# Facilitating Problem Solving Across Representations in Introductory Electricity and Magnetism

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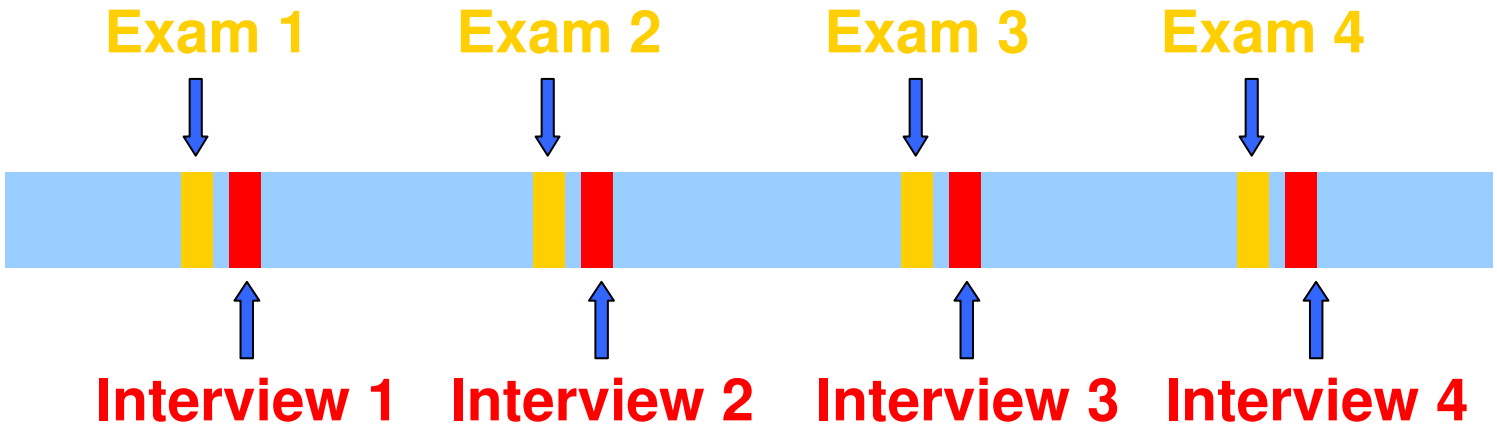
# Objective and Research Questions

- Objective:
  - Facilitate students' problem solving across representations in Electricity & Magnetism (E&M)

- Research Questions:
  - What kinds of difficulties do students have when solving E&M problems in graphical and equational representations?
  - What kinds of hints may help students overcome those difficulties?

# Methodology

- Individual teaching/learning interviews
- 15 students in calc-based E&M course




- Several E&M problems
- Numerical, Graphical, Equational Representations
- Think-aloud problem solving
- Verbal hinting

# Findings – Equational Representation

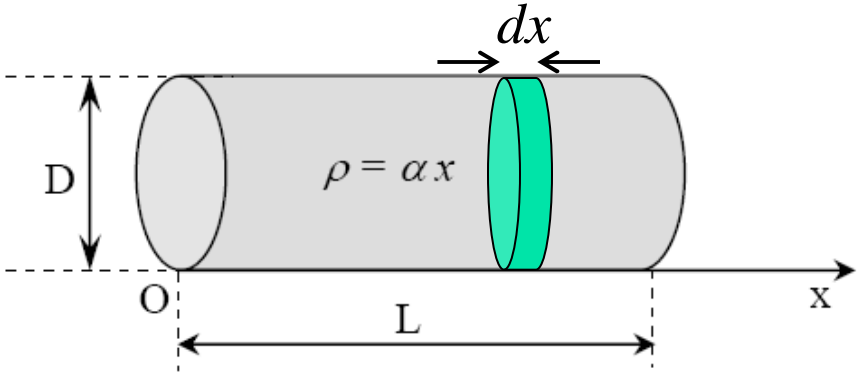
- Common difficulties
  - mapping an equation to physics
  - setting up an integral
  - distinguishing variables and constants

- Helpful hints
  - boundary values and variation of function
  - physical meaning of mathematical notations and operators

# Example – Equational Representation

- Int.2, Prob. 2: Find the resistance of a cylindrical resistor whose resistivity is given as per the equation:

$$\rho(x) = \alpha x$$




Correct solution:

$$dR = \frac{\rho(x)\,dx}{A} = \frac{4\alpha x\,dx}{\pi D^2}$$

$$R = \int dR = \int_0^L \frac{4\alpha x\,dx}{\pi D^2} = \frac{2\alpha L^2}{\pi D^2}$$

Common error:

$$dR = \frac{\rho(x)\,L}{A} = \frac{4\alpha x\,L}{\pi D^2}$$

$$R = \int dR = \int_0^L \frac{4\alpha x\,L}{\pi D^2}\,dx = \frac{2\alpha L^3}{\pi D^2}$$

