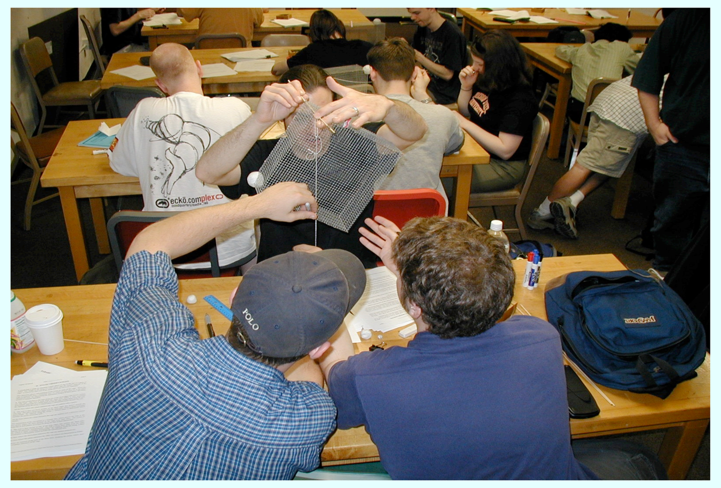
PARADIGMS IN PHYSICS - OREGON STATE UNIVERSITY

REVISING THE UPPER-DIVISION CURRICULUM

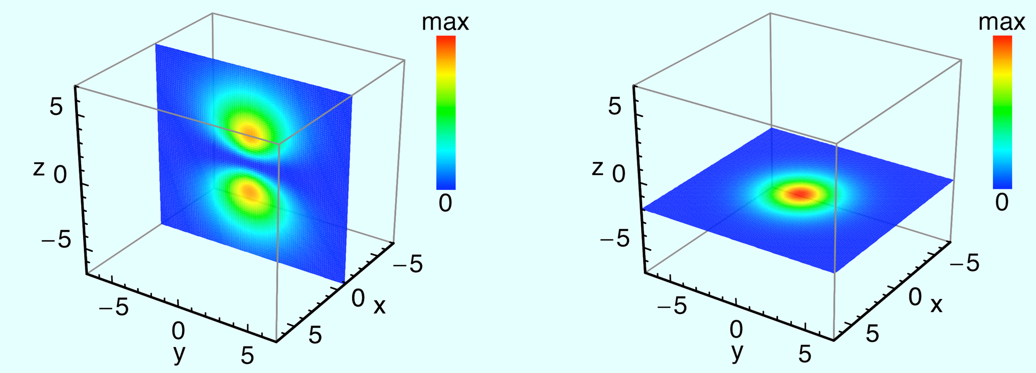


The Paradigms in Physics Project at Oregon State University has reformed the entire upper-division curriculum for physics and engineering physics majors. This has involved both a rearrangement of content to better reflect the way professional physicists think about the field and also the use of a number of reform pedagogies that place responsibility for learning more firmly in the hands of the students. The junior year consists of short case studies of paradigmatic physical situations which span two or more traditional subdisciplines of physics. The courses are designed explicitly to help students gradually develop problem-solving skills. We have developed many effective classroom activities that are documented on our wiki. Along the way we are also learning what it takes to design and implement large-scale modifications in curriculum and to institutionalize them.

The Development Team

FACULTY:

Corinne A. Manogue
David H. McIntyre
Janet Tate
Tevian Dray
Emily Van Zee
Barbara Edwards
David Roundy
Allen L. Wasserman
Philip J. Siemens
William M. Hetherington
Henri J. F. Jansen
Kenneth S. Krane
Albert W. Stetz
William W. Warren, Jr.
Yun-Shik Lee
Ethan Minot
Dedra Demaree
Elizabeth Gire (postdoc)



PARADIGMS CURRICULUM

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.

Jr P	•Symmetries & Idealizations •Static Vector Fields •Oscillations	•1-D Waves •Spin & Quantum Measurements •Central Forces	•Energy & Entropy •Periodic Systems •Rigid Bodies / Reference Frames •Class Mech (C)
Sr C	•Math Methods •E & M	•Quantum Mechanics •Thermal Physics •Optics	

DISSEMINATION

Textbooks

"Paradigms In Physics: Quantum Mechanics"
David H. McIntyre, Corinne A. Manogue, & Janet Tate
(Addison Wesley, publication late 2011).

"The Geometry of Vector Calculus"
Tevian Dray & Corinne A. Manogue
physics.oregonstate.edu/BridgeBook (Online text, 2010).

"The Geometry of Special Relativity"
Tevian Dray
physics.oregonstate.edu/coursewikis/GSR (Online text, 2010).

