Tapping into Juniors' Understanding of E&M: Development of the CUE Assessment

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Overview

As part of a research-based effort to improve junior level E&M[1], we created a conceptual assessment to evaluate student understanding of upper-division E&M concepts -- **the Colorado Upper-Division Electrostatics (CUE) Assessment.** Preliminary validation and results are presented.

All course materials & the CUE available: www.colorado.edu/sei/departments/physics_3310.htm

Learning Goals

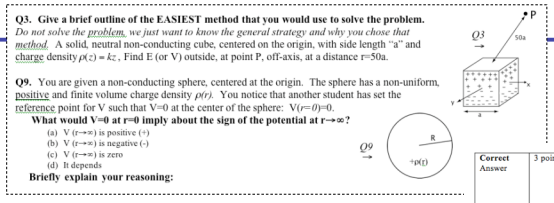
Content in course is canonical: Griffiths[2] Chapter 1-6.
Ten broad learning goals were developed by a **working group** of 10 faculty, including:

	Students should be able to ...
MATH/PHYSICS CONNECTION	... achieve physical insight through the mathematics of a problem
VISUALIZE	... sketch the physical parameters of a problem
COMMUNICATION	... justify and explain their thinking and approach to a problem.
PROBLEM-SOLVING	... choose and apply the appropriate problem-solving technique

E&M defines what it *means* to learn physics as a major.
These goals represent often-implicit expectations of faculty
Goals drove instruction in transformed courses[1] as well as the development of CUE

About the CUE

- A 17-question conceptual assessment to be given in 50-minute lecture
- Optional 7-question (20-minute) **pre-test**
- Aims to measure achievement on **learning goals**
- Detailed **grading rubric** developed
- Mostly **short answer** with one multiple choice question
- Asked students to:
  Choose a problem-solving method & defend that choice, sketch E field patterns, graph electric field strength and potentials, and explain the physics and mathematics underlying steps in common problems


Q3. Give a brief outline of the EASIEST method that you would use to solve the problem. *Do not solve the problem, we just want to know the general strategy and why you chose that method.* A solid, neutral non-conducting cube, centered on the origin, with side length "a" and charge density $\rho(z) = kz$, Find E (or V) outside, at point P, off-axis, at a distance r=50a.

Q9. You are given a non-conducting sphere, centered at the origin. The sphere has a non-uniform, positive and finite volume charge density $\rho(r)$. You notice that another student has set the reference point for V such that V=0 at the center of the sphere: $V(r=0)=0$.
What would V=0 at r=0 imply about the sign of the potential at $r\to\infty$?
(a) V ($r\to\infty$) is positive (+)
(b) V ($r\to\infty$) is negative (-)
(c) V ($r\to\infty$) is zero
(d) It depends
Briefly explain your reasoning:

2 CUE questions

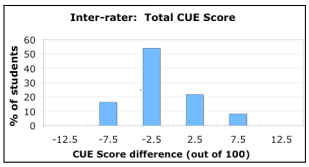
Grading rubric for Q3

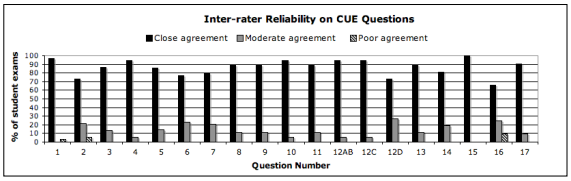
Correct Answer	3 points	Correct answer is multipole expansion using the dipole component. **+1** point if say direct integration + 2.5 for dipole only +0.5 for approximation or multipole + 2 for multipole only + 1 for dipole or + 1 for approximation
Explanation	2 points	Full credit for saying dipole dominates because the observation point is far away. **1.5 points** for "multipole because r>>a" **+1** point if said that it's a dipole but give no further explanation **+1** point if mention higher order multipoles (but not a dipole) **+0.5** for saying the integration is hard because P is off-axis. If they answered direct integration, full credit requires some mention of what the integral would look like or why they chose this method. **+0.5** for a poor explanation of how they would go about it (eg., writing down Coulomb's Law).

