PARADIGMS IN PHYSICS - OREGON STATE UNIVERSITY

REVISING THE UPPER-DIVISION CURRICULUM

PARADIGMS IN PHYSICS

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. We have developed many effective classroom activities that we are sharing in national workshops. 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

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CONTENT

Junior Year Paradigms

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.

Fall
- Symmetries & Idealizations
- Static Vector Fields
- Oscillations

Winter
- One-dimensional Waves
- Spin & Quantum Measurements
- Central Forces

Spring
- Energy & Entropy
- Periodic Systems
- Rigid Bodies
- Reference Frames

Senior Year Capstones

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 curriculum because the content builds on the examples of the paradigms in the junior year.
- Classical Mechanics
- Mathematical Methods
- Electromagnetism
- Optics
- Quantum Mechanics
- Thermal and Statistical Physics

Laboratory Courses

Students learn experimental techniques throughout the junior and senior years.
- Electronics (required)
- Computer Interfacing
- Independent research and thesis (required)

Specialty Courses

Students also have the opportunity to take required and elective courses in more specialized fields.
- Computational Physics
- Solid State Physics
- Nuclear & Particle Physics
- Atomic, Molecular, & Optical Physics

INSTITUTIONALIZATION & DISSEMINATION

Faculty Involvement

- Full departmental faculty endorsement
- Department-wide curriculum integration
- Regular group meetings, faculty mentoring on course transfer

Faculty Development Workshops

Spin & Quantum Measurements and Energy & Entropy:
AAPT Winter Meeting Workshops, Austin, TX, January, 2003; Miami Beach, FL, January, 2004
Paradigms Summer Faculty Workshops, Corvallis, OR, June 2003; June 2004
Bridge Faculty Workshops, Corvallis, OR, August, 2003 - 2005; S. Hadley, MA, June, 2004
Quantum Mechanics in the Paradigms:
Paradigms Summer Faculty Workshop, Corvallis OR, August 2006

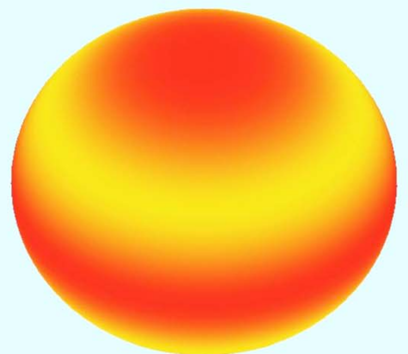
Materials Development

Materials for student use in 15 courses have been developed, classroom tested at Oregon State University, and in use for eight years. Class notes for four courses, in the form of short texts, are complete—we are discussing an appropriate format with commercial publishers. In the next phase of the project, we hope to revise and test these materials at several other institutions, in preparation for widespread national dissemination.

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
- Integrated laboratories
- Projects
- Learning cycles
- Journal research
- Visualization



Color representation of wave function

Lecture vs. Activities

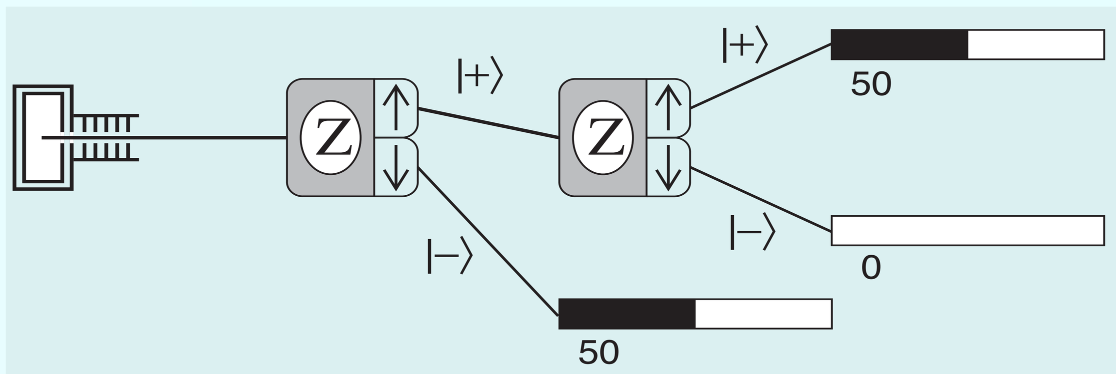
PER at the lower division shows that active engagement is effective but slow. At the upper-division there is lots of material to cover. We have experimented with the ideal split between lecture and active engagement. We have discovered that each method has its strengths.

