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Technology-Enhanced Learning through Smartphone Experiments: Teaching Optical Absorption in Resource-Limited Classrooms

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INTRODUCTION & AIM

Technology-enhanced education offers inclusive pathways to strengthen student engagement and research orientation, particularly in resource-constrained laboratories. This study presents a low-cost, smartphone-assisted classroom experiment to estimate the absorption coefficient (α) of transparent polymeric sheets and glass using the Beer–Lambert law, which describes exponential attenuation of light in homogeneous media [1]. By integrating luminance sensing with theory, the activity promotes interdisciplinary learning across physics, chemistry, and life sciences[2]. The absorption cross-section has been calculated using the Lambert-Beer formula. The band gap energy can be calculate by using Tauc's plot. Refractive index can be calculated by using Moss relation.

Develop and evaluate a low-cost, smartphone-assisted experiment for estimating the absorption coefficient of transparent materials using the Beer–Lambert law, thereby enhancing conceptual understanding of optical absorption, quantitative analysis, and inquiry-based learning in resource-constrained and inclusive science education settings.

METHOD

- Experimental Set up
  - Paper Box
  - Smartphone
  - Black circular
  - Target/disc

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- Baseline Measurement
- Record reflected
- Luminance without Sample (I_0) using Phy-phox app

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- Sample Placement Colored Transparent Poly-paper of thickness x placed over target

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- Measurement with sample
- Record reflected luminance (I)

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- Data Analysis
- Calculate absorption Coefficient

$$\alpha(\upsilon) = \frac{1}{x}\ln\left({}^{I_0}/_{I}\right)$$

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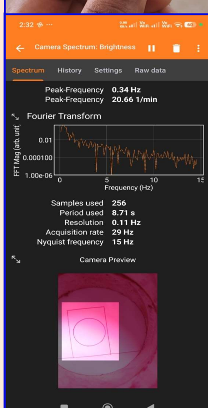
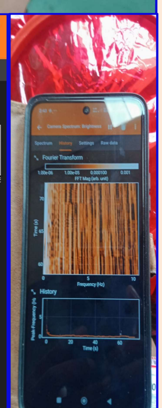
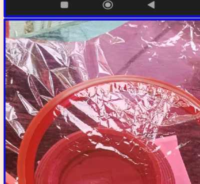
- Results
- Wavelength- dependent attenuation and absorption behavior.







RESULTS & DISCUSSION

The observed attenuation followed the Beer–Lambert trend, and estimated α values showed clear wavelength dependence, reinforcing concepts of optical absorption and material response. Students demonstrated gains in conceptual clarity, quantitative reasoning, and experimental design. The approach also shows promise for low-cost exploratory screening of surface changes in plant leaves, indicating potential for interdisciplinary extensions in biology and environmental science.

Beer-Lambert Law Formula

$$\alpha(\upsilon) = \frac{1}{x}\ln\left({}^{I_0}/_{I}\right)$$

Where,
- I is the intensity with the ample
- I_0 is the initial intensity
- x is the depth of the poly paper
- $\alpha(\upsilon)$ is the coefficient of absorption

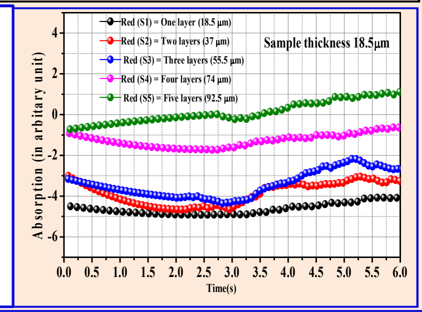


Figure shows the variation of optical absorption with time for different numbers of transparent poly-paper sheet layers. The absorption increases with increasing sheet thickness, indicating greater light attenuation and consistent behavior with the Beer–Lambert law. A gradual increase in absorption with measurement time is also observed. Results for blue-colored poly-paper sheets are presented as a representative example, although sheets of several other colors were similarly examined. Each sheet had a thickness of approximately 18 µm, measured using a screw gauge. The experimental setup employed inexpensive and readily available materials commonly found in undergraduate and school-level physics laboratories. The target consisted of a circular pattern drawn with a red ballpoint pen and photographed using an Android smartphone for luminance-based absorption analysis.

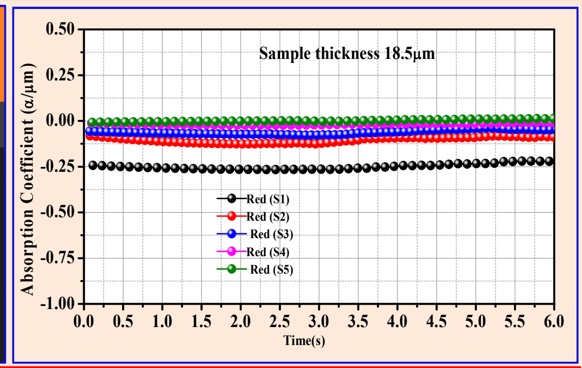


Figure shows the absorption per micrometer for red-colored paper sheets of different thicknesses (one to five layers) as a function of time. The absorption per unit thickness remains nearly constant for each layer set throughout the measurement period, in good agreement with the expected behavior predicted by the Beer–Lambert law.

CONCLUSION

The proposed method provides an accessible, inclusive, and cost-effective pathway to teach optical absorption using everyday devices. It supports inquiry-based learning, boosts engagement in under-resourced settings, and aligns with technology-enhanced education for Special and Inclusive Education contexts. Absorption has been increased with the increasing of the thickness of the poly -paper. The absorption also increased with the increase of time duration.

FUTURE WORK / REFERENCES

Future studies may integrate smartphone-based colorimetric and image-analysis techniques to quantify spectral absorption in biological and environmental samples. Validation against standard spectrophotometers, incorporation of machine-learning-assisted data analysis, and large-scale educational assessments could further enhance the scientific and pedagogical value of this low-cost approach.

References:

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