International Natural Sciences Tournament, 2010-2016
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Unit X*

1. Hibernation

In 1961 Yuri Gagarin made the first human spaceflight. Fifty five years later, in spite of all the difficulties and failures of space programs, humankind still has not lost the hope of interstellar flight. Lots of science fiction books and movies describe the risks of launching so-called "generation starship", which could reach the destination only after several generation changes among the passengers. Therefore, in future necessary will be the technologies, which could let a group of trained individuals to fly towards new discoveries and set up a colony in another planetary system before the end of their lives.

Propose a method of human hibernating for a long-term space flight. Consider the details of entering hibernation state and getting out of it. Providing that the spacecraft can achieve 0.5% speed of light, explore if the radiation, relativistic effects or astronomical objects will affect the proposed method.

2. Back to the future

To make the time machine from the movie "Back to the Future" work, 1 GW of electric power is required. This power in the movie can be generated with the help of nuclear reactor. As soon as the main heroes get to the past, the nuclear fuel becomes unavailable, so the only way to get back to the future is using a lightning spark as an energy source. Keeping lightning under control is not an easy task. Most of the energy, produced by the electric discharge and captured by lightning rod, is known to be spent on heating the atmosphere. Only a tiny part of this energy can be preserved. Estimate, how much energy can be obtained with the help of a lightning rod. Propose other methods of extracting atmospheric electricity. Point possible application area. Estimate practicability of the proposed methods for different regions of the Earth.

3. Sepsis

Sepsis remains one of the most common reasons for high mortality rate among the hospitalized patients in developed countries. For the last century, in spite of dynamic medicine development, the survival index of the patients with sepsis has failed to be improved. Scientists and practicing doctors come to the conclusion that contemporary medical guidelines are ineffective and may even do harm to the patient.

Study the last theories of sepsis pathogenesis from molecular level to the level of the entire organism. Propose new methods of the treatment of this disease clarifying their working mechanisms. Suppose what the side effects of the proposed method can be.

4. Smart sorbent (by Tion company)

One of the trends in air filtration field is the problem of purification from the gaseous chemical pollutants. A classic example of the solution to this problem is the usage of various sorbents. For example, in gas masks the sorbent is used to absorb toxins appearing either from chemical industry or chemical weapons. On other hand, sorbents are being used in kitchen hoods to absorb unpleasant odors that may appear during food preparation. As may be seen from these examples,

the application of sorbents is widespread: from household routine to specialized military purposes. Therefore, in each individual case required is the development and the usage of the individual sorbent, capable of absorbing certain chemical substances with high capacity. Thus, it is difficult to use sorbents under the conditions of previously unknown chemical composition of gaseous pollutant or in presence of chemical pollutants of wide range. Propose the model and the working principle of "smart sorbent", capable of adapting to the environmental conditions. The sorbent in question should change its properties for the maximum absorbing efficiency of the chemical pollutants, currently presenting in the air.

5. **Dry food**
   Dry pet food is produced by the extrusion of the flour of meat or vegetable origin. While being stored, the fats in the composition of the product can be oxidized, resulting in food spoiling. Propose a method of protecting the food from oxidizing and prolongation of its term of storage. Putting additives and antioxidants (BHA, BHT) into the composition is undesirable as it can decrease the attraction of the food for the pets.

Unit Y*

1. **The 5th sense**
   In the last few years, there has been a large development in the area of limb prostheses engineering. Mind-controlled bionic limbs or parts of exoskeletons are not just a science fiction, but real working devices. However, in spite of the fact that the ways of motor functions recovery have already been found, sensory perception is still unavailable for all types of prostheses. From physiological point of view, explain the importance of the interaction between motor and sensory parts of nervous system for making static and dynamic movements by an individual limb. Propose various modules, which could provide prostheses with sensory function. Clarify their working mechanism and principle of their interaction with the nervous system.

2. **Emperor's ring**
   Long ago gemstones were believed to possess mysterious and magical properties. For example, rich people, who were afraid of being poisoned, often wore rings with rubies. A ruby was thought to change its color if put into poisoned drink, warning about the danger. Do the gemstones, applicable for the detection of widespread poisons, poured into beer or wine, really exist in nature? If so, describe their composition and working mechanism. Relying on contemporary scientific knowledge, propose a method of creating gemstone indicators, applicable for jewelry. The created gemstone should be an indicator to several poisons.

