Analysis of Student Performance in Computer-Based vs. Paper-based Exams in Introductory Physics

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Motivation

- The use of computer-based exams has become increasingly popular in educational settings due to their potential benefits:
  - Efficient distribution and grading
  - Immediate feedback
  - Reduced paper usage
- To learn:
  - The effectiveness of computer-based exams in terms of student learning and performance
  - The factors that affect students' performance

Research Questions

1. How does student performance in computer-based exams compare to paper-based exams in introductory physics course?
2. What are the differences between the techniques used by the students in computer-based vs. paper-based exams in introductory physics courses?
3. What factors influence the performance of students in computer-based vs. paper-based exams in introductory physics courses?

Data Collection

- The data collection took place in large introductory physics courses at the University of Houston, where there were class sections taking computer-based exams and paper-based exams.
- The course content and materials are identical for both groups.
- The data being evaluated is the students' written work on their exams.

Analysis of written work

	5	4	3	2	1	0	NA(Problem)	NA(Solver)
USEFUL DESCRIPTION	The description is useful, appropriate, and complete.	The description is useful but contains minor omissions or errors.	Parts of the description are not useful, missing, and/or contain errors.	Most of the description is not useful, missing, and/or contains errors.	The entire description is not useful and/or contains errors.	The solution does not include a description and it is necessary for this problem /solver.	A description is not necessary for this problem. (i.e., it is given in the problem statement)	A description is not necessary for this solver.
PHYSICS APPROACH	The physics approach is appropriate and complete.	The physics approach contains minor omissions or errors.	Some concepts and principles of the physics approach are missing and/or inappropriate.	Most of the physics approach is missing and/or inappropriate.	All of the chosen concepts and principles are inappropriate.	The solution does not indicate an approach, and it is necessary for this problem/ solver.	An explicit physics approach is not necessary for this problem. (i.e., it is given in the problem)	An explicit physics approach is not necessary for this solver.
SPECIFIC APPLICATION OF PHYSICS	The specific application of physics is appropriate and complete.	The specific application of physics contains minor omissions or errors.	Parts of the specific application of physics are missing and/or contain errors.	Most of the specific application of physics is missing and/or contains errors.	The entire specific application is inappropriate and/or contains errors.	The solution does not indicate an application of physics and it is necessary.	Specific application of physics is not necessary for this problem.	Specific application of physics is not necessary for this solver.
MATHE-MATICAL PROCEDURES	The mathematical procedures are appropriate and complete.	Appropriate mathematical procedures are used with minor omissions or errors.	Parts of the mathematical procedures are missing and/or contain errors.	Most of the mathematical procedures are missing and/or contain errors.	All mathematical procedures are inappropriate and/or contain errors.	There is no evidence of mathematical procedures, and they are necessary.	Mathematical procedures are not necessary for this problem or are very simple.	Mathematical procedures are not necessary for this solver.
LOGICAL PROGRESSION	The entire problem solution is clear, focused, and logically connected.	The solution is clear and focused with minor inconsistencies	Parts of the solution are unclear, unfocused, and/or inconsistent.	Most of the solution parts are unclear, unfocused, and/or inconsistent.	The entire solution is unclear, unfocused, and/or inconsistent.	There is no evidence of logical progression, and it is necessary.	Logical progression is not necessary for this problem. (i.e., one-step)	Logical progression is not necessary for this solver.

Figure 1: Problem-Solving Assessment Rubric by Docktor and Heller (2009)[1]

Useful Description

- Organizing problem statement into a symbolic or visual representation
- “useful” if it guides further steps in the solution
- Examples:
  - Restating known and unknown quantities with symbols
  - Sketch/picture
  - Abstracted physics diagram (force, energy, motion, rays, etc.)

Physics Approach

- Selecting appropriate physics concepts and principle(s)
- Examples of concepts:
  - Vector, momentum, average velocity
- Examples of principle:
  - Conservation of energy
  - Newton’s second law
  - Ohm’s law

Special Application of Physics

- Applying the physics concepts and principle(s) to the specific problem
- Examples:
  - Statement of definitions
  - Relationship between defined quantities
  - Initial conditions
  - Assumptions/constraints