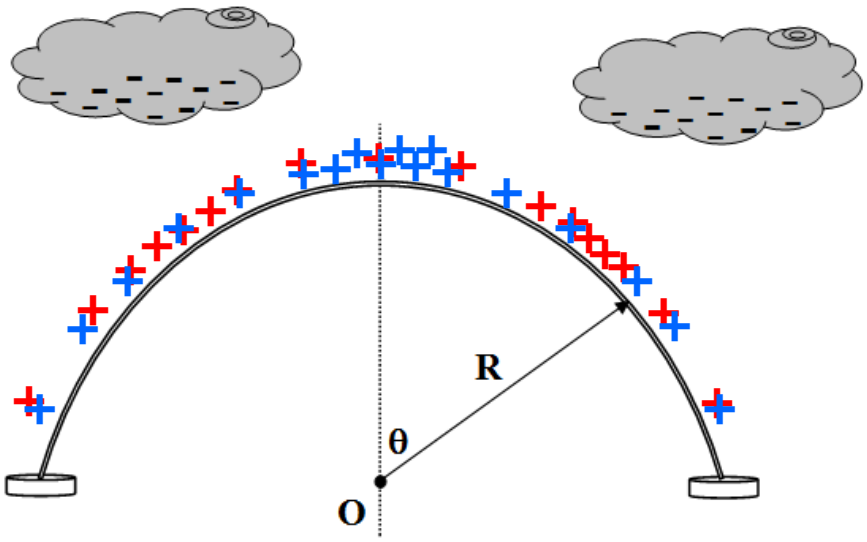
# Findings – Graphical Representation

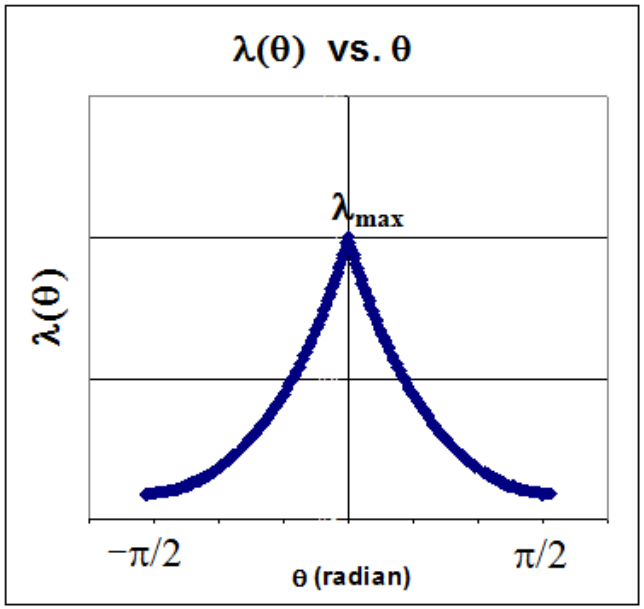
- Common difficulties
  - interpreting graph information
  - matching integral with area under the curve

- Helpful hints
  - special values on the graph
  - relation between integrand and function being plotted

# Example – Graphical Representation

- Int.1, Prob. 3: Draw charge distribution on the arch. Charge density is given by a graph.

