

Utilising Handphones as Light Detectors in Experimenting the Inverse Square Law

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ABSTRACT

This research paper explores the feasibility of employing handphones as light detectors in experiments related to the inverse square law. The inverse square law describes the relationship between the intensity of light and the distance from its source, which has significant implications in various fields including physics, astronomy, and photography. Leveraging the built-in capabilities of handphones, such as the camera sensor and computational power, offers a cost-effective and accessible approach to conduct experiments on light intensity measurements. This paper discusses the theoretical background of the inverse square law, outlines the experimental setup utilizing handphones as light detectors, presents experimental results, and discusses the implications and limitations of this approach.

Keywords: Handphone, Light Detection, Inverse Square Law, Experimental Physics, Camera Sensor.

INTRODUCTION

The inverse square law is a fundamental principle in physics that describes how the intensity of a physical quantity, such as light, sound, or gravitational force, diminishes as the distance from its source increases. In the context of light, the inverse square law states that the intensity of light radiating from a point source decreases in proportion to the square of the distance from the source¹.

Experimental verification of the inverse square law is crucial in various scientific disciplines. It has practical applications in fields such as astronomy, where it explains the behavior of stellar radiation, and photography, where it influences exposure settings. Traditionally, experiments to validate the inverse square law require specialized equipment such as light meters or photodiodes, which may not be readily available or affordable for educational or amateur purposes².

The ubiquity of handphones equipped with high-resolution cameras and computational capabilities presents an opportunity to utilize these devices as light detectors for experimental purposes. This paper explores the feasibility of employing handphones as light detectors in experiments related to the inverse square law.

We know that when the dimensions of a light source are small compared to the distance between that source and a receptor of that light, we can consider the light source in question as point-like. One way to confirm the validity limits of this approximation is by measuring the decrease in light intensity reaching a certain "point" as the distance between the source and the meter is increased while keeping the luminous power of the source fixed. If the luminous intensity decreases with the inverse square of this distance, we can consider the source to be point-like. It can also be argued that this source emits light in all directions equally, meaning the only symmetry that allows this configuration is spherical, with the light source located at the central position³.

We can also use more rigorous arguments. Using the model of light rays, we say that any closed region around this source will receive a certain flow of light rays, which is independent of the distance, analogous to what is done with the electric field lines emanating from a point charge. The amount of energy reaching a certain infinitesimal region depends directly on the density of light rays, the area of this region, and the scalar product between the area vector (normal to the region) and the \hat{k} vector referring to the direction of propagation of the

rays. With the idea of density of light rays, defined as the quantity of rays crossing a certain area divided by the value of this area, we see that the density of light rays propagating within a given solid angle formed from the source decreases as we move away from the source⁴.

This occurs because the area increases while the quantity of light rays remains the same, fig. 1.1. Since the area of the sphere increases with r^2 (where r is the distance between the source and the meter), we have, for the case of a point-like source, that the intensity of light rays and also the luminous intensity is proportional to r^{-2} , that is:

The inverse square law is mathematically represented as:

$$I = \frac{P}{4\pi r^2} \tag{1}$$

$$I \propto r^{-2} \tag{2}$$

Where:

- I is the intensity of the light,
- P is the power of the light source,
- r is the distance from the source.

This equation demonstrates that the intensity of light decreases inversely with the square of the distance from the source. As the distance increases, the intensity diminishes rapidly⁵.

