EXPERIMENTAL COMPETITION

15 January, 2014

Please read the instructions first:

1. The Experimental competition consists of one problem. This part of the competition lasts 3 hours.
2. Please only use the pen that is provided to you.
3. You can use your own non-programmable calculator for numerical calculations. If you don't have one, please ask for it from Olympiad organizers.
4. You are provided with ***Writing sheet and additional papers***. You can use the additional paper for drafts of your solutions but these papers will not be checked. Your final solutions which will be evaluated should be on the ***Writing sheets***. Please use as little text as possible. You should mostly use equations, numbers, figures and plots.
5. Use only the front side of ***Writing sheets*****.** Write only inside the bordered area.
6. Fill the boxes at the top of each sheet of paper with your country (***Country*****),** your student code (***Student Code***), the question number (***Question Number*****)**, the progressive number of each sheet **(*Page Number***), and the total number of ***Writing sheets*** (***Total Number of Pages***). If you use some blank ***Writing sheets*** for notes that you do not wish to be evaluated, put a large X across the entire sheet and do not include it in your numbering.
7. At the end of the exam, arrange all sheets for each problem in the following order:
    - Used ***Writing sheets*** in order;
    - The sheets you do not wish to be evaluated
    - Unused sheets and the printed question.

   Place the papers inside the envelope and leave everything on your desk. You are not allowed to take any paper or equipment out of the room

Magnetic interactions (15 points)

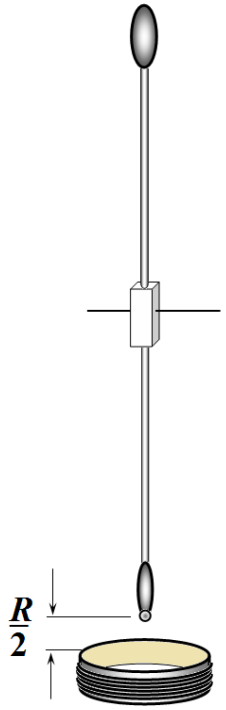
Instruments and equipment: tripod, pendulum with a bead magnet, clay, ruler, magnetic beads, stopwatch, power supply (battery of the voltage 4.5V) , 6 Ohm rheostat, coil, multimeter, switch, connecting wires, nails, piece of chocolate.

The pendulum consists of two wooden chopsticks stuck into the eraser. There are two pieces of clay fixed at the free ends of both chopsticks, the lower piece of clay contains a metal magnetized bead inside. Pendulum axis is simply a steel needle piercing the eraser.

Another magnetized bead is mounted on another piece of clay provided.

Attention! *Do not change the orientation of magnetized beads during the experiment!*

Part 1. Interaction with the magnetic field of a coil



Put the pendulum axis on the rack of the tripod. Make sure that the pendulum can make free oscillations without touching the tripod with the wooden chopsticks or the eraser. By changing the clay masses at the ends of the chopsticks make the oscillation period larger than 2 seconds. In the equilibrium position both chopsticks should be vertical.

1.1. Measure the oscillation period of the pendulum. Evaluate the corresponding experimental error.

Attention! In the subsequent parts error estimation is not required!

Place the coil under the pendulum so that the distance from the center of the coil to the magnetized bead in the pendulum to be approximately equal to half the radius of the coil.

Connect the coil to the power supply so that you could change and measure the strength of the current flowing through it.

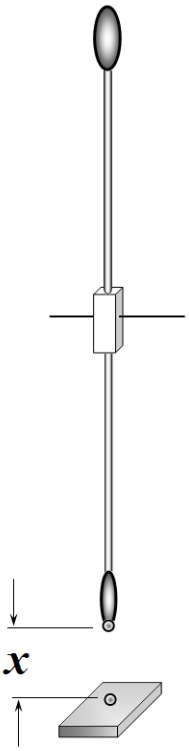
Attention! *Be sure to use the key, switch it on while doing measurements only, otherwise the battery will quickly discharge!*

1.2. Draw schematically an electric circuit that you have used for making measurements.

1.3. Measure the dependence of the oscillation period of the pendulum on the current in the coil. Plot the corresponding graph.

1.4. Based on the experimental data obtained prove that the force, acting on the magnetic bead, is proportional to the current in the coil. Justify your conclusion graphically.

Part 2. Pointlike interactions



Place the magnetized bead fixed on a piece of clay right under the pendulum. The beads should attract each other!

It can be assumed that the interaction force is central, i.e. it is directed along the line connecting the centers of the two beads. The magnitude of that force depends on the distance between the centers of the beads according to the law

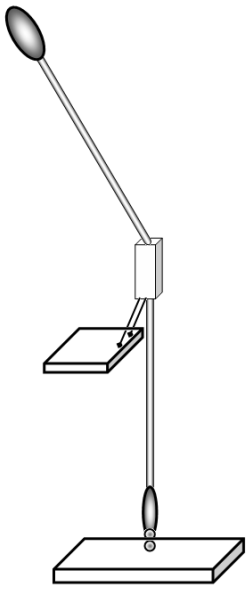
$$F = \frac{C}{r^{\gamma}} \ . \qquad (1)$$

2.1. Put down the equation of motion of the pendulum in this case. Obtain the formula for the period of small oscillations.

2.2. Measure the dependence of the period of small oscillations on the distance between the centers of the beads. Plot the corresponding graph.

2.3. Using the experimental data obtained, evaluate the exponent γ in formula (1). Justify formula (1) graphically.

Part 3. Magnetic piece of chocolate



Let us reduce the damping by changing the design of the pendulum. Stick the upper chopstick into the eraser to make an angle of approximately $30°$. Stick two nails into the eraser to play the role of two legs on which the oscillations are performed. Attach two beads to the bottom of the pendulum. Make sure that the pendulum is steadily balanced on its legs while performing oscillations. To adjust the pendulum you can mount the ruler in the rack as a support.

Place a piece of chocolate under the pendulum, but do not take off its wrap! The lower end of the pendulum should move along the piece of chocolates at a distance of 1-2 *mm*.

It turns out that a piece of chocolate can affect the pendulum motion.

3.1. Establish experimentally which physical characteristics of the pendulum are affected by the piece of chocolate.

3.2. Take necessary measurements to confirm your assumption. Justify your answer graphically.