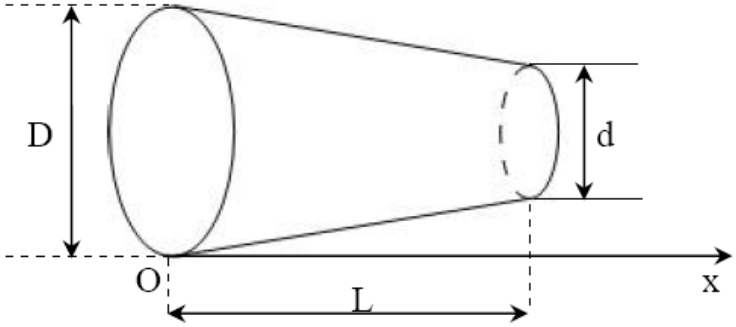


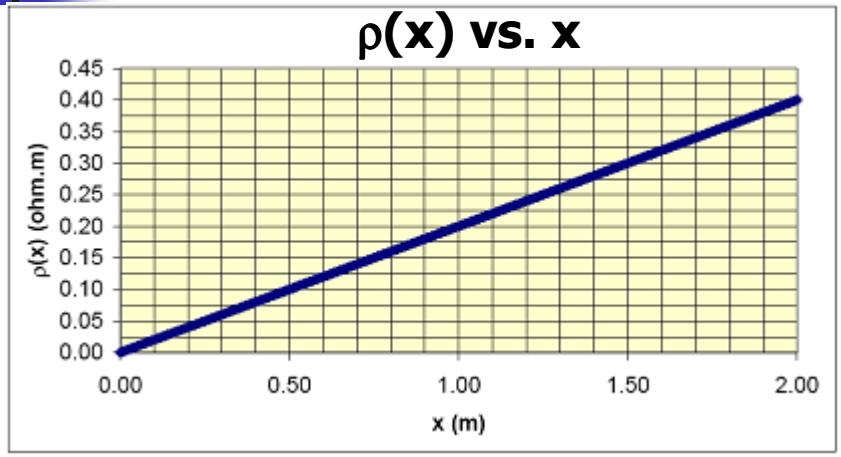

Correct charge distribution

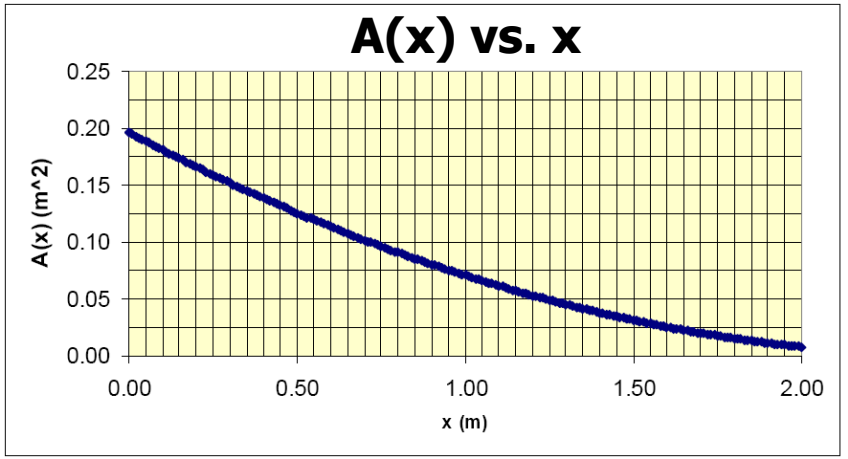
# Example – Graphical Representation

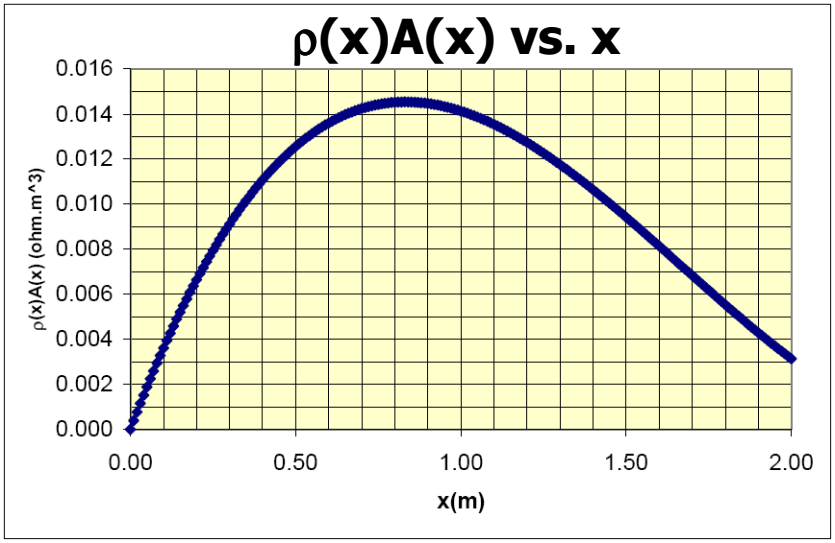
- Int. 2, Prob. 4: Find the resistance of a resistor whose resistivity and cross-sectional area change along its length.