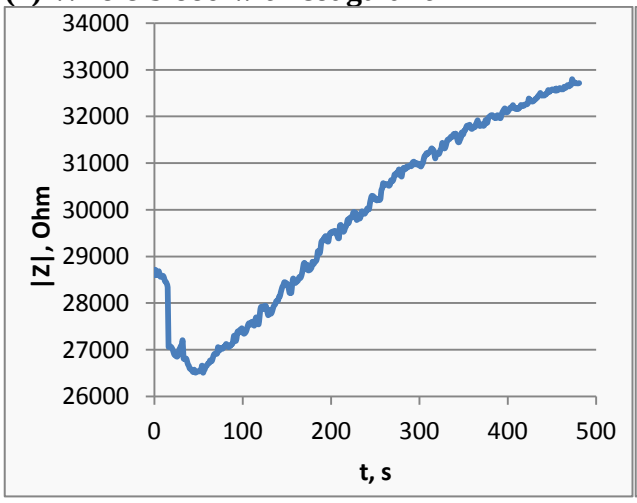
3. **Hungry pets**
   While producing pet food, which is represented by meat chunks in gravy, the meat is boiled in hermetic pack and must undergo sterilization at temperature above 100^0C. The consumer value is the final product with pieces of meat in visibly transparent gravy. However, with current boiling technology the obtained gravy is cloudy. At the same time, adding or removing something after the loading of the initial products and the thermal treatment is impossible.
   Propose a modification to the technological process, which could allow one to obtain transparent gravy while boiling all types of meat in hermetic pack. The process should be as simple and fast

as possible. Remember, that the final product must remain safe, wholesome and attractive for the pets!

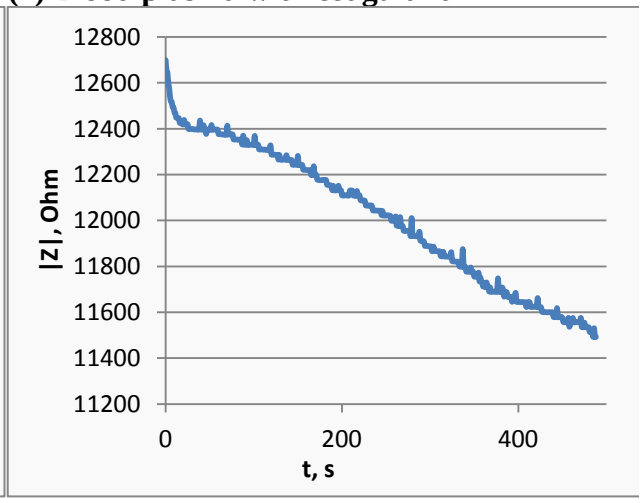
4. **Coagulation control**

Blood coagulation control is essential for the people with coagulation disorders or while anticoagulation therapy. Therefore, perspective is the development of devices, that can allow one to determine the parameters of blood coagulation at home. Particularly, one of the residents of Novosibirsk Academpark is currently developing such a device. This device is based on the method of body fluid (whole blood and blood plasma) impedance change measurements in the presence of a coagulation agent. The device will allow the patients to measure INR (international normalized ratio), which is a very important characteristic of blood coagulation, fast and easy and away from medical institutions. Thus, it will help the patients to control INR at home. The measurement technique is based on the registration of impedance change of a blood sample with current frequency of 50 kHz. In the figures two measurements are represented (in all of the diagrams dependence of impedance change of the sample on time in seconds is shown), obtained under similar conditions with the given device with 15 µl of blood/plasma of the same patient with INR 0.1. Explore, what processes take place when coagulant is added (tissue factor) into whole blood and plasma. Explain the difference between the experimental results in cases 1 and 2. Due to what physical, chemical and biological processes the impedance begins to increase after 100 s (after extremum point in diagram 1); and why does not the same happen in diagram 2?

