Measurement of the gravitational acceleration by secondary school and university students with the use of remote laboratories

Pavel BROM (1), Radka HAKL (1) and František LUSTIG (2)

(1) Škoda Auto University, Department of Quantitative Methods, Na Karmeli 1457, CZ 29301, Mladá Boleslav, Czech Republic
(2) Jan Evangelista Purkyně University, Pasteurova 3544/1, Ústí nad Labem, CZ 40001, Czech Republic

Abstract. This contribution summarizes several theoretical models for the value of the gravitational acceleration *g*. Significant deviations among the predicted theoretical values from these models can be observed. They are compared with experimental values from worldwide open remote laboratories within the World Pendulum (WP@ELAB) Project. Moreover, behaviour of several UJEP and Škoda Auto University students in the Czech remote laboratory with a mathematical pendulum with variable length at UJEP is correlated with the quality of the submitted reports of these students involved in the pedagogical research. The most interesting findings of the first log file analysis are presented and discussed.

Introduction

Learning about the Earth's gravity belongs to the basic course of physics. Nowadays, secondary school and university students may perform both traditional measurement of the gravitational acceleration *g* or remotely controlled laboratory with no need to travel onto distant sites to verify that *g* depends especially on the latitude and elevation. Students should compare their experimental values with the theoretical but they can derive or find more model functions whose predictions may differ significantly. In this contribution we discuss how attractive and effective various approaches can be for students to learn about gravity, with the use of real remotely controlled experiments accessible freely via internet. The remote experiment Mathematical Pendulum with variable suspension length is based on our ISES hardware and software platform. It was described in detail in [1]. The remote laboratory, including documentation, is accessible at www.ises.info. Activity of the students in the Czech remote laboratory at UJEP can be observed through log files and compared with the results in the students' reports providing unequivocal assignment of the log file record to the student. The authors did not manage to find any papers relevant to the topic so the presented log file analysis would be the first. Some log file analyses had been performed earlier considering the other experiment topics (e.g. photoelectric effect, see [2]).

Theoretical formulas for the gravitational acceleration *g* and research questions

The Earth's gravity varies between 9.78 to 9.83 $\mathrm{m\cdot s^{-2}}$. Students may easily derive the dependence of g on the latitude φ and elevation h for the spherical static and rotating Earth. In addition, the Hayford ellipsoid is taken into account. Furthermore, students can find several series expansions for g, e.g. the international gravity formula (IGF) by WELMEC [3]

$$g_{\left[\mathrm{m\cdot s^{-2}}\right]}(\varphi,h)=9.780\,318\cdot\left[1+0.0053024\cdot\sin^2\varphi-5.8\cdot10^{-6}\cdot\sin^2(2\varphi)\right]-3.085\cdot10^{-6}\cdot h_{[\mathrm{m}]} \quad (1)$$

The predicted theoretical values from these models can be compared in the graph in the Fig. 1.

The authors were interested whether students can learn effectively from real remote experiments, which theoretical framework and experimental setup available online students prefer.

Methods and findings

A case study with 4 secondary school and 6 university students was performed. Submitted reports were assessed and the students' activity could be observed through log file records. Majority of the students chose the real remote experiment with the variable-length mathematical pendulum in the Czech remote laboratory, which they regarded to be simplier, more user-friendly and intuitive including experimental data processing. Typical results are visualised in the graph in the Fig. 1 including experimental uncertainties. Measurements in the WP@ELAB laboratories [4] were performed and added by the authors. The log file analysis revealed usual short exploration of the virtual environment and playing phase before the students' measurements.

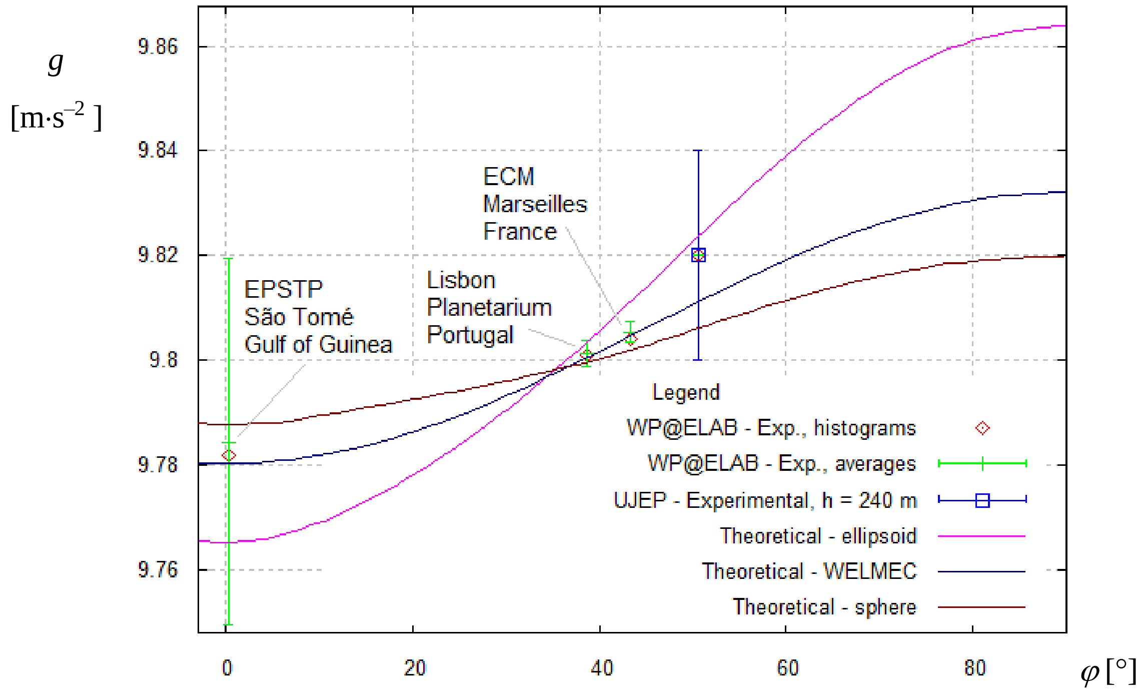

Fig. 1. Experimental values of the Earth's gravity in comparison with theoretical values from several models.

Conclusion

Real remote experiments accessible freely via internet bring for students an interesting and challenging opportunity to measure the gravitational acceleration worldwide as well as to discuss the deviations between experimental and theoretical values. Students prefer the remotely controlled experimental setup where live video stream is available, where the data processing seems to be simplier and clear. The students' correct measurement procedure was confirmed with the log file analysis.

References

[1] F. Lustig, P. Brom, E. Hejnová, Remote physics experiment Mathematical pendulum as an attractive alternative to traditional laboratory exercises, *JoP:Conf. Ser.* **2715** (2024) 012020.

[2] Z. Lustigova, P. Brom, Educational datamining in virtual learning environment, *iJAC* **7** (2014) 39-42.

[3] Theoretical gravity, *Wikipedia* [online] https://en.wikipedia.org/wiki/Theoretical_gravity.

[4] M. Santos et al., World Pendulum Alliance, *Proc. of 2019 5th Experiment@ int. conf.*, ISBN 978-1-7281-3637-0 (2019) 272-273.