

RE-THINKING THE RUBRIC FOR GRADING THE CUE: THE SUPERPOSITION PRINCIPLE

Justyna P. Zwolak, Mary Bridget Kustusch and Corinne A. Manogue

 Department of Physics, Oregon State University, Corvallis, OR 97331

Supported in part by

 NSF DUE - 1023120.



INTRODUCTION

- Recently, the University of Colorado developed the Colorado Upper-Division Electrostatics (CUE) Diagnostic to “serve as a comparative instrument to assess upper-division E&M courses” [1, 2].
- We believe, that while the questions on the CUE cover many of our learning goals in an appropriate manner, the rubric for the CUE is particularly aligned to topics and methods of teaching at CU.
- As an example, we highlight CUE problem involving the superposition principle.
- Using student data from both OSU and the CU, we discuss the limitations of the current rubric, present results using a different analysis scheme, and discuss the implications for assessing students’ understanding.

CUE INSTRUCTIONS

(“...”) give a brief outline of the EASIEST method that you would use to solve the problem. Methods used in this class include but are not limited to: *Direct Integration*, Ampere’s Law, *Superposition*, *Gauss’ Law*, Method of Images, Separation of Variables, and Multipole Expansion.”

GRADING RUBRIC FOR Q5

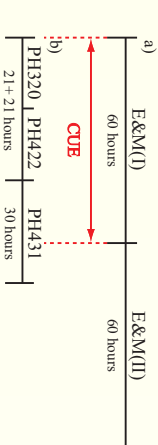
- Answer:** Correct answer is superposition. (3 pts)
- 0 points for only saying Gauss’ Law
 - +1 point for saying integration or dipole.
 - +1 point for superposition of charges but not fields ($e\cdot g_r$, for $4/3\pi(R^3 - r^3)\rho_0$).
 - 0 for “total charge of sphere with cavity”
- Explanation:** Full answer is superposition of two oppositely charged spheres and then Gauss’ Law to solve for E of each sphere. Need to indicate what is being superposed for full credit ($e\cdot g_r$, an antisphere of negative charge density). (2 pts)
- +1 point for stating what is superposed — two oppositely charged sphere
 - (+0.5 point if they don’t state the spheres are *oppositely* charged)
 - +1 point for explaining how to solve using the two charged spheres.

REFERENCES

- Stephanie V. Chasteen and Steven J. Pollock. Transforming upper-division electricity and magnetism. *AIP Conference Proceedings*, 1064:91–94, 2008.
- Available from the Science Education Initiative. www.colorado.edu/sci/departments/physics.htm.

TRADITIONAL E&M (I) COURSE VS. PARADIGMS

- Junior year:** two Paradigms in Physics courses (Griffiths Chapters 1, 2 and 5):
- PH 320: *Symmetries and Idealizations*
 - PH 422: *Static Vector Fields*
- Senior year:** Capstones in Physics course (Griffiths Chapters 3, 4, 6, 7 and briefly 9-11)
- PH 431 : *Electromagnetism*



Standard semester schedule (a) vs. OSU quarter schedule for E&M courses (b).

THE SUPERPOSITION PRINCIPLE QUESTION

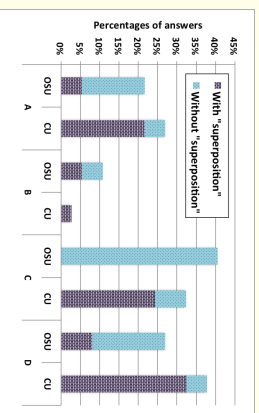
Q5. A charged insulating solid sphere of radius R with a uniform volume charge density ρ_0 , with an off-center spherical cavity carved out of it (see Figure). Find E (or V) at point P, a distance $4R$ from the sphere.



- Data Sources:
- $N = 90$ (3 semesters) of OSU students’ solutions (Post PH 422)
 - $N = 64$ of students’s solutions provided by the University of Colorado (Post E&M(I))

DATA ANALYSIS (USING NEW CATEGORIES OF RESPONSES)

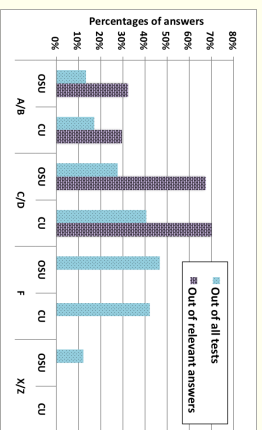
Frequency of use of the term “superposition” in students’ answers at OSU vs. CU.



- Of all relevant answers (A – D), 81% of CU students explicitly used the term “superposition”, the same percentage of OSU students did **not** use this term.

- Of all ambiguous/incorrect answers (C and D), only 11% of OSU students **did** explicitly use the term “superposition,” compared to 57% of CU students.

Frequency of correct (A/B), incorrect (C/D), irrelevant (F) and lack of answer (X/Z) at OSU and CU.



- At both schools only ~ 15% of all students took a clearly correct (electric or potential field) approach to this problem (~ 30% of relevant responses).
- At both schools almost 70% of students were either unclear about what they wanted to add/ superpose or clearly talked about adding charges.

CONCLUSIONS

- The rubric, which gives more credit for terminology over method, preferences course materials such as CU’s (lecture notes, clicker questions, tutorials, *etc.*), which emphasize terminology.
- The rubric in its current form does not provide information about an area where students seem to be struggling, independently of instructional approach.

EXAMPLES

Examples from the exams used for calibration that received almost full credit:

“I might try some type of superposition here. It could be easy to subtract the off-centered spherical cavity.” (Test 11: 4 pts)

“This would be solved using Gauss’ law with the law of superposition to subtract the one sphere from the other.” (Test 12: 4 pts)

NEW CATEGORIES OF RESPONSES

- A** Clearly talks about adding electric fields:
- A1 uses the word “superposition”
 - A2 does not use the word “superposition”
- B** Clearly talks about adding potentials:
- B1 uses the word “superposition”
 - B2 does not use the word “superposition”
- C** Seems to be adding charges:
- C1 uses the word “superposition”
 - C2 does not use the word “superposition”
- D** Ambiguous about what is being added / superposed:
- D1 uses the word “superposition”
 - D2 does not use the word “superposition”
- F** Irrelevant answer
- X Did not answer
 - Z Answered “I don’t know”

ACKNOWLEDGMENTS

We would like to thank Steve Pollock, Rachel Pepper and Bethany Wilcox for discussions about the CUE and for sharing some of the CU test data.