

## Transforming Upper-Division Electrodynamics (E&M II)

<http://per.colorado.edu/Electrodynamics>

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## Course Description

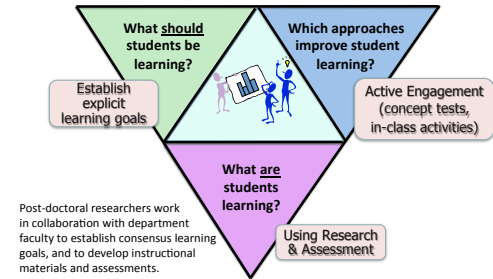
2<sup>nd</sup> semester upper-division physics course on electrodynamics (primarily junior physics majors)

- Time-dependent Maxwell equations
- Conservation principles
- Potentials and fields
- EM waves
- Radiation
- Special relativity

Standard textbook:

D. J. Griffiths, *Introduction to Electrodynamics*, 3<sup>rd</sup> Ed.

## SEI<sup>†</sup> Transformation Process



<sup>†</sup> Science Education Initiative

## Research on Student Learning

### IDENTIFYING STUDENT DIFFICULTIES

- Analyze and archive responses to homework and exam questions, clicker questions, in-class activities
- Observe discussions/questions in class and during HW problem-solving sessions
- Listen to experienced instructors

### 1-ON-1 & GROUP STUDENT INTERVIEWS

- Confirm student difficulties and discover new ones
- Validate tutorial problem statements and diagrams
- Simulate group activities during tutorial development

## Explicit Learning Goals →

### EXAMPLES OF CONTENT LEARNING GOALS Students should be able to:

- Correctly apply Stokes' Law and the Divergence theorem, and be able to use them to convert equations from differential to integral form (and vice-versa).
- Apply Ohm's Law (in the form  $\mathbf{J} = \sigma \mathbf{E}$ ) to relate the current density to the electric field, and calculate the total current for a given situation.
- Find the boundary conditions for EM waves starting from Maxwell's Equations, and apply the correct boundary conditions to solve for and interpret reflected and transmitted waves.

### EXAMPLES OF BROADER LEARNING GOALS Students should be able to:

- Translate a physical description of a problem to a mathematical equation necessary to solve it.
- Articulate their expectations for the solution to a problem, such as direction of the field, dependence on coordinate variables, and behavior at large distances.
- Recognize symmetries and be able to take advantage of them in order to choose the appropriate method for solving a problem.

## In-Class Activities →

### CONCEPT TESTS

- Actively engage students in learning process
- Encourage group discussion and scientific argumentation skills
- Provide valuable real-time feedback to instructors

### TUTORIALS

- Used during class to supplement lectures
- Guided tasks help students develop important concepts for themselves
- Require from 5 to 45 minutes, depending on tasks

## Concept Tests

### CAN BE USED FOR A VARIETY OF PURPOSES

**CONCEPTUAL:** Questions that don't rely on complex mathematics.

**APPLICATION:** Use an abstract idea in the context of a real-world situation

**NEXT STEP:** Underscore key ideas in a long derivation, proof or in-class calculation

**MATH/PHYSICS:** Make connections between equations and the physical situations they describe

## Tutorials

In-class activities have been implemented in several ways:

- Taking 5 minutes to do important derivations
- Section by section, interspersed with short lectures
- Using partial or entire class periods uninterrupted

Mixed emphasis on conceptual vs. procedural knowledge:

- Conceptually challenging materials focus, e.g., on whether quantities are *zero* or *non-zero*
- Simple derivations or calculations help develop math skills and lasting understanding

## Assessments →

### CONCEPTUAL & FUNDAMENTAL SKILLS

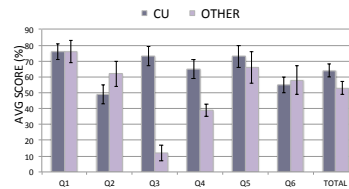
- Pre/post-instruction versions
- Focus on important topics (as defined by learning goals)
- Useful for students to assess their own understanding

### STUDENT PERCEPTIONS

- Online end-of-semester student survey
- Focus on perceived usefulness of transformed curriculum for their learning
- Opportunity for essential student feedback

## Conceptual & Fundamentals

- Given at CU and one other institution in SP12
- Required 1 class period
- Significant differences seen in areas targeted by in-class activities used at CU



## Student Perceptions

Percentage of class rating these as "useful" or "very useful" for their learning

