SEI PHYSICS FACULTY UPDATE

What resources are available?
Where can I find them?
What should we do next?
The Science Education Initiative at the University of Colorado

- 5-year, $5M (Chancellor)
- catalyze and support improvements in science education
- Physics, MCDB, IPHY, APS, EBio, GeoSci, Chem

 Currently in the final year of funding.
What has been done?

• **SEI Proposal in ’07 (+ 3 more NSF grants)**

  - Phys 2210: Classical Mechanics / Math Methods
  - Phys 3220: Quantum I
  - Phys 2130: Modern Physics
  - Phys 3310: Electricity & Magnetism I (statics)
  - Phys 3320: Electricity & Magnetism II (dynamics)
  - Phys 3340, 4430, 5430: Advanced Lab

• **Structure** (working groups, 7 postdocs, and PER)
Our approach to course transformation

What *should* students learn?

- Establish learning goals

What *are* students learning?

- Applying research & assessment

Which instructional approaches improve student learning?

- Faculty & Staff

- Apply research-based teaching techniques & measure progress
What should students learn?

Learning goals & student difficulties

What should students learn?  
What are students learning?  
Which instructional approaches improve student learning?
Explicit learning goals

“What do we want students to be able to do by the end of the course?”

- Broad interdepartmental collaboration:
- Directs course transformations and assessments.
- Beneficial for instructors and students.
E&M 1

Students should be able to:

...calculate and sketch the direction of the dipole moment of a given charge distribution.

...outline the general steps necessary for solving a problem using separation of variables.
#5 – Problem-solving techniques

Students should be able to:

...choose and apply the problem-solving technique that is appropriate to a particular problem.

...justify their approach for solving a particular problem.
Do not solve, but give “the easiest method you would use to solve the problem” & “why you chose that method”.

\[ \rho(r) = \rho_0 e^{-r^2/a^2} \]

33% of students did not recognize Gauss’ law as the easiest way to solve. \((N=325)\)

24% of students incorrectly chose Gauss’ law as the easiest way to solve. \((N=325)\)
How to improve learning?

**Instructional Approaches**

- **What *should* students learn?**
- **What *are* students learning?**

Which instructional approaches improve student learning?
Upper-division courses

• **Materials** for instruction and evaluation
  – Clicker Questions
  – Tutorial-style Activities
  – Homework and Exam questions
  – End-of-course assessments
The position of a moving particle is given by
\[ r(t) = b \cos \omega t \hat{x} + b \sin \omega t \hat{y} \]

Describe this orbit:

A) circular, uniform motion
B) circular, non-uniform motion
C) helical
D) elliptical
E) Other!!

Bonus q: Is it moving CW or CCW?
Part 1 – Getting Oriented

A particle moves in the plane. We could describe its motion in two different ways:

CARTESIAN: I tell you the particle's location by giving its coordinates in the Cartesian (x, y) system.

POLAR: I tell you the particle's location in polar coordinates (r, \theta).

(a) Draw a picture showing the location of the point at some arbitrary time, labeling the Cartesian coordinates (x, y) and the polar coordinates (r, \theta).

(b) Using this picture, determine the formula for \hat{x} and \hat{y} (\hat{x} & \hat{y}). Your answer should contain x, y, r, and \theta.

(c) Write down the analogous expression for \hat{r} and \hat{\theta} (\hat{r} & \hat{\theta}). Your answer should contain x, y, r, and \theta.

(d) I claim the position vector in Cartesian coordinates is \vec{r} = \hat{x}x + \hat{y}y. Again, do you agree?

(e) I claim the position vector in polar coordinates is \vec{r} = r \hat{r}. Is this consistent with your picture above?
Upper-division courses

• **Materials** for instruction and evaluation
  – Clicker Questions
  – Tutorial-style Activities
  – Homework and Exam questions
  – End-of-course assessments

• **Resources** for instructors
  – User’s guides
  – Documentation of observed student difficulties
  – One-on-one support from post-docs
Where can I get these materials?

- Modern Physics (2130)
- Classical Mechanics I (2210)
- Electrostatics (3310)
- Electrodynamics (3320)
- Quantum I (3220)
- Advanced Lab (3340, 4430, 5430)

All materials available at:

www.colorado.edu/sei/physics/
What are students learning?

Research & Assessment

What *should* students learn?

What *are* students learning?

Which instructional approaches improve student learning?
Data sources

- Classroom observations & student work
- Student interviews
- Attitude surveys
- Traditional exams
- End-of-course conceptual assessments
Research validated course assessments

- **E&M 1:** *Colorado Upper-Division Electrostatics Assessment* (CUE)

- **E&M 2:** *Colorado Upper-Division ElectrodyNamics Test* (CURrENT)

- **Classical Mechanics:** *Colorado Classical Mech./Math Methods Instrument* (CCMI)

- **Quantum Mechanics:** *Quantum Mechanics Assessment Tool* (QMAT)

- **Advanced Lab:** *Colorado Learning Attitudes about Science Survey for Experimental Physics* (E-CLASS)

*Used at universities around the country*
Sample outcomes (E&M1 CUE scores)

Order of courses listed is randomized

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<th>CUE Score (%)</th>
<th>Standard Lecture-Based Courses</th>
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- Post-Test
- Average (across courses)
SEI Future directions: A perfect storm

Lots of postdocs for one more year:
E&M, Class. Mech./Math Methods, QM, Adv. Lab

Revisiting the desired outcomes of a physics major?

Coordinating across the major?

Emphasizing scientific practices?
SEI Future directions: Baby Steps

- Development of math skills
  \[ f(x) = \sum_{n=0}^{\infty} \frac{f^{(n)}(x_0)}{n!} (x - x_0)^n \]

- Integrating analytics and computational modeling
  ```math
  g = 9.8; l = 2;
sol = NDSolve[\{\phi''[t] = -g/l Sin[\phi[t]], \phi'[0] = 0, \phi[0] = 3\}, \phi, \{t, 0, 10\}];
  ```

- Open-ended problem solving:

- Oral/written communication skills in all courses
Do you have questions/thoughts about...

...what is available?
...where can you find it?
...what we should do next?
...anything else?

www.colorado.edu/sei/physics/