- The Instructor:
  - Paints big picture.
  - Inspires.
  - Covers lots fast.
  - Models speaking.
  - Models problem-solving.
  - Controls questions.
  - Makes connections.
- The Students:
  - Focus on subtleties.
  - Experience delight.
  - Learn slowly, but in depth.
  - Practice speaking.
  - Practice problem-solving.
  - Control questions.
  - Make connections.

EXAMPLES

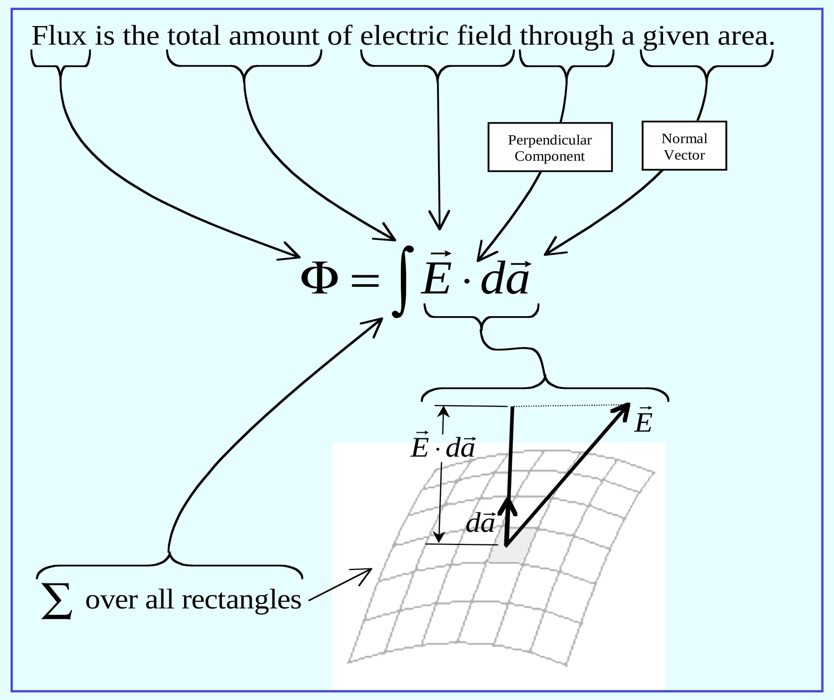
Early Quantum Mechanics

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 experiments (Schroeder & Moore, Am. J. Phys. **61**, 798-805, 1993), students infer the wave function from "data" as in real experiments. (Traditional curricula approach these problems backwards: predicting the results of experiment from "knowing" the unknowable wave function.)



Multiple Representations

Kerry Browne, in his Ph.D. thesis (OSU 2002), showed that while students may be able to employ different representations of physical quantities (pictorial, graphical, algebraic, words, etc.) they often have trouble relating these representations. We include activities that explicitly encourage students to make these links.



RESULTS

Websites

http://www.physics.oregonstate.edu/paradigms
http://www.physics.oregonstate.edu/portfolios
http://www.physics.oregonstate.edu/bridge

These sites contain:
1. an introduction and overview of the project 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, primarily for the use of students at our own university.

Publications

1. C. A. Manogue and K. S. Krane, *The Oregon State University Paradigms Project: Re-envisioning the Upper Level*, Physics Today **56**, 53-58 (2003).
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, 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).
4. T. Dray and C. A. Manogue, *Using Differentials to Bridge the Vector Calculus Gap*, College Mathematics Journal **34**, 283-290 (2003).
5. D. H. McIntyre, *Using Great Circles to Understand Motion on a Rotating Sphere*, American Journal of Physics, **68**, 1097 (2000).

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