Experimenting with a luxmeter and exploring illuminance

JÁN DEGRO
Faculty of Science, UPJS Košice, Slovakia

This paper presents ideas for experiments and projects measuring illumination with a luxmeter. The activities are suitable for basic and secondary school pupils.

1. Luxmeter

The main purpose of photometry is to measure visible radiation in a manner that corresponds to human eye perception. To gain such results, one has to consider the physical properties of light stimuli as well as the basic characteristics of eyesight. The most common task of photometry is to measure illuminance in luxes.

The intensity of illumination – illuminance – is measured by a luxmeter. A common luxmeter consists of the measuring device itself and a sensor. The sensor is made of selenium or silicon photocells. A schematic sketch of a gate photocell can be seen in fig. 1.a. Such a photocell is not yet suitable for measuring illuminance since it does not fulfil the most significant requirement – its spectral sensitivity is different from human eye. Comparison of photocell and human eye sensitivity can be seen in fig. 2. A luxmeter that does not have an eye correction should not be used for measurements of this type [1].

Special attention should also be paid to another part of a luxmeter – the cosine adapter. Fig. 1.b depicts a cosine adapter by Harting-Helweig and one by Reeb-Tosberg. A photocell without a cosine adapter would produce measurement error proportional to the angle of incidence of the light [1].

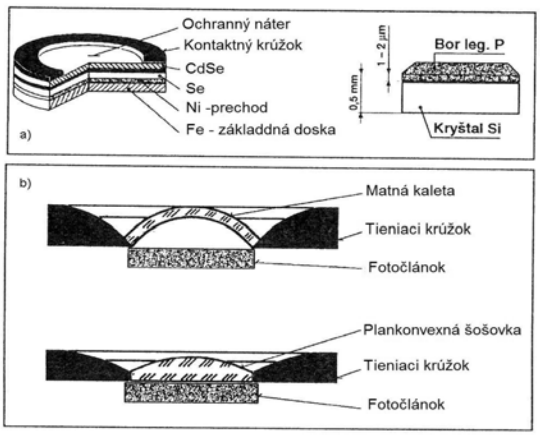

Fig.1a: Gate photocell.
Fig.1b: Types of cosine adapters [1].

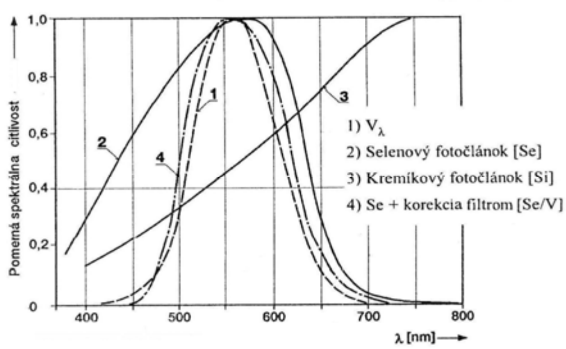

Fig. 2: Comparison of photocell and eye sensitivity. V_λ - Eye spectral sensitivity [1].

There are a lot of interesting experiments that can be performed with a luxmeter in a classroom. These experiments can be split into two groups [2, 3]:

- The discovery of the photometric law
- Illumination and human health

2. Student discovery of the photometric law

Tasks:

- Estimate the dependence of the illuminance E on the distance r from the light source.
- Estimate the dependence of the illuminance E on the angle of incidence φ.
- Discuss the experimental dependencies with pupils, and use mathematical knowledge and previous experience in physics to find the appropriate mathematical function describing the studied phenomenon.

Experiment results:

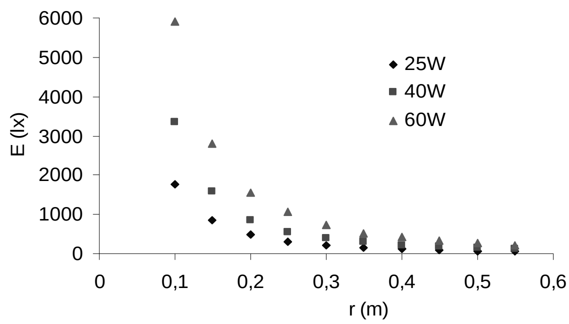

Fig. 3: Dependence of illuminance E on distance r from light bulb, $\varphi = 0°$.

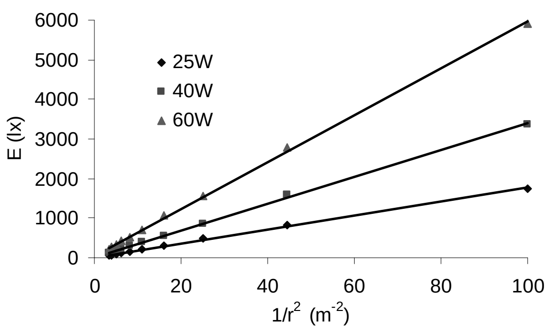

Fig. 4: Dependence of illuminance E on $\frac{1}{r^2}$ for values on fig. 3.