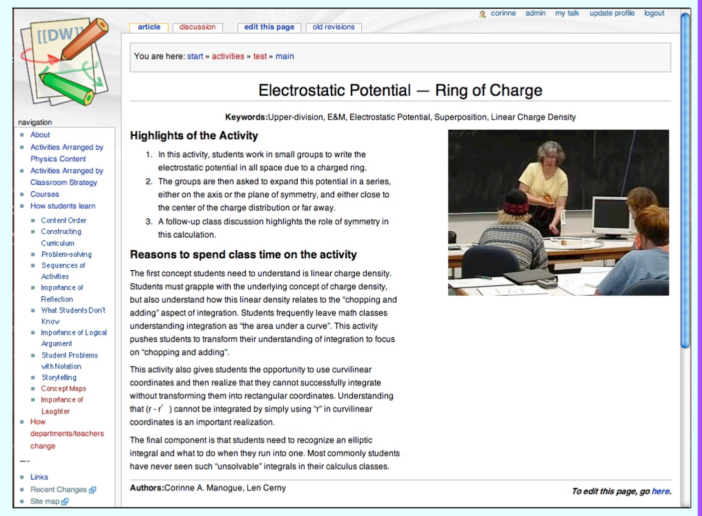
"Thermal Physics: Concepts and Practice"
Allen Wasserman
(Cambridge Press, publication summer 2011).

Website

http://www.physics.oregonstate.edu/portfolioswiki

This wiki site contains:

1. An introduction and overview of the projects for the interested public.
2. Information for institutions interested in adopting our curriculum or developing new upper-division curricula of their own, including information about workshops, links to publications, detailed syllabi for the new courses, and descriptions of individual activities.
3. Detailed materials for many of the new courses:
   - •Case studies of learning through small group activities
   - •Instructor's Guides
   - •Videos of classroom practice
   - •Advice about how to use active engagement strategies
   - •Narratives of classroom activities
   - •Textbooks



PEDAGOGY

Types of Active Engagement

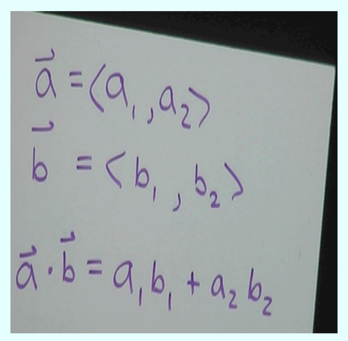
Long blocks of class time have allowed us to experiment with a number of different pedagogies which encourage both collaborative and independent learning.

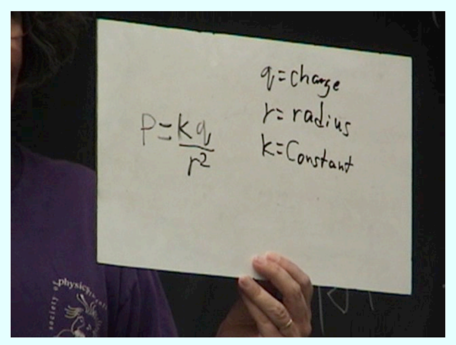
- •Small group activities
- •Simulations
- •*Maple/Mathematica* visualization
- •Integrated laboratories
- •Kinesthetic activities
- •Small white board questions

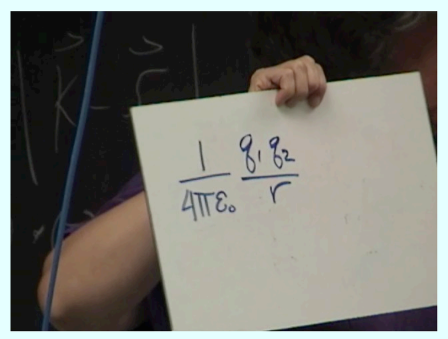
Example: Small white board questions

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

- **Review**: Ask students to write down what they already know about a topic
- **Recall**: Ask students to recall a specific formula
- **Compute**: Ask students to perform a short calculation
- **Apply**: Ask students to apply what you've just presented
- **Translate**: Ask students to express something in a new representation.
- **Next Step**: Ask students to do the next step in a derivation.



