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.
Example – Graphical Representation

Int. 2, Prob. 4: Find the resistance of a resistor whose resistivity and cross-sectional area change along its length.
Correct solution: \[ R = \int_0^L \frac{\rho(x) \, dx}{A(x)} = \text{area under the curve of } \frac{\rho(x)}{A(x)} \text{ vs. } x \]

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