EXPERIMENTAL COMPETITION

13 January, 2018

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

The Law of Archimedes (15.0 points)

Instruments and equipment: stopwatch, test-tube, beaker, wide vessel, set of nuts 6 pcs., plastic ruler, strip of millimeter paper, piece of cotton wool, piece of film.

In the theoretical competition, you should have obtained a formula for the period of vertical oscillations of a floating test-tube

$$T = 2\pi\sqrt{\frac{h_0}{g}}, \quad (1)$$

where h_0 is the depth of immersion of the test-tube in equilibrium position.

Today you have to verify this formula experimentally.

In this experimental competition, consider the acceleration of gravity $g = 9{,}81\ \mathrm{m/s^2}$ and the water density $\rho = 1000\ \mathrm{kg/m^3}$.

Place the nuts into the test-tube, only when there is a piece of cotton wool in it!

Part 1. Installation parameters

1.1. Using a strip of millimeter paper, measure the outer diameter of the tube with a minimum error. Give a sketch of your measurements. Estimate the error in measuring the diameter.

1.2. Measure the length of the tube and estimate its error.

1.3. Gently add the nuts inside the test tube one by one.

1.3.1. Measure the dependence of the immersion depth of the test-tube on the number of nuts placed in it.

1.3.2. Construct a graph of the obtained dependence. Determine the numerical values of the parameters of the obtained dependence.

1.3.3. Give the theoretical formula for the dependence of the immersion depth of the test-tube on the number of nuts inside it. Using the measurement results, determine the mass of one nut and the mass of the empty test-tube. Estimate the error in measuring these masses.

Part 2. Oscillations of the test-tube

2.1. Using formula (1) and the measurements results of Part 1 plot a graph of the theoretical dependence of the period of oscillations of the test-tube on the number of nuts inside it. Select the coordinates so that the obtained relationship would be linear and its linearity is not affected by the error in determining the immersion depth.

In this experiment it is possible to measure the oscillation periods only for 4, 5 and 6 nuts inside the tube. When measuring, be extremely accurate and careful: withdraw the tube from the equilibrium position and measure the time of 3-5 oscillations. Repeat measurements at least 5-10 times. Write down only those results when the tube has oscillated vertically. When performing measurements with 6 nuts, close the tube with a piece of film. If water gets into the tube, ask the organizers to replace a piece of cotton wool in the tes- tube.

2.2. Measure the periods of oscillation of the test-tube in the beaker and in the wide vessel with a different number of nuts placed in the test-tube.

2.3. Draw your experimental values on the graph plotted in Part 2.1. Specify on your graph which points correspond to particular dependencies.

2.4. Most likely, the results of your measurements will differ from the theoretical calculations.

Possible reasons that can explain the observed deviations are indicated in the table below:

No.	Possible reason
1	Measurement errors
2	Oscillation damping
3	An increase in the effective mass of a moving test-tube due to water entraining
4	Change in pressure under the tube when it moves as compared to hydrostatic pressure
5	Surface tension forces

For each of the reasons listed, indicate "yes" if you think that it explains the observed deviations, and "no" if you think that it does not explain the observed deviations.