Illuminance: the 1/d² law

FizziQ activity · High school · 35 min

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With the smartphone light sensor, students measure illuminance at increasing distances from a lamp and verify the $1/r^2$ law in FizziQ. High school, Android.

Learning objectives

- Measure illuminance at multiple distances from a point light source using the smartphone light sensor
- Verify the inverse square law: $E \propto 1/r^2$ for light from a point source
- Plot illuminance versus distance and illuminance versus $1/r^2$ to demonstrate the relationship
- Determine the luminous intensity of the source from the graph
- Understand the geometric origin of the inverse square law and its universality

Instruments and sensors

Light meter (lux) · Light sensor (ambient light sensor)

Materials

- Android smartphone with FizziQ app and light sensor
- A lamp without a shade as a point light source
- A room that can be darkened
- A tape measure
- FizziQ experiment notebook
- Note: the protocol remains adaptable to any comparable light-measurement tool.

Protocol

1. Set up the experiment in a room that can be completely darkened (close blinds, turn off all lights except the test source).
2. Choose a small, bright lamp without a shade to approximate a point source. A bare LED bulb or a small desk lamp works well.
3. Place the lamp on a stable surface. Set up a tape measure extending outward from the lamp along a straight line on a table or the floor.
4. Open FizziQ on an Android smartphone and select the Light Sensor (Lux) measurement. (Note: on iPhones, this sensor may not be directly accessible.)
5. Position the smartphone sensor at 10 cm from the lamp, facing the light source directly. Record the illuminance value after it stabilizes (wait 5 seconds).
6. Move the smartphone to 15 cm, then 20 cm, 30 cm, 40 cm, 50 cm, 75 cm, and 100 cm, recording the illuminance at each distance.
7. Record at least three readings at each distance and calculate the average to reduce noise.
8. Enter all data pairs (distance r, illuminance E) in the FizziQ notebook.
9. Plot E versus r. The curve should show a steep decrease that flattens at larger distances.
10. Now plot E versus $1/r^2$. This graph should be a straight line through the origin if the inverse square law holds.
11. Determine the slope of the E versus $1/r^2$ line. This slope equals $I/(4\pi)$, where I is the luminous intensity of the source in candelas.
12. Calculate the luminous intensity I and compare with the manufacturer's specification for the lamp if

available.

Expected results

The illuminance should decrease rapidly with distance, showing a characteristic $1/r^2$ profile. At 10 cm from a typical desk lamp (10-15 W LED), the illuminance may be 5000-20000 lux; at 100 cm, it drops to 50-200 lux. The plot of E versus $1/r^2$ should be approximately linear, with a coefficient of determination R^2 above 0.95 for clean data. Deviations from perfect linearity are expected at very short distances (where the source is not a point) and at large distances (where ambient light becomes significant relative to the source). Reflections from walls and ceiling also contribute stray light that adds a roughly constant offset to the readings, slightly degrading the linearity at larger distances.

Questions

- Why does the illuminance decrease as $1/r^2$ rather than as $1/r$?
- What geometric property of spheres explains the inverse square law?
- In what situations would the inverse square law not apply (non-point sources, focused beams)?
- How does the inverse square law apply to sound intensity? To gravitational force?
- If you double the power of the light source, how does the illuminance at a fixed distance change?
- Why is it important to perform this experiment in a darkened room?

Going further

- Repeat the experiment with the room lights on and subtract the ambient illuminance to recover the inverse square law
- Use different types of light sources (candle, LED, incandescent) and compare their luminous intensities
- Investigate the directional emission pattern of a lamp by measuring illuminance at different angles
- Test whether a flashlight (focused beam) obeys the inverse square law
- Use two light sources at known positions and verify the superposition principle for illuminance