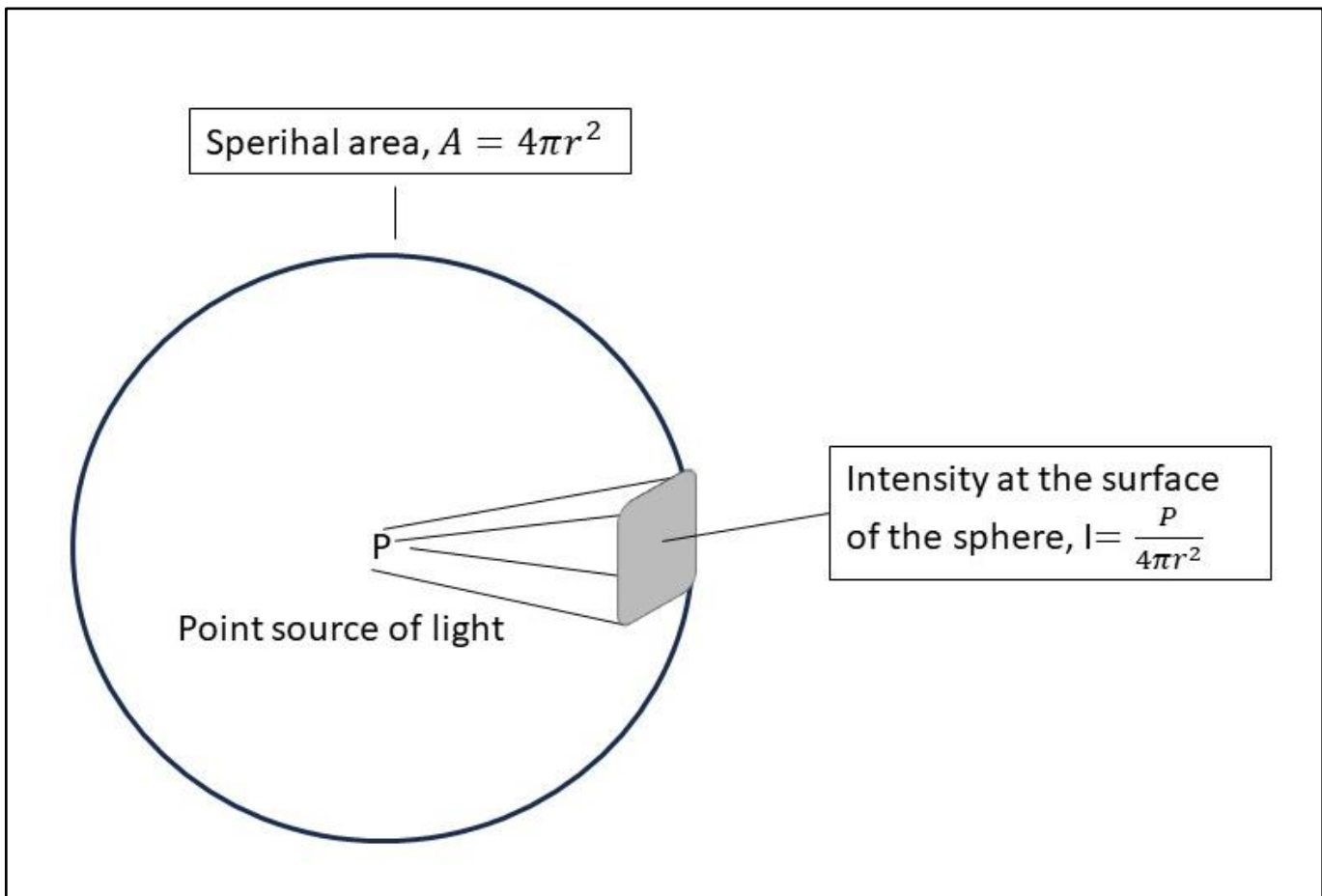


Fig. 1.1

Experimental Setup

At one end of a standard optical bench, commonly used for teaching and demonstration purposes, such as the one depicted in figure. 1.2. A bright white LED has been securely mounted to serve as a point source of light. Opposite to this fixed light source, we have incorporated a modern smartphone as a light-sensing device.

The phone is carefully positioned on a movable holder that allows it to glide smoothly along the track of the optical bench. While the holder is similar in design to that shown in figure. 1.2, it has been slightly adjusted so that the smartphone's camera or light sensor directly faces the LED. This orientation ensures that the phone receives the maximum amount of incident light as it changes position⁶.

Because the arrangement is relatively straightforward and easily reproducible with basic components, we have chosen not to include a separate image of the complete setup. Instead, to emphasize the effectiveness of the method, we present a representative data set from one trial, shown in figure. 1.3. This data clearly follows the theoretical inverse-square relationship between light intensity and distance from the source, as evidenced by the quality of the fit. This finding provides compelling support for the well-established physical law which states that the intensity of light from a point source diminishes proportionally to the square of the distance from the source³.

