



MATHEMATICS

5 points:

The Town of Lakes is inhabited by three types of people: Knights always tell the truth, Knaves always lie and Jokers tell the truth or lie at random. The Lakes police detained three people: Jerry, Rob, and Chris one of whom stole the car from the city mayor. Police knows that one of three is the Knight, another one is the Knave and the third one is the Joker. Police also knows that the person who stole the car always tells the truth. They said the following:

- Jerry: I am not guilty
- Rob: He tells the truth
- Chris: I stole the car

Who actually stole the car and who of three was the Knave?

10 points:

The Silvertown is inhabited by three types of people: Knights always tell the truth, Knaves always lie and Jokers tell the truth or lie at random (this goes both for men and women). It is known that the Knights are married only to Knaves and Knaves are married only to Knights. Two married couples have been interviewed:

- Mr. Smith: Mr. Robertson is a Knight.
- Mrs. Smith: My husband is right; Mr. Robertson is a Knight.
- Mrs. Robertson: That's right. My husband is indeed a Knight.

What are each of the four people, and which of three statements are true?

PHYSICS

5 points:

An amount of energy needed to melt 1 g of ice is $L=333$ Joule. An amount of energy needed to heat up 1g of water by 1°C is $C=4.2$ Joule (this is called specific heat of water). Imagine that you have a glass with $M=100\text{g}$ of hot water at temperature $T=70^{\circ}\text{C}$, and add 10 g of ice at 0°C to it. What will be the temperature in the glass once the ice melts? Neglect any energy exchange with the environment.

If you can, please do this experiment yourself, and check your theoretical prediction (extra credit will be awarded).

Note: experiments rarely give an outcome that you expect. Don't be afraid to report deviation from theory.

10 points:

Assuming that Moon's orbit is circular, how would Moon's sidereal month change if the Moon would be made out of cast iron?

The shape of the Moon and its distance from the Earth remain exactly the same. Neglect all forces other than the gravitational force between the Moon and the Earth. The mass of the Moon is 1.23% of the mass of the Earth. The average density of the Moon is 3.3 g/cm^3 , the density of cast iron is 7.2 g/cm^3 .

The period of the Moon's orbit as defined with respect to the celestial sphere (of the fixed stars, nowadays the International Celestial Reference Frame (ICRF)) is known as a sidereal month because it is the time it takes the Moon to return to a given position among the stars (Latin: sidera): 27.321661 days (27 d 7 h 43 min 11.5 s).

CHEMISTRY

5 points:

Aelita spaceship was heading back to the Earth after successful completion of its mission: exploration of the Vega planetary system. *Aelita* has almost passed the dark brown dwarf when it was hit by a meteorite. It was just a tiny piece of rock, but due to the enormous speed it caused severe damage to *Aelita*: one of two main reactors was completely destroyed, the section with scientific equipment was almost totally devastated, and the oxygen storage was partially destroyed. The spaceship could not continue its flight, and the captain has ordered to prepare for landing onto the planet orbiting the brown dwarf. Preliminary analysis of the planet's atmosphere demonstrated that the atmosphere is composed of two gases with a relative abundance 1 : 4. The first component of the atmosphere has a molecular weight of 32, and the second has a molecular weight of 28, so one crew member concluded these two gases are oxygen and nitrogen, and, therefore, people from *Aelita* could use it for aspiration, thereby saving their own oxygen reserves. Unfortunately, the scientists from *Aelita* were unable to confirm or refute this idea, because the analysis of the chemical composition of these two gases was impossible: All equipment, except the simple mass-spectrometer (a device that measure molecular mass of chemical substances) was destroyed by the meteorite.

Do you think it is 100% safe to breathe the planet's atmosphere?

10 points:

It is well known, at least, it WAS well known to every young chemist that aqueous ammonia reacts with iodine solution to produce nitrogen iodide ($\text{NI}_3 \cdot \text{NH}_3$). This solid is extremely shock sensitive, and it explodes upon touching. The explosion generates nitrogen and iodine, the latter forms as a cloud of black smoke. Due to the relatively low explosion energy, small amount of nitrogen iodide produce no damage, just noise and smoke, which made it popular among young chemists.