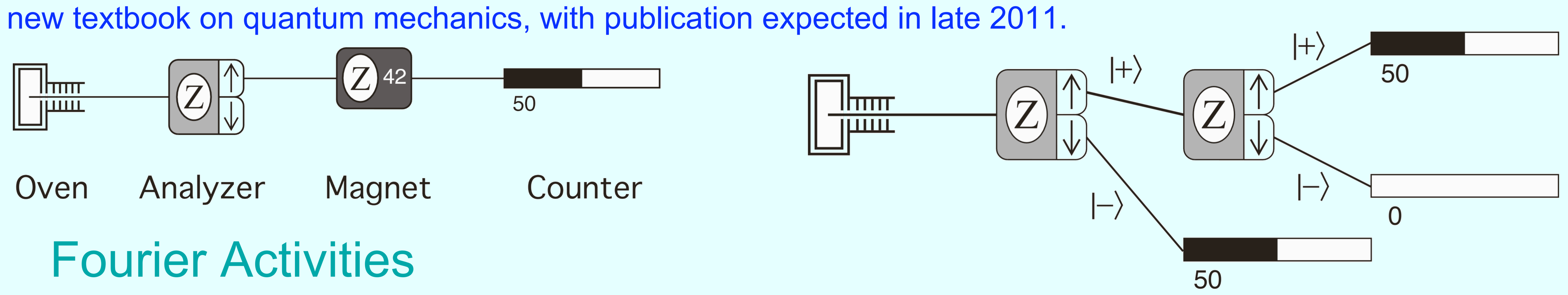




EXAMPLES

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 successive Stern-Gerlach spin experiments (Schroeder & 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 spins 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	Tool	Outcome
• Guess coefficients	• Maple	• Intuition
• Calculate coefficients (paper & comp)	• Paper, Maple	• Mathematics
• Transform impulse response	• Excel FFT	• Dual Spaces: ω-t
• Periodic system mode frequencies	• CUPS FFT	• Normal Modes
• FFT experiments	• Labview	• Aliasing,leakage

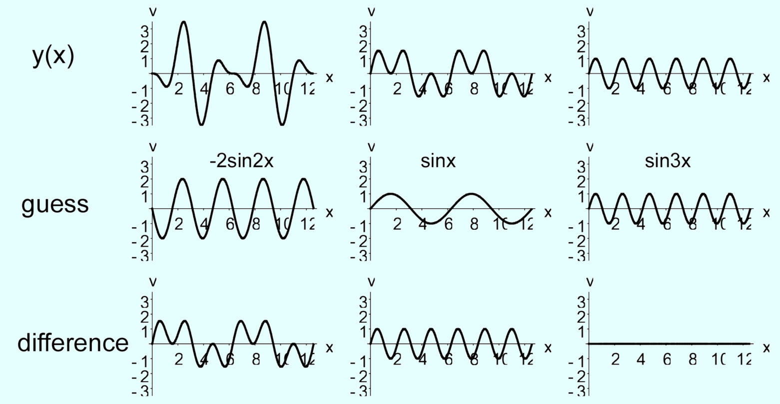
The plots shown below are from a Maple activity where students are asked to guess the Fourier coefficients of a simple linear combination of sine functions. It is designed to develop students' Fourier intuition and also to make sure they know how to add functions pointwise.

Maple coding:

$$y(x)=4\sin x\left(1-\cos x\right)-4\sin^3 x$$

Fourier series:

$$y(x)=\sin x-2\sin 2x+\sin 3x$$



RESULTS

1. The expected outcomes of our project are (1) textbooks on Quantum Mechanics, Vector Calculus, Special Relativity, and Thermodynamics; (2) a wiki web site with curricular materials and faculty support materials; (3) better understanding of student reasoning in upper division courses.
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 adopting 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 develped explicit classroom activities that require students to bride this gap.

Publications

1. D. H. McIntyre, *Using Great Circles to Understand Motion on a Rotating Sphere*, American Journal of Physics, **68**, 1097 (2000).
2. C. A. Manogue, P. J. Siemens, J. Tate, and K. Browne (Department of Physics) & M. L. Niess and A. J. Wolfer (Department of Science and Mathematics Education), *Paradigms in Physics: A New Upper-Division Curriculum*, American Journal of Physics **69**, 978-990 (2001).
3. C. A. Manogue and K. S. Krane, *The Oregon State University Paradigms Project: Re-envisioning the Upper Level*, Physics Today **56**, 53-58 (2003).
4. T. Dray and C. A. Manogue, *Using Differentials to Bridge the Vector Calculus Gap*, College Mathematics Journal **34**, 283-290 (2003).
5. C. A. Manogue, K. Browne, T. Dray, and B. Edwards, *Why is Ampere's law so hard? A look at middle-division physics*, American Journal of Physics, **74**, 344-350 (2006).
6. D. H. McIntyre, J. Tate, and C. A. Manogue, *Integrating Computational Activities into the Upper-Level Paradigms in Physics Curriculum at Oregon State University*, American Journal of Physics **76**, 340-346 (2008).

ACKNOWLEDGEMENTS

National Science Foundation
•DUE-9653250, 0231194, 0618877
•DUE-0088901, 0231032

Oregon State University
•Department of Physics
•College of Science
•Academic Affairs

Mount Holyoke College
•Hutchcroft Fund

Grinnell College
•Noyce Visiting Professorship