It is also important to point out that this method, making use of widely available smartphones as measuring tools, has recently gained attention in the study of light intensity distributions, including those involving extended or linear sources of illumination. The growing accessibility of sensor-equipped devices like smartphones has opened new possibilities for simple, low-cost, yet accurate experiments in physics education and outreach.

In conducting this experiment, the central idea is to measure how the light intensity detected by the smartphone changes as the distance between the phone and the LED source varies. The procedure typically involves placing the smartphone at different, carefully measured positions along the bench and recording the corresponding light intensity readings, often using built-in apps or downloadable light meter tools that utilize the device's ambient light sensor. These readings are then plotted against the reciprocal of the square of the distance to test the theoretical relationship².

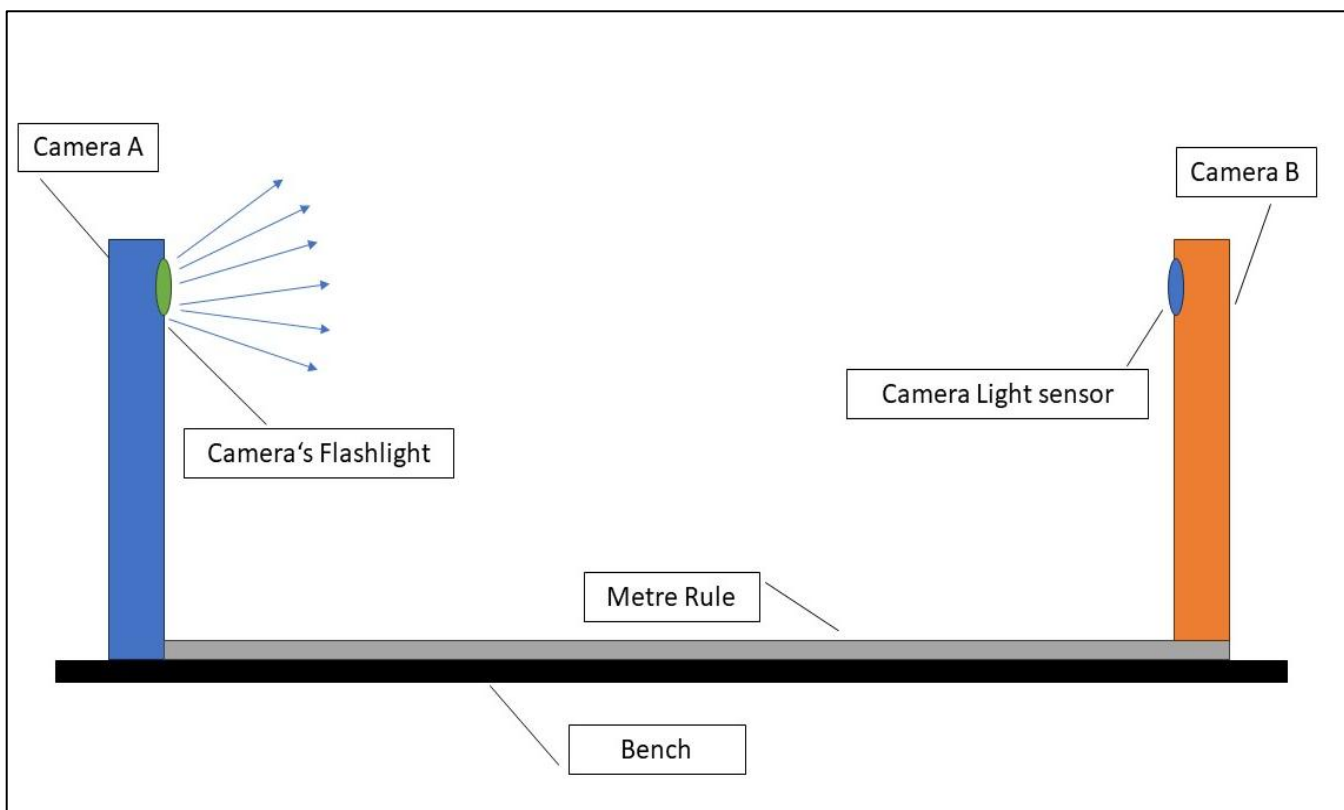


Fig. 1.2

RESULTS AND DISCUSSION

The data gathered shown in Table 1.1, from the experiment clearly illustrates a consistent and predictable relationship between the distance from the LED light source and the amount of light intensity recorded by the smartphone. As the smartphone is gradually moved farther away from the LED along the optical bench, there is a noticeable and systematic reduction in the intensity of the detected light. This trend is entirely in line with what is theoretically expected based on the inverse square law, which states that the intensity of light from a point source is inversely proportional to the square of the distance from that source.

