Transforming Upper-Division Undergraduate Electricity & Magnetism I

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Overview

We adapt research-based techniques known to be effective at the introductory level as proof-of-concept in how an upper-division course may be transformed in order to improve student learning.

Multiple research-based assessments were used in order to evaluate effectiveness of the transformations (see next poster).

All course materials are available online at www.colorado.edu/sei/departments/physics_3310.htm

Why Upper-Division E&M?

Electricity & Magnetism:
- Is a core course for majors
- Defines what it *means* to learn physics as a major
- Requires sophisticated problem-solving
- Is often taught using traditional lecture
- Is often taught through abstract formalism
- Has canonical content

E&M is highly valued by faculty as a core course for training majors; so changes can be departmentally sensitive.

Our efforts get at the heart of what the department wishes its majors to learn.

Faculty Input

This project combined the skills of two typically non-overlapping groups:
- Faculty teaching introductory courses using methods of active engagement
- Faculty teaching upper-division courses using traditional lecture

Faculty involvement should increase **sustainability of changes** and alignment with **faculty values.**

A working group of ~10 PER and non-PER faculty met biweekly to discuss course learning goals and content.

Image credit[1]

Learning Goals

Content is canonical: Griffiths[2] Chapter 1-6.
Ten broad learning goals were developed by faculty. For example:

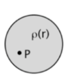
Students should be able to achieve physical insight through the mathematics of a problem

Students should be able to choose and apply the appropriate problem-solving technique

Students should be able to justify the reasonable-ness of a solution (using limiting cases, units, etc.)

Give a brief outline of the EASIEST method you would use to solve this problem.

Q7. A solid non-conducting sphere, centered on the origin, with a non-uniform charge density that depends on the distance from the origin, $\rho(r) = \rho_0 e^{-r^2/a^2}$ where a is a constant. Find E (or V) inside at point P.



Question from the Colorado Upper-Division Electrostatics (CUE) Assessment. Assesses progress on learning goals

Classroom Techniques

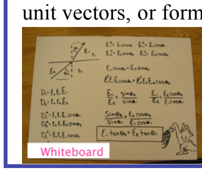
Class blended traditional lecture with interactive engagement methods -- not as dramatic a departure from the traditional approach as other transformation efforts[3,4]. Techniques included:

Interactive lecture style involving high levels of student-student and student-teacher interaction

Clicker questions and peer discussion

Illustrative simulations and demonstrations

Kinesthetic activities such as pointing to indicate unit vectors, or forming a line charge[3].



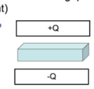
Student work on small whiteboards. E.g., sketch a function, solve problem, make concept map.

Concept Tests (clickers)

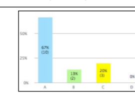
- 2-3 clicker questions in each 50-min class
- 5-7 minutes per clicker question
- Allowed us to gauge student understanding
- Allowed students to discuss challenging ideas
- **Kept students engaged and following lecture**
- **Asked student to expand or apply lecture topics**
- **Prepared students to learn from lecture**

An ideal (large) capacitor has charge Q. A neutral *linear* dielectric is inserted into the gap (with given dielectric constant)

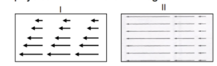
Where is D discontinuous?
i) near the free charges on the plates
ii) near the bound charges on the dielectric surface



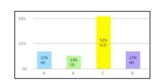
A) i only B) ii only C) i and ii ONLY
D) i and ii but also other places E) none of these/other



Which of the following *could* be a static physical E-field in a small region?



A) Both B) Only I C) Only II D) Neither



The SEI has compiled a guide to best practices in clickers [5].

Homework

In order to more explicitly target learning goals, we modified traditional homework.

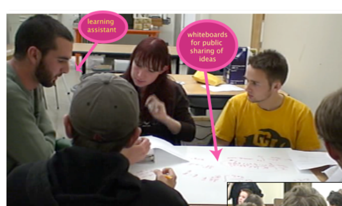
For example:
- Real-world contexts
- Articulating expected answer
- Making sense of final answer
- Approximations, expansions, estimations…

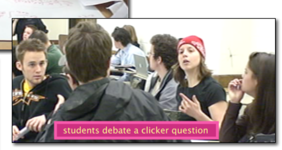
Q2. DIVERGENCE AND CURL

Consider a field $\mathbf{E} = c\frac{\vec{\mathbf{r}}}{r^2}$ (which is NOT the field from a point charge at the origin, right?!)

a) **Sketch it.** Calculate the divergence *and* the curl of this **E** field. Test your answers by using the divergence theorem and Stoke's theorem. **Is there a delta function at the origin like there was for a point charge field, or not?**
b) What are the units of c? **What charge distribution would you need to produce an E field like this? Describe it in words as well as formulas. (Is it physically realizable?)**

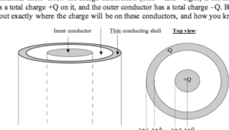
Sample HW problem aligned with learning goals. Non-traditional portions in bold.





Part 1 – Conceptually Understanding Conductors

A coax cable is essentially one long conducting cylinder surrounded by a conducting cylindrical shell. Draw the charge distribution (little + and – signs) if the inner conductor has a total charge +Q on it, and the outer conductor has a total charge –Q. Be precise about exactly where the charge will be on these conductors, and how you know.



Consider how the charge distribution would change if the inner conductor is shifted off-center, but still has +Q on it, and the outer conductor remains electrically neutral. Draw the new charge distribution (little + and – signs) and be precise about how you know.

Portion of a CU tutorial

Homework Help Sessions

- Two 2-hour sessions per week
- Optional (65% class attendance)
- Instructor assisted in Socratic style
- Helped students solve homework problems

Tutorials

- 10 weekly tutorials* under continued development
- Optional (50% class attendance)
- Socratic guided inquiry
- Run with assistance of undergrad Learning Asst[6].
- Prepared students for next homework by helping them conceptually interpret the mathematics

* Inspired by:
OSU "Paradigms"[3]
"Griffiths by Inquiry"[4]
U. Washington Tutorials[7]

Results & Conclusions

Success of the transformation was evaluated by:
- New conceptual assessment (CUE) and BEMA[8]
- Conventional exam problems
- Student interviews and end-of-term evaluations

Compared to a traditional lecture, **students scored higher on all assessments**[9] *(see other poster)*, and were **very enthusiastic about the course**.

Pedagogical techniques that improve learning in introductory classes can have similar benefits in upper-division, resulting in improved learning for future physicists, teachers and engineers.

References

[1] http://projectreadsf.blogspot.com/2007/02/tips-for-tutors-from-february-round.html
[2] D.J. Griffiths, Introduction to Electrodynamics, 3rd Ed. Upper Saddle River, New Jersey: Prentice Hall, 1999.
[3] C. Manogue et al, Paradigms in Physics: A New Upper Division Curriculum, *Am.J.Phys.* **69,** 978-990 (2001). Curricular materials online at www.physics.oregonstate.edu/portfolioswiki.
[4] B. Patton, Jackson by Inquiry, APS Forum on Education Newsletter, Summer 1996, and B. Patton and C. Crouch, Griffiths by Inquiry, Personal Communication.
[5] http://www.colorado.edu/sei/fac-resources/guide.html
[6] http://stem.colorado.edu/la-program
[7] L. McDermott, P. Shaffer, and the PEG *"Tutorials in Introductory Physics,"* Prentice Hall, 2002.
[8] L. Ding et al, *Phys Rev ST: PER,* **2**, 010105, 2006.
[9] BEMA scores were not statistically significantly different.

Acknowledgements

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