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PRETEST AND THE VERIFICATION OF MEASUREMENT TOOLS FOR A PILOT SURVEY OF THE EFFECTIVENESS OF A REMOTE LABORATORY EXPERIMENT

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Abstract

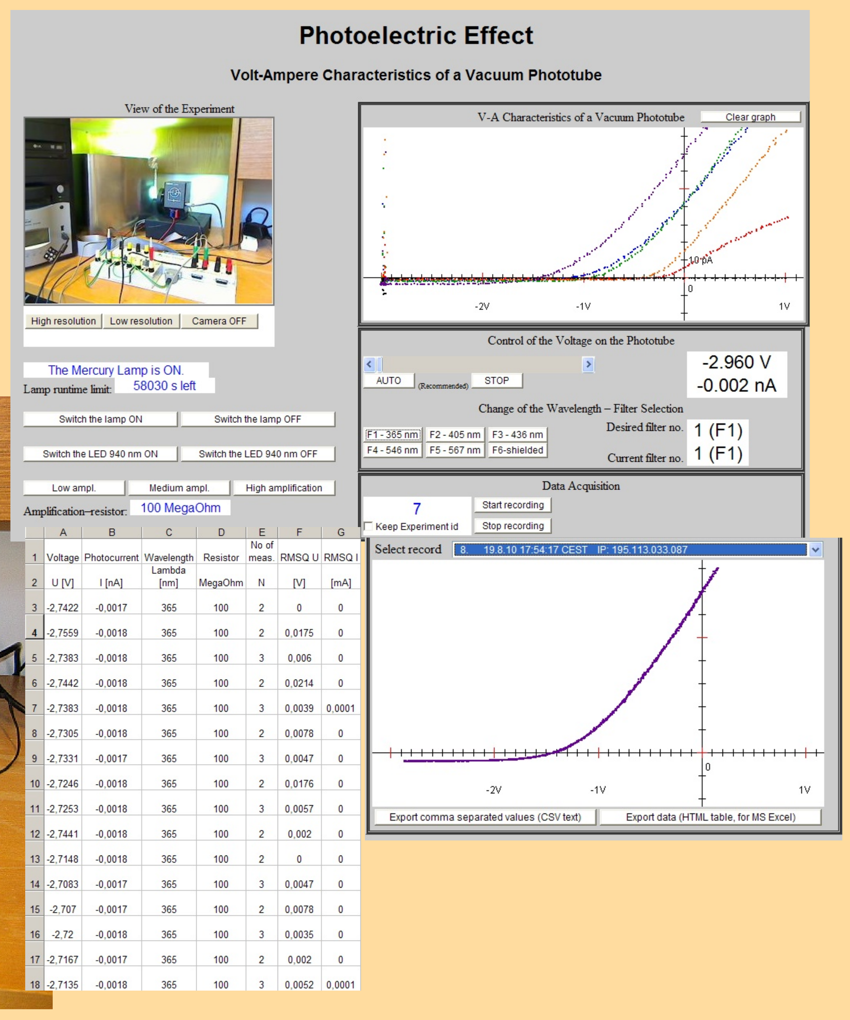
In our contribution we focus on a new strategy in physics teaching and learning called the integrated e-learning, which aims the traditional e-learning materials to be added effectively: 1) virtual experiments (i.e. applets, simulations), 2) remotely controlled experiments as real objects. We demonstrate this approach by our suggestion how to present and explain the photoelectric effect, followed by labworks (performed at school, or at home) with goals to verify the Einstein's formula, to determine the Planck constant and the work function as well.

Furthermore, we present the first results of a minipedagogical experiment and we discuss problems, important factors and difficulties as a preparation for a pilot survey of the effectiveness of the real remote laboratory at UK MFF (www.ises.info). We have proposed and verified several adequate measurement instruments, especially questionnaires and analyses of the real behavior of students, using log files.