Validation & Reliability

- Validated in think-aloud interviews & 3 semesters of test administration
- 7 questions dropped, 2 questions added, 5 questions substantially modified to arrive at final instrument
- CUE score moderately correlated with course grade (r=0.49, p<<0.01) at CU
- Good reliability as measured by Cronbach's alpha (0.82)
- **Inter-rater reliability on total CUE score is high** (as tested by 36 exams scored by two experienced graders)
  - ✓Average difference of 1.4% ± 0.6% -- much less than interclass differences given in Results, below.
  - ✓Graders agree within 10% for all students and within 5% for most (76%) students
- **Inter-rater reliability *per question* on CUE is acceptable**:
  - ✓Within "close" agreement for 75% of students on all questions but two
  - ✓In *exact* agreement for at least 45% of students on all questions but one
  - ✓Standard deviation of rater-differences on questions range from 0 to 28% (average 12%)

On average, we can discern CUE scores within 5% overall and 20% per question.





"Close" agreement is within ±20% (±1 point on a 5 point question), "moderate" is within ± 20-50% (±1-2.5 points on a 5 point question) and "poor" is off by 50-100%.

Results

Post-test

- The **post-test** was given to 226 students at CU and elsewhere.
- Four courses were taught using the transformed course materials (IE1-3 at CU and C-IE at a private liberal arts college) using student-centered instruction such as clickers and tutorials, and homework based on learning goals.
- **All courses using the transformed materials scored higher on the CUE than courses not using the materials***
- Three instructors using transformed curriculum (IE1, IE2, and C-IE) had never taught E&M before, yet received high CUE scores, suggesting curricular rather than instructor effects.

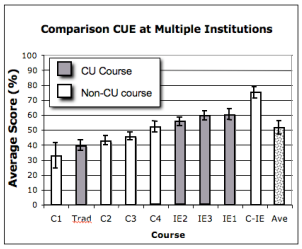
**All but IE2 are stat. significant*

Pre-test

- **Pre-test** scores (7 questions out of 17) are about 30%, similar to freshmen just completing intro E&M (N=25).
- **Learning gains** (on those same 7 questions) are 20-30%
- Pre-test scores for private liberal arts college (C-IE) are higher than those at other institutions, but learning gains are similar

Pre/post test scores (matched by student).

Code	Pre-test (%)	7-Q Post-Test (%)	Gain (Post-Pre)
CU Freshmen	30 ±3.0	N/A	N/A
IE2	30 ±2.3	51 ±2.9	21±2.8
IE3	33 ±3.2	61 ±3.4	28±3.0
C-IE	43 ±6.3	71 ±5.9	29±7.6
C1	33 ±5.3	47 ±12.5	15±9.3



Trad = traditionally taught course at CU (N=26);
IE1-3 = transformed courses at CU (N=21, 48, 27);
C-IE = private liberal arts college using CU materials (N=12)
C1-4 = primarily lecture-based courses at other univs (N=6, 18, 52, 39).

"Comparison CUE scores" are a subset of the CUE given in common, due to changes in the exam over time. CUE given in-class except C1. Response rates 75-100%. Error bars represent SE of the mean.

Conclusions

- We have developed an open-ended assessment that taps students' mastery of some of the skills expected of a junior E&M student.
- *See invited poster session for detailed analysis of student responses*
- The assessment shows good reliability and validity such that interclass differences can be discerned; analysis still in progress
- The CUE appears to measure differences that we care about -- such as the effect of pedagogical transformations and student population.

References & Acknowledgements

[1] S.V. Chasteen and S.J. Pollock *PERC Proc. 1064*, AIP, Syracuse, NY, 2008, p 91-94 and S. V. Chasteen and S. J. Pollock, *PERC Proceedings 2009*, submitted.
[2] D.J. Griffiths, Introduction to Electrodynamics, 3rd Ed. Upper Saddle River, New Jersey: Prentice Hall, 1999.

Use the CUE in your course!
All course materials & the CUE available at www.colorado.edu/sei/departments/physics.htm

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