From the dependencies in fig. 3 and 4, we can conclude that E is proportional to $\frac{1}{r^2}$.

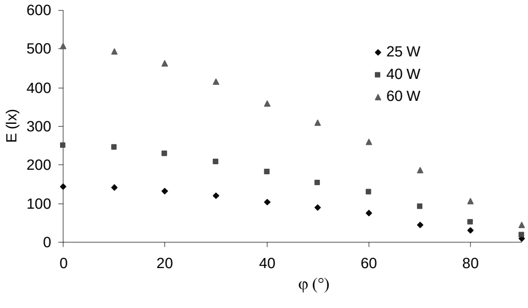

Fig. 5: Dependence of illuminance E on angle of incidence φ, $r = 0{,}36$ m.

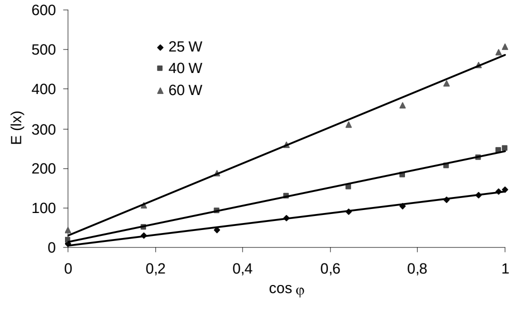

Fig. 6: Dependence of illuminance E on $\cos\varphi$ for values from fig. 5.

From the graphs in fig. 5 and 6, we can conclude that E is proportional to $\cos\varphi$.

The final conclusion is that E is given by the formula

$$E = k\frac{1}{r^2}\cos\varphi = \frac{I}{r^2}\cos\varphi, \qquad (k = I - \text{source irradiance}) \qquad (1)$$

However, equation (1) is exact only in the case of a point light source. This equation is sometimes called the photometric law. This "discovery" can be followed by a mathematical derivation if desired.

3. Illuminance in a classroom

Good light quality and appropriate illuminance are a necessary requirement for safe work and leisure time. The government regulation STN EN 12464-1 defines required illuminance values for interiors. Table 1 shows a selection of illuminance standards E for school interiors. The standard values are meant as reference values [5] for horizontal workplace surfaces at a height of 0,85 m above the floor [1, 5].

Professional measurements of illuminance (daylight, artificial and combined) in workplaces are offered by some state institutions, e.g. the Regional Institute of Public Health. The requirements and standards for illuminance measurements are given by the Slovak health ministry [6] and government [7].

Because illuminance is a very important part of a healthy environment and professional measurement methods are not suitable for classroom use, it is useful to perform simple experiments with a luxmeter at different spots at school.

Room	***E* (lx)**	**Room**	***E* (lx)**
Computer lab	300	Entrance hall	200
Lecture room	500	Stairway	150
Demonstration desk	500	Dining hall	200
Drawing room	750	School kitchen	500
Laboratory	500	Gymnasium	300
Library, reader's hall	500	Corridors	100

Tab.1: Standard values of nominal illuminance E for different places inside school buildings (STN EN 12464-1 standards)

Is the illuminance in our environment good and healthy? This question has strong motivational potential for students. *Let's transfer the question into the following tasks:*

- Estimate the values of illuminance E for different spots in your school: classrooms, laboratories, corridors, dining room, gymnasium, etc. Compare your measured values to the values given by government standards (EN12464-1). Suggest changes that could be made in the case of significant differences.
- Draw a plan of your room (house) and mark the placement of the light sources. Estimate the illuminance in both workplaces and resting places. Compare your

measured values to the values given by government standards (EN12464-1). Suggest changes that could be made in the case of significant differences.

Example of measurement results

Figures 7 and 8 show the measurement results in a classroom, while figures 9 and 10 are results from a laboratory. The letter L marks each row of desks in the classroom. The classroom is facing towards the west. Windows are at the side belonging to the back row of the graph. The laboratory is a corner room facing north. There are two windows on the back wall and one on the side wall. The measurements took place at 11 AM.