Once upon a time, two nine grade students prepared few grams of nitrogen iodide in their home laboratory, put it in a small paper packet and brought it to school (freshly prepared nitrogen iodide is wet, which makes it relatively stable and suitable for transportation). They dropped it in the hallway and left to dry. The first person to come to the hallway was school's principal, who stepped on the packet. Unfortunately, by that moment nitrogen iodide was already dry. A loud explosion occurred, and the principal disappeared for a moment in a dense cloud of a black smoke. When the smoke cleared, the principal got mad, because all walls and ceiling of the recently renovated hallway

looked terrible. They were covered with ugly dark blue spots, and they definitely required fresh painting.

It took just few minutes for the principal to identify the culprits. They were apprehended and taken to the principal office. (Frankly speaking, the principal liked these two talented boys, and he didn't plan to punish them too severely.) "Gentlemen, do you realize what have you done?" - asked principal strongly. "What do you propose me to do with the hallway?"

"Sir" - replied one boy gingerly, "it is possible to fix it." "Ok, gentlemen" - the principal said, "Do whatever you want, but the hallway must return to its original state. You will not be punished if by tomorrow morning the ceiling and the walls will be virgin white."

"They will" - replied two boys politely, but firmly. They were good chemists, after all.

As they said, tomorrow the hallway was nice and clean. What did the young chemists do for that?

BIOLOGY

5 points:

Bacteria are among the smallest living organisms on the planet. They are found in large quantities in almost all places and perform a variety of functions in nature for human uses. What might be some negative consequences for man and nature if bacteria completely disappeared from the face of the Earth?

10 points:

Our gut includes two types of bacteria ("intestinal flora"): bacteria that make us sick (*pathogenic bacteria*), and bacteria that help our body to absorb food and regulate our immune systems and which feed exclusively off of pathogenic bacteria (*beneficial bacteria*). Imagine that Alison's gut has 2 million beneficial and 2 million pathogenic bacteria. What would happen if, for the next 2 weeks, Alison took a drug that selectively killed off her pathogenic bacteria? Draw a diagram to show how both populations of bacteria would react over time (using a blue line for beneficial bacteria, and red line for

pathogenic bacteria). Would taking such a drug be good for her health or bad for her health? Would you expect the impact on her health to change over time, and if so, how? Explain your answer, referring to your diagram.

COMPUTER SCIENCE

Solutions must be typed and submitted in one of following formats:

.txt .c .cpp .java .py

Solutions written in Java, C, C++, Python and pseudo-code are accepted.

Pseudo-code guidelines are at

http://users.csc.calpoly.edu/~jdalbey/SWE/pdl_std.html

5 points:

Calculate and show all work

$$\begin{array}{r} (77_8 * 80_{16}) - (3320_4 * 10_{16}) \\ \hline 1000000_2 * 40_8 \end{array}$$

10 points:

Intro:

Every year, after students are admitted to SigmaCamp, they get a list of semilabs, and rank in order of preference their top 4 choices. SigmaStaff then have to match students so that everyone gets a semilab they want. Please help us and write an algorithm that will do it automatically.

Problem:

You have 2 input files. The first one is a list of Sigma semilabs with the corresponding maximum number of students, the format is a table with N rows and each row consists of 2 integers -

semilab_number, max_students.

The second file is a table with M rows ($M > N$) where each row has 5 integers - student_id, choice_1, choice_2, choice_3, choice_4

where

$1 \leq \text{choice}_x \leq N$

Develop an algorithm to match students with exactly 2 semilabs . The output should be:

- 1) A list of students along with 2 semilab numbers
- 2) A list of 5 numbers: number of students who got their 1st choice, 2nd choice, 3rd choice, 4th choice, not their choice.
- 3) Output "no valid match" if it is not possible to complete the students-to-semilabs matching.