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Characterization of linear light sources with the smartphone's ambient light sensor

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The smartphone's ambient light sensor has been used in the literature to study different physical phenomena.[1-5] For instance, Malus's law, which involves the polarized light, has been verified by using simultaneously the orientation and light sensors of a smartphone.[1] The illuminance of point light sources has been characterized also using the light sensor of smartphones and tablets, demonstrating in this way the well-known inverse-square law of distance.[2,3] Moreover, these kinds of illuminance measurements with the ambient light sensor have allowed the determination of the luminous efficiency of different quasi-point optical sources (incandescent and halogen lamps) as a function of the electric power supplied.[4] Regarding mechanical systems, the inverse-square law of distance has also been used to investigate the speed and acceleration of a moving light source on an inclined plane[5] or to study coupled and damped oscillations.[6] In the present work, we go further in presenting a simple laboratory experiment using the smartphone's ambient light sensor in order to characterize a non-point light source, a linear fluorescent tube in our case.

Basic theory

The smartphone's ambient light sensor is able to measure the illuminance (E) provided by an optical source, which is defined as the luminous flux (φ) per unit area (A):

$$E = \frac{\varphi}{A}. \quad (1)$$

We can consider the optical source as a point source when its size is negligible compared to the distance between the detector and the source. In this case, the emitted wavefronts can be considered as spherical surfaces of radius r centered on the point source. Thus, in mathematical terms, the illuminance can be expressed as

$$E = \frac{\varphi}{4\pi r^2}. \quad (2)$$

Therefore, for point optical sources, the illuminance is governed by the inverse-square law of distance. However, if the resulting illuminance from a non-negligible size light source were to be calculated at a given distance, an integral over the actual geometry of the source would have to be performed. One way to avoid using concepts that are more complex in high school and first-year university levels is to consider a linear source as an example of a non-point source. In this case, the luminous flux is distributed over cylindrical wavefronts (Fig. 1), so the illuminance is characterized by the following equation,

$$E = \frac{\phi}{2\pi r L}, \quad (3)$$

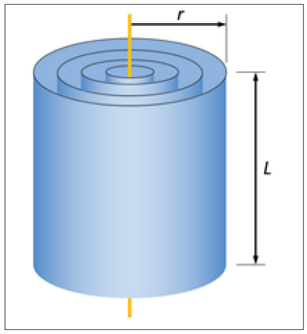

Fig. 1. Cylindrical wavefronts produced by a linear light source.

where r is the distance from the detector to the center of the linear source of length L. Thus, the luminance is only proportional to the inverse of the source-detector distance and not to the inverse of the squared distance. It can be noticed that Eqs. (2) and (3) are completely analogous to the equation of the electric field generated by a point charge ($E \sim 1/r^2$) or by an infinite line of charge ($E \sim 1/r$), respectively. The objective of this work is to verify experimentally the illuminance dependence, $1/r$, for linear sources using the ambient light sensor of a smartphone.

Experiments and results

Most smartphones nowadays bear a light sensor, which allows illuminance of any light source placed nearby to be measured. Here, we will also use the light sensor but this time to measure the resulting illuminance of a light source of non-negligible size. To keep it simple, we have chosen the case of a linear source that is represented in our experiments as a conventional fluorescent tube of length L = 120 cm. The fluorescent tube (OSRAM T8, 36 W, 3350 lm) and the smartphone (Samsung Galaxy S7), while measuring the illuminance with the light sensor, are included in the photo of Fig. 2.

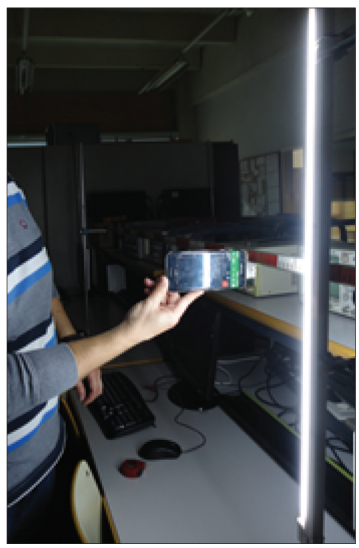

Fig. 2. Photo of the experimental setup.