Real remotely controlled experiment on the photoelectric effect in the Czech remote laboratory

www.ises.info

- A Phywe vacuum phototube with high-input-impedance operational amplifier accessible 24/7 to anyone.
- 5 wavelengths available – spectral lines of a mercury lamp (125 W) to verify the Einstein's formula for the photoelectric effect.
- 1 additional wavelength – a high-intensity IR LED (940 nm) to verify the threshold behaviour of the phenomenon.
- 2 common methods available:
  a) simplier charging a capacitor up to the stopping voltage,
  b) more complex study of the volt-ampere characteristics of a vacuum phototube.
- Data acquisition (DAQ) with easy import into a MS Excel sheet for the futher process by students at their homes.



Web-based instructional design – not rigid

Homework for secondary-school students

- Read the e-text with the theory available at www.ises.info – recommended.
- Run the PhET applet on the photoelectric effect – optional.

PhET.colorado.edu

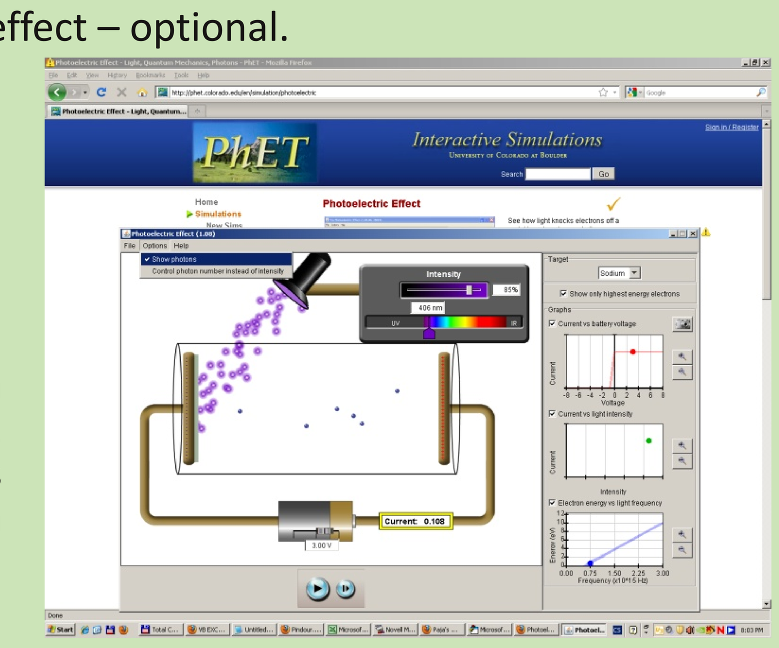


Figure: The PhET simulation with graphs being plotted simultaneously. These graphs are used in the e-text as well so that one can study their origin by the interaction with the applet.

- Perform tasks listed at www.ises.info – compulsory
  (*e.g. try to predict whether we can observe photocurrent with the shielded phototube and verify your prediction, the same for infra-red light 940 nm incident onto the photocatode (source: IR LED); study the V-A characteristics for the other wavelengths in order to verify the Einstein's formula and to determine the Planck constant and the work function, plot graphs $U_0(\lambda)$, $E_{k,max}(f)$; estimate the errors of your experimental results*)
- Submit a report with your results and their discussion to the teacher – compulsory.

Results of the pretest

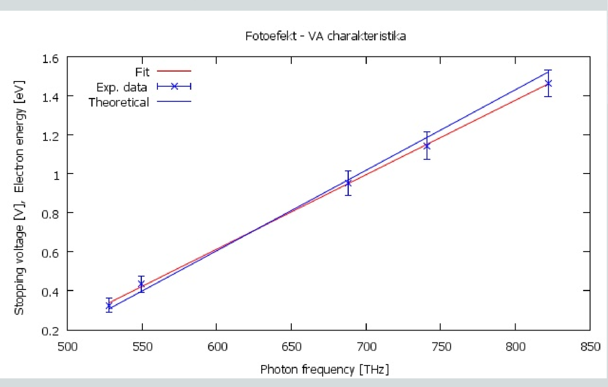
Typical results

The work function: $A = (1.68 \pm 0.04)$ eV
Threshold wavelength: $\lambda_0 = (740 \pm 20)$ nm
The Planck const.: $h_{fit} = (6.12 \pm 0.08) \cdot 10^{-34}$ J·s
Literature value: $h = 6.62 \cdot 10^{-34}$ J·s

Considering the errorbars of all the points $U_0(f)$, the error of the result might be up to 10 %.

