versa).

5 points:
1. If they were in this environment long enough (e.g., weeks or months), how would their sleep-wake cycles be affected, and why?

2. Would slightly increasing or decreasing the ambient water temperature affect this process, and if so, how and why?

10 points:
1. Besides measuring sleep-wake cycles, identify two other biological processes that one could monitor to determine the individual's endogenous circadian rhythm? Describe an experimental setup by which you could monitor them without disrupting the experiment.

2. In addition to the suprachiasmatic nuclei (SCN), which form the "master clock," other peripheral oscillators exist in other cells. Is it possible for different parts of the body to be oscillating at different frequencies? Why or why not?

COMPUTER SCIENCE

- You can write and compile your code here:
  http://www.tutorialspoint.com/codingground.htm
- Your program should be written in Java or Python
- No GUI should be used in your program: eg., easygui in Python. All problems in POM require only text input and output. GUI usage complicates solution validation, for which we are also using *codingground* site. Solutions with GUI will have points deducted or won't receive any points at all.
- Please make sure that the code compiles and runs on http://www.tutorialspoint.com/codingground.htm before submitting it.
- Any input data specified in the problem should be supplied as user input, not hard-coded into the text of the program.
- Submit the problem in a plain text file, such as .txt, .dat, etc. **No .pdf, .doc, .docx, etc!**

Intro:

Every year, after students are admitted to SigmaCamp, they get a list of semilabs to choose from, and specify, in order of preference, their top 4 choices. SigmaStaff then have to match students so that everyone gets semilabs they want.

For both problems, your program will read and process 2 input text files:
- The first file (named semilabs.txt) is a list of Sigma semilabs with the corresponding maximum number of students; the format is a table with N rows where each row consists of 2 integers: semilab_number, max_students. Here semilab_number is assumed to be non-repeating integers from 1 to N, one for each semilab. But max_students can be arbitrary positive integers. You can assume that N will not exceed 10.
Sample semilabs.txt file can look like the following:

```
1  4
2  4
3  4
4  3
5  3
6  5
```

- The second file (named students.txt) is a table of M rows (where M > N) where each row has 5 integers: student_id, choice_1, choice_2, choice_3, choice_4, where $1 <= choice\_x <= N$ with each of the 4 choices distinct. You can assume that M will not exceed 15.

Sample students.txt file can look like the following:

```
111 3 2 4 1
3 1 3 4 2
4 2 1 6 3
223 6 1 2 3
211 3 4 1 6
98 6 3 1 2
44 1 2 4 3
52 6 1 4 2
67 2 3 4 1
21 2 4 1 6
```

5 points:

For this problem, your program should read the 2 input files and compute the popularity of each semilab. The output should be N rows, where each row contains the semilab number followed by 4 integers indicating the number of students who requested the semilab as their 1st to 4th choices, followed by the total "popularity" of the semilab.
For the sample input files, the following output should be produced:

```
1 2 3 3 2 10
2 3 2 1 3 9
3 2 3 0 3 8
4 0 2 5 0 7
5 0 0 0 0 0
6 3 0 1 2 6
```

Hint:

Using two-dimensional array makes the task easy.

10 points:

For this problem, your program should read the 2 input files and determine if there is an assignment that gives each student his/her 1st choice as well as another semilab from the other 3 semilabs he/she indicated. If there is no such assignment possible, then output "no satisfactory match". If such an assignment is possible, print:
- M rows, one for each student, containing student_id, assigned_semilab_1, assigned_semilab_2;
and
- a list of 4 integers: number of students who got their 1st choice, 2nd choice, 3rd choice and 4th choice.
For the sample input files, the program should produce:

```
111 3 4
3 1 2
```

```
4  2  6
223  6  3
211  3  6
98  6  3
44  1  4
52  6  4
67  2  1
21  2  1

10  1  5  4
```

Hint:

You can use a depth first search using the two-dimensional array of choices. Don't forget to keep occupancy counts in an array.

LINGUISTICS

5 points:

Consider the following words/phrases from a language spoken in the northwest of Russia:

kujŋətenək	'near the glass'
raralqək	'on top of the roof'
raraɣiŋən	'into the basement'
aŋqakin	'from the sea'
aŋqan	'sea'
keŋən	'bear'
keŋəlqəkin	'from the bear'
raralqən	'roof'
kujŋəŋ	'into the glass'
keŋək	'inside the bear'
aŋqatenək	'on the shore'

Problem: translate into this language the following words/phrases and explain your reasoning.

1. basement
2. inside the house
3. glass
4. from the roof
5. to the bear

10 points:

Consider the following sentences in a Uralic language:

Am os am ürtum Pet'a men as'agamen eruptijagamen.
'I and my friend Petja love our fathers.'

Man nang samyn pusmaltiluv.
'We heal your eye.'

Nang ürtyn eruptilyn.
'You love your friend.'

Am samagum pantijagum.

'I close eyes.'

Am man luvuv os nang ampanyn pusmaltijanum.
'I heal our horse and your dogs.'

Problem: Translate the following and explain your reasoning.

Into English: *Man üratanuv eruptijanuv.*
From English: You heal my father and my friend.