In order to collect the sensor data, the Physics Toolbox Suite free application for Android has been used.[7] Using this simple experimental setup (Fig. 2), measurements of the illuminance were carried out at each distance r during 30 s. The background light was controlled such that it was kept close to zero. To perform a new measurement, the sensor was covered with an opaque black cloth until it was placed at the new posi-

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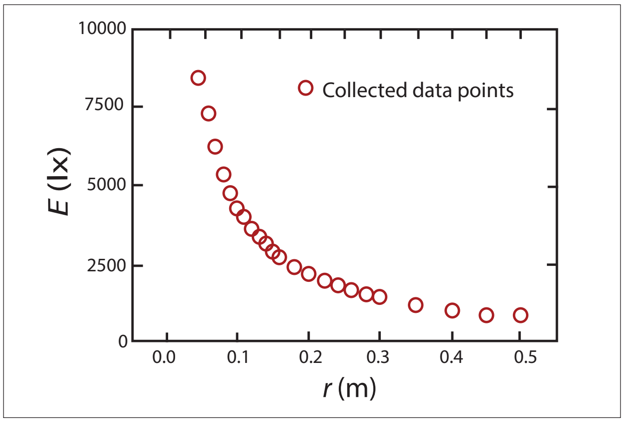

Fig. 3. Data points collected with the light sensor. The inverse of distance depence of the illuminance can be observed.

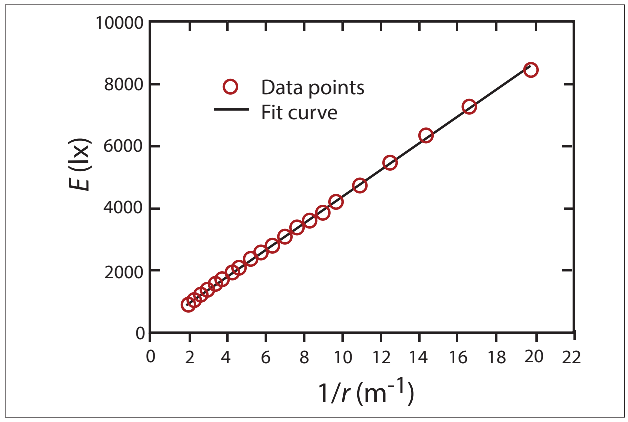

Fig. 4. Measured data points (open red circles) of the illuminance and linear fit (black solid line) vs. the inverse distance.

tion, and so on for the other measurements. The illuminance was averaged at each point over 30 s. The results showing the depence of the illuminance $E \sim 1/r$ are included in Fig. 3.

The luminous flux in Eq. (3) has been obtained by means of a linear fit using the data for E, directly measured with the light sensor vs. the inverse distance $1/r$ as

$$E = a\frac{1}{r}, \tag{4}$$

where a is a constant to be determined. The output of the fitting is shown in Fig. 4. A linear correlation coefficient of 0.9991 was obtained that shows clearly the linear dependence between the plotted variables. The resulting value of the slope, $a = 431.3$ lx m, was used to calculate the luminous flux $\phi = a2\pi L = 3252$ lm. This value was compared with the one reported by the manufacturer, 3350 lm. A percentage deviation of 3% was obtained, which indicates the effectiveness for teaching of the methodology presented here.

This simple setup and experiment shows that the smartphone's ambient light sensor is fair enough to verify the inverse-distance law for linear sources ($E \sim 1/r$). This kind of smartphone physics experiment is being implemented with success in the first engineering courses at the School of Design Engineering, Universitat Politècnica de València, Spain.

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