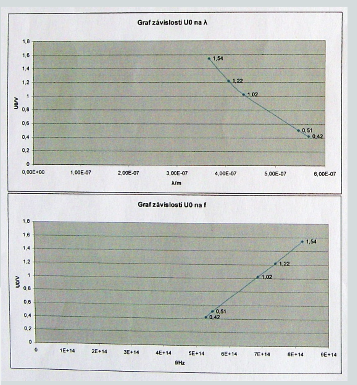
$$h_{exp} = (6.1 \pm 0.6) \cdot 10^{-34} \text{ J·s},$$

$$A_{exp} = (1.7 \pm 0.2) \text{ eV}.$$



Measurement tools and data sources

Reports and questionnaires



Stud. ID	Means really used by the students			Students' attitudes – Lickert scale (1–very positive ... 5–very negative)			
	Real exp.	PhET Sim.	Theory e-text	Diffi-culty	Bene-fit	Enter-tainment	Arran-gement
1	1	0	1	3	2	2	1
2	1	1	1	3	2	1	1
3	1	0	1	2	2	1	3
4	1	0	1	2	3	3	3
5	1	0	1	2	2	3	1
6	1	1	1	1	2	1	2
7	1	1	1	2.5	1	2	2
8	0	1	1	2	2	3	3
9	1	1	1	2	3		1
10	1	1	1	1	1	1	2
Av.	0.9	0.6	1.0	2.1	2.0	1.9	1.9
σ	0.3	0.5	0.0	0.7	0.6	0.9	0.8

- All the students managed to download data and determine experimental values of the Planck constant and the work function.
- The teacher corrected mistakes (rounding, sources of the syst. error).

Log file

- Analysis of the log file revealed that more than 50 % of the students downloaded also someone else's experimental data (?!).

Discussion

- Students evaluated the whole labwork quite positively, there was no negative evaluation.
- Students appreciated having to apply a linear fit in order to determine a significant physical constant and a material constant (work function) – mostly for the first time in their life. They practised calculations and did a revision before their school-leaving exam.
- Students got awareness of typical values of photocurrent and its measurement.
- A few students claimed their surprise about the technology of remote experimenting.

- The teacher appreciated opportunity for students to perform a historical and essential experiment of quantum physics (next to the PhET simulation). A vacuum phototube is not available at the school.
- The developers got feedback and suggestions how to improve GUI and the questionnaire.

Acknowledgment

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Conclusion

We can recommend to use real remote experiments for students' re-discovery of a new phenomenon, further the simplified PhET applet for the first explanation of the physical background and the stopping voltage method before the measurement, and especially we suggest to perform a real remote experiment with traditional outcomes – students' reports. We can conclude that we have managed to move labworks from school lessons to home with a good feedback and control over the teaching-learning process for the teacher.

We have discussed the first results of a small pilot pretest performed on 10 students at a secondary school. Students' attitudes to the integrated e-learning strategy (concerning the topic photoelectric effect) were quite positive, motivating and inspiring for the developers and hopefully for more science teachers.

The very first experience as a preparation for a survey has verified suitable measurement tools and data sources like questionnaires, students' reports as outcomes, and analysis of log files, which can be added some standard test on knowledge, understanding, and perhaps ability to apply it. Within a suitable research design that considers many factors mentioned in the text the pilot survey should be performed on a greater number of participants.