Beer-Lambert law with a lux meter

FizziQ activity · High school · 25 min

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Using the smartphone lux meter in FizziQ, students measure light through stacked tracing paper and plot ln(T) against N to verify the Beer-Lambert absorption law.

Learning objectives

- Measure luminous illuminance with the smartphone lux meter
- Calculate an optical transmission coefficient
- Experimentally verify the Beer-Lambert law
- Plot and interpret a ln(T) versus N graph
- Understand exponential decay in the context of light absorption

Instruments and sensors

Light meter (lux meter) · Light sensor

Materials

- Smartphone or tablet with the FizziQ app
- A constant light source (LED desk lamp or second phone's flash)
- 8-10 sheets of tracing paper
- A darkened room
- Note: the protocol remains adaptable to any comparable light-measurement tool.

Protocol

1. Set up in a dark room or close the curtains. Ambient light is the main source of error.
2. Place a constant light source (LED desk lamp or a second phone's flash) about 30 cm above the smartphone's light sensor.
3. Open FizziQ and select the Brightness (lux meter) instrument. Place the smartphone flat, sensor facing up.
4. Record the brightness with no sheets: this is I_0, the reference incident intensity.
5. Place a first sheet of tracing paper on the sensor. Record I_1. Add a second sheet. Record I_2. Continue up to 8-10 sheets.
6. For each measurement, note the number of sheets N and the brightness I(N).
7. Calculate the transmission coefficient $T(N) = I(N)/I_0$ for each N.
8. Plot T versus N: you obtain an exponentially decreasing curve.
9. Plot ln(T) versus N: if the Beer-Lambert law holds, you obtain a straight line with slope $-\alpha$, where α is the absorption coefficient per sheet.
10. The law is written: $T(N) = \exp(-\alpha N)$, or equivalently $I(N) = I_0 \times \exp(-\alpha N)$. Calculate α and compare between different types of sheets.

Expected results

The brightness visibly decreases with each sheet, but the relative decrease is constant. The graph of ln(T) versus N is a straight line with negative slope, confirming the exponential law. The linearity of ln(T) is typically excellent ($R^2 > 0.98$). Typical transmission per sheet: 82-92% for tracing paper, 40-60% for colored plastic, 95-98% for clear glass.

Questions

- Why does transmission decrease exponentially rather than linearly with the number of sheets?
- What happens if the sheets are not all identical?
- How is this experiment related to spectrophotometry in chemistry?
- What is the difference between absorbance and transmittance?
- Could you use this method to measure the concentration of a colored solution?
- Why is ambient light the main source of error?

Going further

- Replace the sheets with colored solutions of increasing concentration to verify Beer-Lambert as a function of c
- Compare different materials (tracing paper, tissue paper, colored plastic, fabric)
- Investigate whether the wavelength of light affects the absorption coefficient by using colored filters
- Measure absorption of sunglasses and compare with their stated UV protection ratings
- Build a simple colorimeter to measure the concentration of an unknown solution