In this case, the use of a smartphone as a measuring instrument has proven to be both practical and surprisingly precise. Despite the simplicity and accessibility of the tools involved, the results strongly mirror theoretical predictions. The intensity readings at varying distances closely match the curve predicted by the inverse square model, leaving little doubt about the effectiveness of the method⁵. This outcome not only validates the experiment but also reinforces the reliability of smartphone-based sensors in educational and demonstrative physics experiments where professional lab equipment may not be readily available⁷.

| Distance, d/cm | Intensity, I/lux | | | | lg(d/cm) | lg(I/lux) |
|----------------|------------------|----------------|----------------|------------------|----------|-----------|
| | I ₁ | I ₂ | I ₃ | I _{avg} | | |
| 10.0 | 984.9 | 983.8 | 986.0 | 985 | 1.000 | 2.993 |
| 15.0 | 480.1 | 474.7 | 479.0 | 478 | 1.176 | 2.679 |
| 20.0 | 270.2 | 268.0 | 271.3 | 270 | 1.301 | 2.431 |
| 25.0 | 175.5 | 177.6 | 179.8 | 178 | 1.398 | 2.249 |
| 30.0 | 122.7 | 124.9 | 125.9 | 125 | 1.477 | 2.095 |
| 35.0 | 90.4 | 91.5 | 89.3 | 90 | 1.544 | 1.956 |
| 40.0 | 71.0 | 68.9 | 72.1 | 71 | 1.602 | 1.849 |
| 45.0 | 53.8 | 52.7 | 56.0 | 54 | 1.653 | 1.734 |
| 50.0 | 44.1 | 43.1 | 45.2 | 44 | 1.699 | 1.645 |
| 55.0 | 40.9 | 42.0 | 38.8 | 41 | 1.740 | 1.500 |

