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PER in the Upper Division I

Committee on Research in Physics Education | **Co-Sponsor:** Committee on Physics in Undergraduate Education | **Type:** Inv/Con | **Organizer:** Mary Bridget Kustusch

Description:

Call for Papers: This invited/contributed session will focus on education research conducted at the upper-division undergraduate physics level. Presentations on innovative teaching ideas at this level or physics research with undergraduate students will be included ONLY if there is a significant research component to the presentation.

Abstracts Submitted (# 6)

Abstract Title: Conceptual Blending with Complex Numbers in Upper-division Physics

Paper Type: Invited

Author: Hunter G. Close
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Speaker Order: BF03

We expect our upper-division students to move flexibly between multiple interpretations and representations of mathematics while doing physics. In conceptual blending theory, the human mind fuses two mental spaces into a blend; in this blend, various vital relations compress to allow the mind to achieve new insight. A fundamental vital relation is "identity," through which two cognitive elements become linked. Eigenvalue problems in quantum mechanics invoke identity when we conceive of an operator as transforming a state into an another that is "the same, except for" a scalar factor. The 2-d rotation matrix and its eigenvalue problem offer an interesting arena for investigating the identity relation in student thinking. This talk reports on an observational study using teaching experiments to understand how students manage the identity relation, including their ability to flexibly reassign the identity relation, and whether this ability is associated with any other measures of success.

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Abstract Title: Conceptual vs. Mathematical Representations of Plane Waves in Optics
Paper Type: Contributed

Author: Andrew J. Berger*
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Speaker Order: BF06

A robust grasp of plane waves is helpful for studying advanced optics topics such as reflection, interference, and the wavelength dependence of refractive index. Although there have been many studies of students' understanding of waves, little work has been dedicated to plane waves, which are particularly challenging both conceptually and mathematically. In this study, 30-45 minute interviews about plane waves were conducted with nine upper-level science/engineering majors, all of whom had previously taken courses in electromagnetic theory where plane waves were used. The interviews revealed several aspects of how students struggle to move between conceptual and mathematical representations of plane waves. Examples include a disconnect between 1-D and 3-D waves (relating to 1-D physically but 3-D only mathematically) and the challenge of representing a 3-D, time-varying vector field in a diagram. Emergent design analysis of the interviews will be presented.

Footnotes: *Sponsored by Scott Franklin.

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Abstract Title: Development and Validation of Quantum Mechanics Concept Assessment (QMCA)
Paper Type: Invited

Author: Homeyra R. Sadaghiani
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Speaker Order: BF01

As part of an ongoing investigation of students' learning of quantum mechanics, we have developed a 31-item multiple-choice Quantum Mechanics Concept Assessment (QMCA) instrument for first-semester upper-division quantum mechanics. The QMCA could be used for both instructional and research purposes to measure the effectiveness of different curricula or teaching strategies at improving students' conceptual understanding of quantum mechanics. This tool could also help instructors to identify common student difficulties. In this talk, I will discuss the construction process including the use of student interviews and expert feedback for developing effective distractors. Using data from over 10 different institutions, I will also briefly discuss the results of common statistical tests of reliability and validity, which suggest the instrument is presently in a stable, usable, and promising form.

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Abstract Title: Student Difficulties with Boundary Conditions in Electrodynamics

Paper Type: Contributed

Author: Qing X. Ryan
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Speaker Order: BF04

"Boundary conditions" are an important physics topic that physics undergraduates are expected to understand and apply in many different contexts. In this talk we will present student difficulties using boundary conditions in electrodynamics, primarily in the context of electromagnetic waves. Our data sources include traditional exam questions and think-aloud student interviews. The analysis was guided by an analytical framework (ACER) that characterizes how students activate, construct, execute, and reflect on boundary conditions. Solving these problems also requires using complex notation. While this mathematical tool could be independently analyzed with ACER, we decided to blend and merge the analyses of complex notation with boundary conditions. Thus we are pushing the boundaries of situations where ACER can be applied and we will discuss the benefits and limitations of this framework.

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Abstract Title: Students' Explanations of the Dirac Delta Function During Group Problem-Solving

Paper Type: Contributed

Author: Leanne Doughty
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Speaker Order: BF05

Upper-division physics courses require the use of sophisticated mathematics. In introductory physics, studies have shown that students often lack conceptual understanding of calculus concepts and struggle to implement calculus tools. Research into students' understanding and use of mathematics in upper-level courses is in its early stages. To further this research, we have observed students engaged in group problem-solving during weekly recitation sessions for an upper-division electricity and magnetism course. Early in the course, one task required students to use a Dirac delta function (DDF) to write an expression for the charge density on the surface of a charged hollow cylinder. We report on two group discussions where different students gave a variety of explanations about the purpose of a DDF in this context. By examining these explanations, we can determine the types of understanding students' have about DDFs and which are most productive for their use in physics contexts.

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Abstract Title: Using and Coordinating Multiple Representations of a Quantum System

Paper Type: Invited

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Speaker Order: BF02

In quantum mechanics, we have a rich set of notational systems for representing quantum systems and making calculations. From a distributed cognition perspective, a student and the external representations generated by the student can be thought of as a cognitive system in which the student and the representations interact. The various features of different quantum notations influence this interaction. I will discuss examples of advanced physics students using and coordinating representations of a quantum system using different algebraic notations - wavefunction, matrix and Dirac notations. I will describe four structural features of these quantum notations and discuss how these features interact with student reasoning.

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