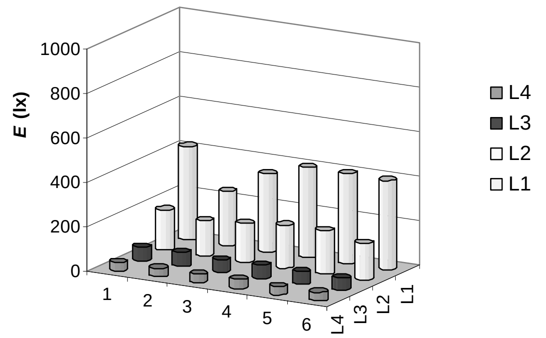

Fig. 7: Dependence of desk illuminance *E* on its placement inside a classroom: natural light from a cloudy sky. L – desk row

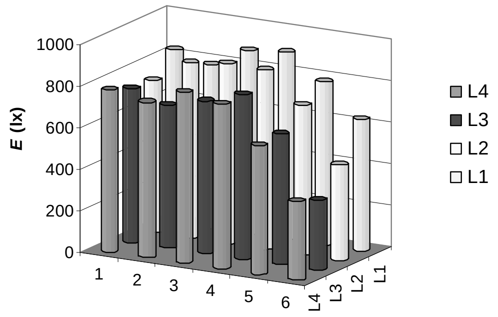

Fig. 8: Dependence of desk illuminance *E* on its placement inside a classroom: natural and artificial light, cloudy sky. L – desk

From the measured values in figures 7 and 8 it can be concluded that the classroom fulfils the standards only when we turn on the artificial lights.

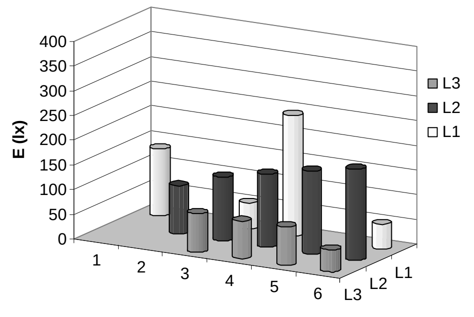

Fig. 9: Dependence of desk illuminance *E* on its placement inside a classroom: natural light, no artificial light, cloudy sky. L – desk row

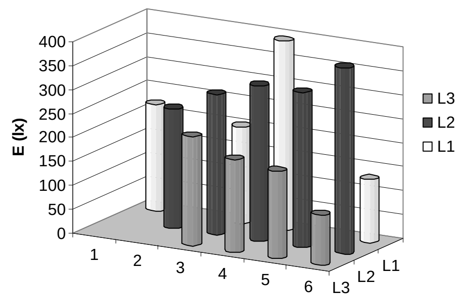

Fig .10: Dependence of desk illuminance *E* on its placement inside a laboratory: natural and artificial light, cloudy sky.

From the measured values in figures 9 and 10 we can see that the laboratory does not fulfil the standards. It is located in a historical building that has smaller windows than a classroom located in a modern building. This room is 4 metres high, its walls are

0,5 metre thick, the lights are equipped with modern power saving bulbs and are placed too high above the desks.

From these results as well as from further experiments studying illuminance in different conditions like weather, season, different times of day, etc., pupils can make these conclusions:

The illuminance of my desk depends on:

- outside light conditions (e.g. weather, time of day,) and so on
- the architecture of the building (e.g. spatial orientation to cardinal directions, number and size of windows, number and quality of light sources).

In the case of illuminance values that do not fulfil standards, let the pupils start a discussion about the reasons for the improper light conditions. They will suggest possible solutions to improve the situation.

4. Suggestions for projects

Suggestions: Illuminance in my working place, influence of a lampshade on illuminance, illuminance at your home, illuminance at school, the dependence of illuminance on time after a fluorescent light has been turned on, comparison of classic and power-saving light sources, light in outdoor places.

Further information on these suggestions, such as motivations, question setup, measurement results, and more can be found at this address

http://exphys.science.upjs.sk/degro/pokus/pokusy.html

References

[1] Plch J.: Světelná technika v praxi. IN-EL Praha, 1999.
[2] Degro J.: *School experiments with a luxmeter.* Phys. Educ. 42 (2007), 275-280.
[3] Degro J.: *Vybrané kapitoly z environmentálnej fyziky.* Diel 1. PF UPJŠ Košice 2006.
[4] Lepil O., Kupka Z.: *Fyzika pro gymnázia*. Optika. Prometheus Praha, 1993
[5] STN 12 193 (36 0074) EN 12464-1 *Osvetlenie pracovných miest*. Časť 2. *Vnútorné pracovné miesta*. 2004.
[6] Ministerstvo zdravotníctva SR: Metodická príručka. *Meranie a vyhodnocovanie osvetlenia.* Bratislava, August 1997.
[7] Nariadene vlády SR č. 269/2006 z 19 apríla 2006 *o podrobnostiach o požiadavkách na osvetlenie pri práci*. Zbierka zákonov, časť 96, str. 1589-94, 2006.

This paper was created as a part of the KEGA project.