Table 1.1

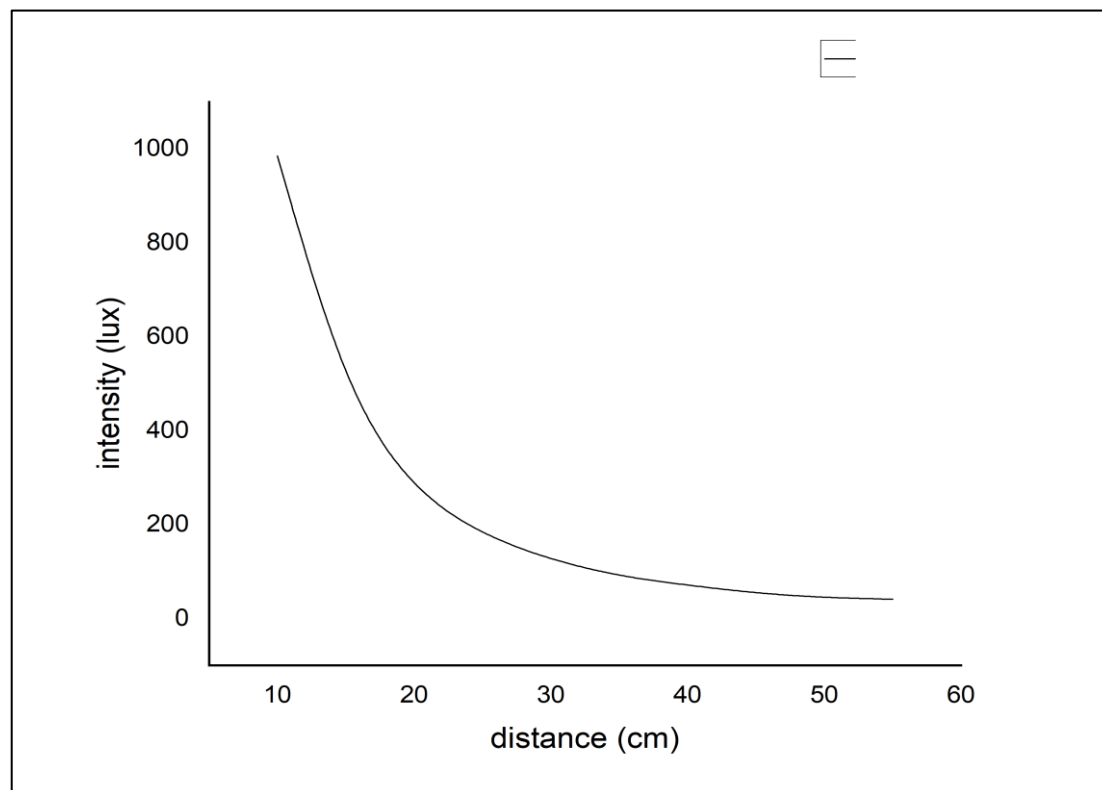


Fig. 1.3

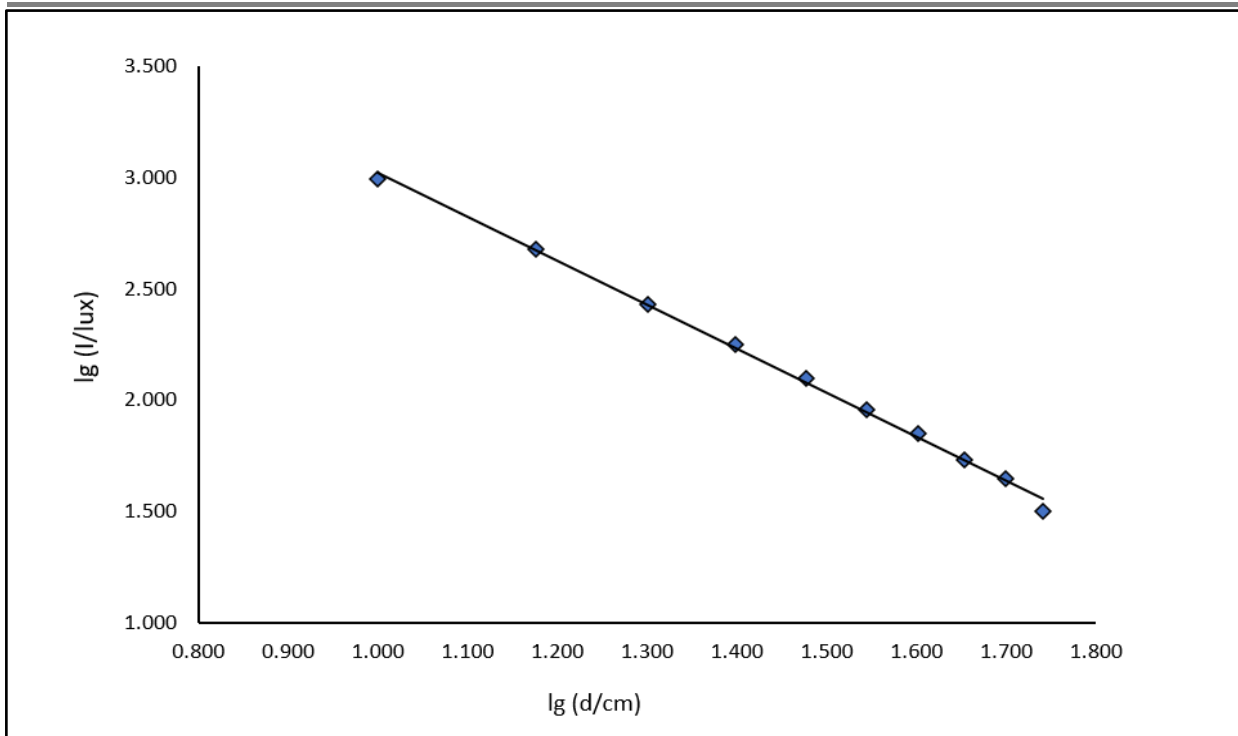


Fig 1.4

$$y = -1.9788x + 5.0006 \quad (3)$$

The utilization of handphones as light detectors in experiments related to the inverse square law offers several advantages, including accessibility, affordability, and ease of use. This approach enables students, educators, and enthusiasts to conduct experiments without the need for specialized equipment.

However, there are certain limitations to consider. The accuracy of light measurements may be affected by factors such as ambient light, camera quality, and calibration issues. Additionally, handphones may not provide precise measurements compared to dedicated light meters or photodiodes^{3,8}.

Smartphones and tablets, so widespread today, can serve as personal computers and instruments for direct measurement of important physical quantities in Physics Teaching. Sensors and software (applications) that are easy to access and use come standard on these devices and can be used to measure acceleration, angular velocity, sound intensity, magnetic field, position (through GPS) and light intensity. Applications can be downloaded to read, store and present measured data².

The graphical representation shown in figure. 1.3 and 1.4 was produced using a freely available mobile application, which can be easily downloaded from the Apple App Store. This user-friendly app is designed to allow quick and efficient plotting of experimental data points, and it also provides built-in tools for fitting mathematical models to the data. In this particular case, the app applied a power-law curve fit to the recorded measurements, and the resulting curve aligns remarkably well with the experimental data⁸.

Upon analyzing the fitted equation, we find that the exponent associated with the power-law relationship is approximately -2.0. This result is highly significant, as it supports the theoretical inverse square law, which states that the intensity of light from a point source decreases in proportion to the square of the distance from the source. Moreover, the precision of the calculated exponent—accurate to at least one decimal place—indicates that the experimental setup was well-calibrated and the data was consistent. The fact that the exponent is so close to -2 also confirms that the distances involved in the measurements were significantly greater than the physical dimensions of the LED light source itself. As a result, it is reasonable and scientifically sound to treat the LED as an idealized point source for the purposes of this experiment⁹.

