Research-based Curriculum for Developing Mathematical Tools for Upper-Division Physics

Warren Christensen
North Dakota State University

Idris Malik
North Dakota State University

Keywords: Curriculum, Physics, Calculus, Differential Equations

As part of a larger project that investigates the gap between mathematics that is taught in math courses and the mathematics used in upper-division physics courses, we present curriculum on Separation of Variables and Taylor Series. While students are likely to be first introduced to these mathematical concepts in a math course, there exist specific instances where and how physics uses these tools in teaching content. Both mathematical tools are incorporated into the courses of Mechanics, Electricity & Magnetism as well as Quantum Mechanics.

Separation of Variables and the Taylor Series expansion, as used in a physics classroom, often have different emphasis and utility compared to when they are taught in math classrooms. For instance, the Taylor Series is used to expand a complicated equation about a small quantity within the equation in the limit as another quantity becomes very large, thereby simplifying the expression. The infinite Taylor Series is typically truncated to allow for further insight into an approximate expression that's useful for analyzing complex systems.

Methodology

The tutorials were developed to allow students work through the relevant mathematics using a sequence of physics examples from different content areas (the aforementioned Quantum Mechanics, E&M and Upper-division Mechanics). Despite using course-relevant symbols and phrasing, the tutorials attempt to avoid the use of sophisticated physics content. This is intended to alleviate the need to get caught up on physics concepts so that students can gain experience and focus on the complexities of the mathematics at play. Additionally, multiple versions of the tutorials have been created, such that the first topic encountered would be most relevant to the course in which it was given, with additional, less scaffolded examples are intended to boost students' familiarity and skill with each mathematical tool. The tutorials were vetted by experts in mathematics and physics at several points in their development. Furthermore, one-on-one interviews with undergraduate and graduate students were conducted with numerous modifications made to address areas of confusion. Finally, both tutorials have been used in classroom settings where independent student groups working through the tutorials were recorded, transcribed and analyzed.

Results

While initial results are positive–both tutorials were successfully deployed in a classroom environment and generated desired discussion among students–the level of student activity and interaction varied. Engagement in the Separation of Variables Tutorial was limited compared to the Taylor Series Tutorial; however, it is unclear if this was a result of existing classroom dynamics or an indication of needed modifications in the tutorials.[1]

[1] Material based on work supported by NSF PHY 1912152. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of NSF.