(1) Whole blood with coagulant



(2) Blood plasma with coagulant



5. **Spherical horse (by Tion company)**

In industry and at home there is a huge number of tasks associated with purifying the air from various particles. These particles may vary from microorganisms in medical institutions to radioactive aerosols at nuclear power stations…or in the tank moving through the sandstorm . The technologies of air purification from the particles can be different, but the most widespread is the "classic" technology, when the air is passed through the material with open-pored structure, which lets the molecules in with simultaneous retention of the particles. The process of capturing is usually probabilistic. The main filter parameters are their efficiency and capacity.

The efficiency may be described in terms of the probability of capturing particles of a certain size. The capacity of the filter can be described by the pressure drop dependence on the mass of the captured aerosol. Parameters in question depend on filter geometry and its internal structure.
Imagine that you have a 3D-printer, which is capable of printing arbitrary polymeric structures with a resolution of 10 nm. Propose a way to print an "ideal" filter with the help of this printer, i.e. the filter with maximal efficiency and capacity. How can one identify and describe the structure of such a filter before printing it? Note that the answer may depend on the size range of the particles, which are supposed to be filtered out.

Unit Z*

1. **Colorful distillation**
   One of the most important educational aspects is visualization of processes and phenomena. The key specialty of demonstrative experiments is their clarity and spectacularity. However, such an important process as separating liquids by distillation often looks like obtaining colorless fractions out of colorless liquid. Color differences would make this experiment more impressive, understandable and memorable. Propose a method of performing an experiment on separation of at least three liquids by distillation. The experiment must include color changes, which will make clear the process of separation in dephlegmator or fractional column. Resulting fractions must be different in color too.

2. **A Song of Water and Fire**
   One of Russian Academy of Science libraries burned down in 2015. About 5 million books were destroyed; most of them had not been digitized. All the knowledge contained in those books was lost forever. Current fire detectors either have low sensitivity or are very expensive. A possible solution of the problem might be book impregnation, with a special compound featuring release of a specific gas upon smoldering. In that case, the gas could be easily detected with an inexpensive gas detection system. The compound should not compromise quality of books, and such books should be safe to handle, even after a long-term storage. Propose such a compound.

3. **Osmotic eel**
   In the Star Trek: Enterprise series (2000, season 1, ep.1-2), a so-called “osmotic eel” – a small aquatic lifeform — was used to heal a starship captain leg wound he got from a laser rifle fire-fight. Propose a concept of a device or biological object that would autonomously promote healing of burns, deep cuts, and stab or gunshot wounds. The device/object should stop bleeding and promote healing in a timely manner. Would it be possible to use your device/object for internal organs healing as well?

4. **Hot water**
   Solar energy use is one of innovative areas in renewable energy industry, where thermal or electrical energy is produced from sun irradiation. Solar collector systems are a promising technology, widely used for water heating and space heating. However, these systems are usually bulky and heavy; require a sophisticated manufacturing technology and laborious transportation; need an additional energy source as a backup. These features, together with a high cost, render a solar collector system unattractive for outdoorsmen, campers, and other consumers who prefer outdoor activities. Propose an alternative design of an affordable solar collector system (or its

components) for water heating with the following features: lightweight, portability, ease of installation, independent operation mode, and high thermal efficiency.

5. **Space-X on Mars**

One if the aims of the Space-X company is founding a colony on Mars in future. Not enough is just flying to Mars: necessary is to learn how to return the expeditions from Mars and send cargoes to the Earth. For this, needed is the method of producing fuel for a spacecraft under the conditions of Martian colony. In one of the interviews, Elon Musk proposed that methane is the best type of fuel to be produced on Mars. Propose a method of industrial production of optimal, from your point of view, rocket fuel for interplanetary flight. The fuel must be synthesized or mined under the Martian colony conditions. Will the fuel, produced by you, be enough to fly from Mars to the Earth? At least two people must have an opportunity to fly back to the Earth.

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* The problems are divided into units X, Y and Z. Each unit corresponds to a certain tournament day (including final round). The order of units will be announced in three days before the tournament starts. Please, be careful to work through each problem. Remember, that you may refuse to solve any one problem in each block.

No extended solution (*.doc) is needed.
If you have any questions in regard to the presented information, please, do not hesitate to contact us again by:

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