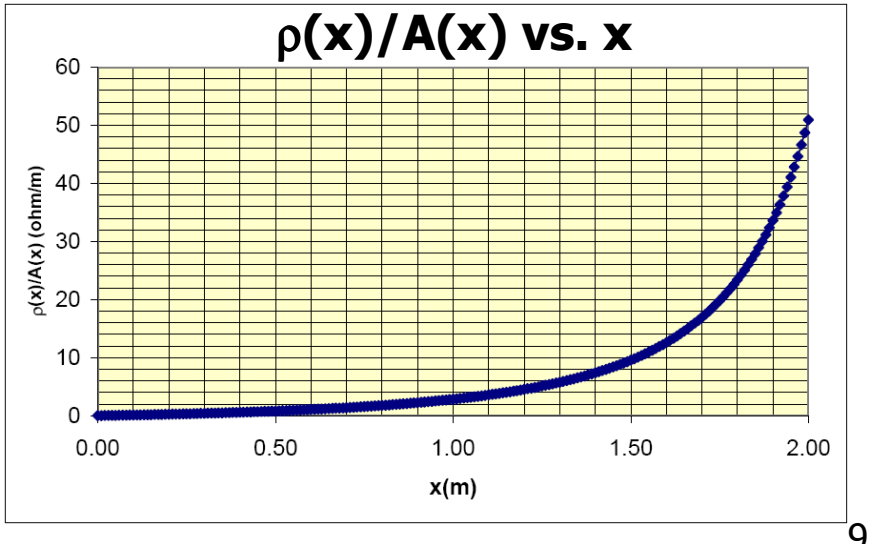


# Example – Graphical Representation

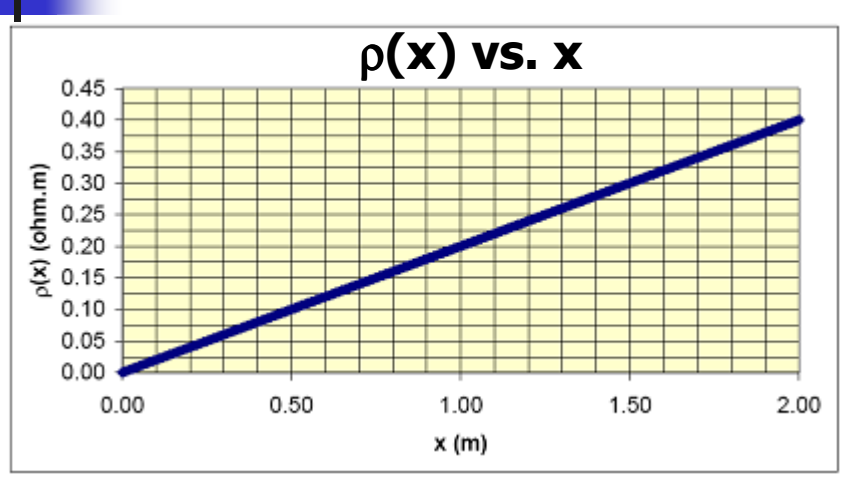


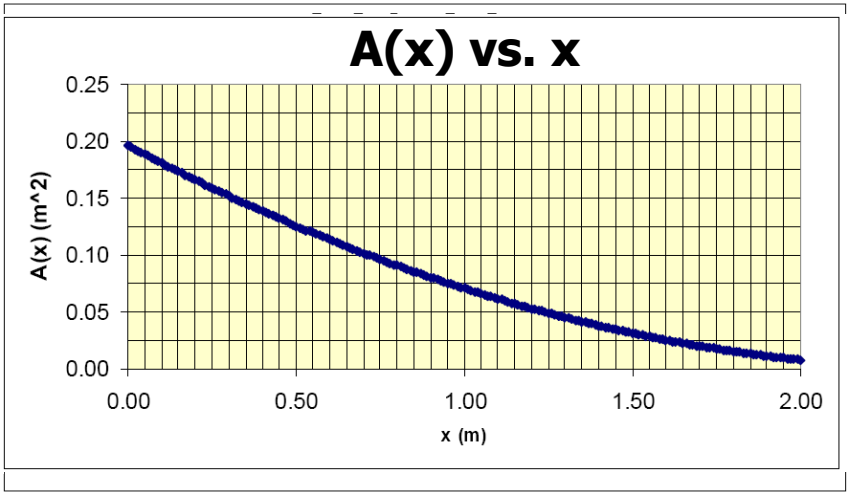



# Example – Graphical Representation



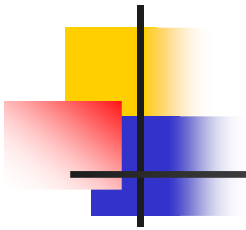




Correct solution: $R = \int_0^L \frac{\rho(x)\,dx}{A(x)} = area\ under\ the\ curve\ of\ \frac{\rho(x)}{A(x)}\ vs.\ x$

Common error: $R = \int_0^L \frac{\rho(x)\,dx}{A(x)} = \frac{\int \rho(x)\,dx}{\int A(x)\,dx} = \frac{area\ under\ the\ curve\ of\ \rho(x)\ vs.\ x}{area\ under\ the\ curve\ of\ A(x)\ vs.\ x}$

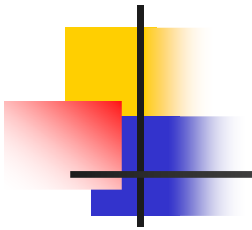
# Conclusion

- Students' difficulties with graphical and equational representations
  - due to their inability to interpret physical meanings of mathematical **notations** and **operators**
- Hints guiding discussion on those meanings activated the connection
  - mathematical representations & physics context



# Future Work

- Create instructional material to facilitate students in solving E&M problems in graphical and equational representations
- Example of such instructional material in Mechanics presented in PERC Targeted Poster Session **1E/3C**



# Thank you

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