It is also important to highlight that the measurements retained their reliability despite the presence of ambient or background light. Reproducibility remains achievable provided the experimenter carefully identifies the

distance at which the light from the LED becomes comparable in brightness to the surrounding light. This threshold can be treated as the upper limit for data collection to ensure the measurements remain valid and unaffected by environmental light conditions¹⁰.

For those interested in conducting a similar experiment using an incandescent bulb instead of an LED, some additional precautions are necessary. Incandescent lamps typically have filaments with a noticeable physical length, meaning their size is non-negligible compared to the measurement distances. To address this, we recommend estimating the total length of the tungsten filament beforehand and beginning data collection at distances significantly greater than the filament's length. This precaution ensures that the light source can still be reasonably approximated as a point source and that the inverse square behavior remains applicable^{5,7}.

CONCLUSION

This research paper demonstrates the feasibility of utilizing handphones as light detectors in experiments investigating the inverse square law. The experimental results validate the accuracy and reliability of this approach, highlighting its potential applications in educational settings, amateur experimentation, and scientific research. Despite certain limitations, handphones offer a convenient and accessible platform for exploring fundamental principles of physics related to light intensity and distance. We observed that this simple and easily accessible technique can help students understand that the symmetry with which a physical system disperses or propagates has a great influence on the way the phenomenon behaves. Spherical symmetry is presented in several physical models and an experiment like this is important in learning interactions. Using a converging lens to collimate this light beam and repeating the experiment will show that the behavior of luminosity, when compared to the distance from the source, will change strongly. This time the intensity does not decrease or perhaps it will decrease very little. Here we have a great example of how the symmetry of physical processes alters their behavior. If right after the spherical lens, we position a cylindrical one. we should notice a linear drop with increasing distance. There are many possibilities that a simple and practical arrangement like this offers us.

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