Light intensity does not always decay with the inverse of the square of the distance: an open-inquiry laboratory

Cecilia STARI (1), Marcos ABREU(1), Martín MONTEIRO (2), Arturo MARTI (1)

(1) Instituto de Física, UdelaR, Montevideo, Uruguay
(2) Universidad ORT Uruguay, Montevideo, Uruguay

Abstract. The square inverse law with distance plays an important role in many fields of physics covering electromagnetism, optics or acoustics. However, as every law in physics has its range of validity. We propose a laboratory where we challenge these concepts by proposing experiments where the intensity of light decays linearly or even remains constant over a range of distances. This laboratory, initially proposed in the context of the COVID19 pandemic, has the virtue of challenging intuition and encouraging the critical spirit of the students.

Introduction

In the last decade, a large number of papers have been published with proposals for experimental activities that can be carried out using smartphone sensors [1]. They has become a tool that is easy to access for students, and can be used both in and out of the formal classroom and allows us to propose activities that increase motivation and interest in experimentation, as well as reinforce decision making, creating opportunities for critical thinking and discussions about the physical model and the limitations of the model and the experimental design.

In this work we propose an instructional laboratory oriented to first-year university students in which we challenge them to obtain the laws of the decay of the light intensity produced by sources of different geometry. This experiment allows a broad experimental and theoretical approach, as it can be adapted to different educational levels or backgrounds [2, 3].

Theoretical background

We know from our daily experience that the intensity of a light source decreases as we move away. In physics courses we usually study the law of decay with the inverse of the distance. However, the decay of light intensity with distance is not always the same but depends on several factors, especially the geometrical shape of the light source. In this laboratory we propose to study the decay of various light sources readily available in laboratories, educational institutions or even homes: point sources (or light bulbs), linear sources (or LED strips), flat sources (or computer monitors) and finally, circular sources (or ring lights such as those available for home video recording).

Each of these light sources exhibits different light intensity decays. In the most common case of point sources, light propagates in all directions and it can be shown that the intensity decays with the inverse of the square of the distance. For example, if the distance to the light source is doubled, then the intensity is four times less. This law however has its ranges of validity, indeed, if the light sensor is very close to the source, it cannot be considered as point source. On the other hand, if the source is very far away, it will probably not reach the minimum threshold of the sensor. For a linear source, such as an LED strip, it can be shown that the intensity decreases as the inverse of the distance. In the case of flat sources, the light intensity remains practically constant (independent of distance) as long as the distance is smaller than the size of the source. Finally, in the case of the ring, curiously, the light intensity has a maximum for an intermediate distance and then decays rapidly.

Experimental set up and results

This experimental activity allows great versatility in the design of the device. It is possible to use commercial lamps as light sources or to use other sources, punctual, linear, plane and circular, that the students have available either in the laboratory or at home. The setup is very simple, shown in Fig. 1a, consisting of a light source, a tape measure and a smartphone. The system needs to be aligned correctly to give accurate results. In all cases, light intensity measurements are made using the light sensor of a mobile phone, recording these values as a function of the distance to the source [3, 4]. Students can analyse and discuss the validity of the proposed model in each of the situations, in relation to the distance to the source and also to the dimensions of the source. For each selected position, several measurements of light intensity were taken over a period of time using *Phyphox app*, determining the average and standard deviation in real time.

The graphs of light intensity as a function of distance (Fig. 1b) allow us to formulate models for each type of source and also to study the validity ranges of each of them. On the occasion of the presentation of this work at the conference we will have the opportunity to discuss the experimental data, the models proposed by the students and the evaluation of the activity.

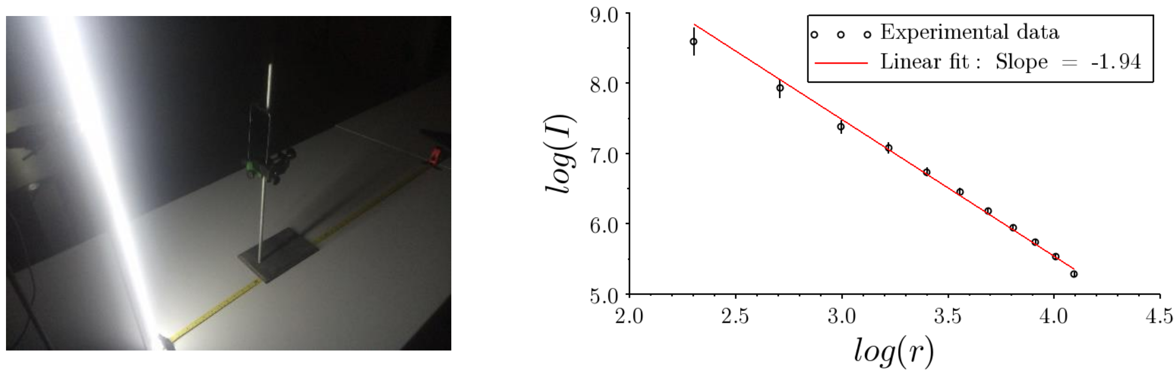

Fig.
1. a) Experimental set up for a linear and b) results of the light intensity as a function of the distance corresponding to a point light source.

Conclusion

This activity was proposed to students as a distance activity, however, due to positive feedback from students, it was maintained even after the confinement measures were overcome. Although very simple in terms of materials and set up, it allows for great versatility and represents a valuable contribution to analyse and discuss, encouraging critical thinking and decision making both in the design of the experiment and discussion and analysis of the results.

References

[1] M. Monteiro and A. C Marti, Resource Letter MDS-1: Mobile Devices and Sensors for Physics Teaching, *American Journal of Physics* **90**(5) (2022) 328-343.

[2] N. Voudoukis and S. Oikonomidis. Inverse square law for light and radiation: A unifying educational approach, *Eur. J. of Eng. and Tech. Res.* **2**(11) (2017) 23-27.

[3] Isabel Salinas, Marcos H. Giménez, Juan A. Monsoriu, and Juan C. Castro-Palacio, Characterization of linear light sources with the smartphones ambient light sensor. *The Physics Teacher* **56** (2018) 562.

[4] M. Monteiro, C. Stari, C. Cabeza and A. C. Martí, The polarization of light and Malus' law using smartphones, *The Physics Teacher* **55**(5) (2017) 264-266.