Laboratory of Experimental Physics **Experiment 111**

Determination of Earth's gravity with the use of differential pendulum

The aim of the experiment is to familiarize with the measurement of Earth's gravity and to determine its value.

Prerequisites

Student should be familiar with the following topics: the law of universal gravitation, simple harmonic motion, simple gravity pendulum, systematic and random measurement errors, Student's t-distribution.

Apparatus

Differential pendulum, stopwatch.

The method

It is possible do determine the Earth's gravity with the use of formula yielding the period of simple gravity pendulum. The result, however, will always have some, difficult to calculate, systematic error (*why?*).

In order to get rid of this error it is possible to perform, using the same pendulum, several measurement differing only in the string length. The error of this difference depends only on the precision of measuring tools used.

For every pair of measurements we may note two formulas for the pendulum period, and then combine them into one in such a way that the resulting formula yields g (Earth's gravity) and depending only on both measured periods and the difference between both string lengths (*why is it advantageous?*).

Course of experiment

1. Student should select and note down position of the slider changing the string length, and measure the time it takes for the pendulum to perform some number of full swings (e.g. 50).
2. This operation should be repeated for several other positions of the slider.
3. Student should pay attention to tighten the slider on the string (*what would be the result of leaving a gap where the string can move during the experiment?*).

Report

The report should contain:

1. Description and explanation of the chosen measurement method.
2. Derivation of the formula used in the calculations.
3. Description of the method of uncertainty determination and the formulas used — the mean value, mean square error of the mean value, the uncertainty of the result (with the use of Student's t-distribution with confidence $\alpha = 0.95$).
4. Explanation of dependence of the uncertainty of individual g value on the value of length difference d.
5. The results (Earth's gravity value) together with corresponding uncertainty.
5. Conclusions.

Additional information

The following information is intended only as a list of formulas and is not a substitute of reading appropriate text in the handbook.

Swing period of the simple gravity pendulum (student should be able to derive this formula):

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Final formula used for calculation of Earth's gravity (student should be able to derive this formula):

$$g = 4\pi^2 \frac{d}{T_1^2 - T_2^2}$$

Mean square error of the mean value:

$$S_{\overline{u}} = \sqrt{\frac{\sum_{i=1}^{m} \left(u_i - \overline{u}\right)^2}{m\left(m-1\right)}}$$

where: u_i — i-th measurement of u, m — the number of measurements made, $\overline{u}$ — the mean value of u.

Final formula for error calculation:

$$\Delta g = t_\alpha S_{\overline{g}}$$

where: t_α — coefficient found in a t-Student distribution table corresponding to selected confidence α,
$S_{\overline{g}}$ — mean square error of the mean Earth's gravity value g.