Paradigms (P) & Capstones (C)
The junior year consists of short case studies of paradigmatic physical situations which span two or more traditional subdisciplines of physics. Most have both a classical and quantum base. They are designed explicitly to help students gradually develop problem-solving skills. The senior year consists of more conventional single-quarter lecture classes in each of the traditional subdisciplines of physics. The format is more condensed than in the old, traditional curriculum because the content builds on the examples of the paradigms in the junior year. An overview of our curriculum is shown at right.

PEDAGOGY

Types of Active Engagement

Late blocks of class time have allowed us to experiment with a number of different pedagogies which encourage both collaborative and independent learning.

- Small group activities
- Simulations
- Maple/Mathematica visualization
- Integrated laboratories
- Computer-assisted activities
- Small whiteboard questions

Example: Small whiteboard questions

Small whiteboards are used to invite classroom participation from each student, similar to electronic classroom responses system in large-enrollment courses.

EXAMPLES

Early Quantum Mechanics

Our rearrangement of content allows students to begin their exploration of quantum mechanics earlier, in the middle of the junior year. In a measurement-based approach using a computer simulation of quantum Stern-Gerlach spin experiments (Schrödinger & Moore, Am. J. Phys. 61, 798-805, 1993), students infer the state vector from "data" as in real experiments. (Traditional curricula approach these problems backwards: predicting the results of experiment from "knowing" the unknowable wave function.) This spin first approach is the basis of a new textbook on quantum mechanics, with publication expected in late 2011.

Fourier Activities

Fourier analysis is integral to several of the Paradigms courses, and we use many computational activities to enhance student learning.

Activity

- Guess coefficients
- Calculate coefficients (paper & comp)
- Transform impulse response
- Periodic system mode frequencies
- FFT experiments

Outcomes

- Intuition
- Mathematics
- Dual Spaces: i
- Normal Modes
- Aliasing, leakage

The plots shown below are from a Maple activity where students are asked to guess the Fourier coefficients of a simple linear combination of sine functions. It is designed to develop students' Fourier intuition and also to make sure they know how to add functions pointwise.

RESULTS

1. The expected outcomes of our project are (1) textbooks on Quantum Mechanics, Vector Calculus, Special Relativity, and Thermodynamics; (2) a wiki site with curricular materials and faculty support materials; (3) better understanding of student reasoning in upper division physics; (4) new publishing avenues for instructors; (5) increased use of student-created software, and (6) feedback from wiki users.

2. The data we use to measure impact include (1) interviews of students during think-out-loud problem solving sessions, (2) feedback from adopting faculty, (3) feedback from our national advisory board, (4) video tapes of classroom activities, (5) feedback from textbook reviewers, and (6) feedback from wiki users.

3. The methods to collect this data include (1) surveys, (2) classroom videotapes, (3) interviews of students, (4) focus groups of students and adopters, and (5) copies of student homework and exams.

4. Key findings: (1) We have identified typical difficulties with student reasoning and addressed these with explicit active engagement classroom materials. (2) We have identified typical faculty difficulties in implementing active engagement strategies and have included multiple resources on our wiki to address this. (3) We have identified that students at this level are not harmonic reasoners (i.e., they do not spontaneously transition between algebra and geometry). We have designed activities that require students to change representations. (4) We have identified problems that students have transferring their mathematics expertise to physics and have developed explicit classroom activities that require students to think beyond this gap.

Publications