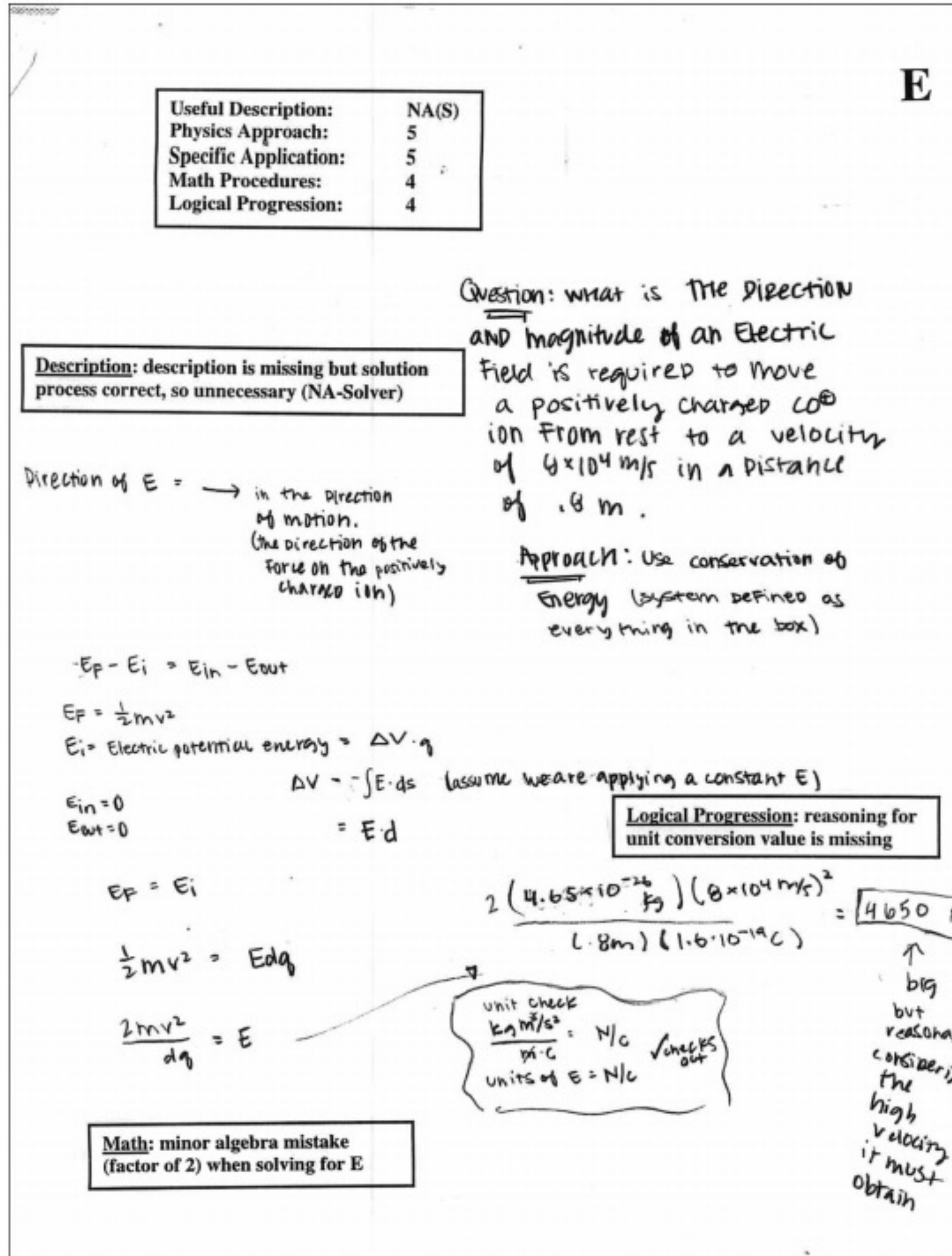
Mathematical Procedures

- Following mathematical rules and procedures correctly and appropriately
- Examples of procedures:
  - Isolate and reduce (algebra)
  - Substitution
  - Quadratic formula
  - Symbolic answer prior to numerical answer
- Examples of rules:
  - Parentheses
  - Square roots
  - Trigonometric identities

Logical Progression

- Communicating reasoning
- Organizing solution clearly and logically

Example 1



E

Useful Description:	NA(S)
Physics Approach:	5
Specific Application:	5
Math Procedures:	4
Logical Progression:	4

Question: what is the Direction and magnitude of an Electric Field is required to move a positively charged C^{+} ion from rest to a velocity of 4×10^4 m/s in a Distance of .8 m.

Description: description is missing but solution process correct, so unnecessary (NA-Solver)

Approach: Use conservation of Energy (system defined as everything in the box)

Direction of E = → in the direction of motion. (the direction of the force on the positively charged ion)

$E_f - E_i = E_{in} - E_{out}$

$E_f = \frac{1}{2}mv^2$

E_i = Electric potential energy = $\Delta V \cdot q$

$\Delta V = -\int E \cdot ds$ (assume we are applying a constant E)

$= E \cdot d$

$E_{in} = 0$

$E_{out} = 0$

Logical Progression: reasoning for unit conversion value is missing

$E_f = E_i$

$\frac{1}{2}mv^2 = Edq$

$\frac{2mv^2}{dq} = E$

$\frac{2(4.65\times10^{-26}\,kg)(8\times10^4\,m/s)^2}{(.8m)(1.6\cdot10^{-19}C)} = 4650$ N/C

unit check $\frac{kg\,m^2/s^2}{m \cdot C}$ = N/C ✓checks out

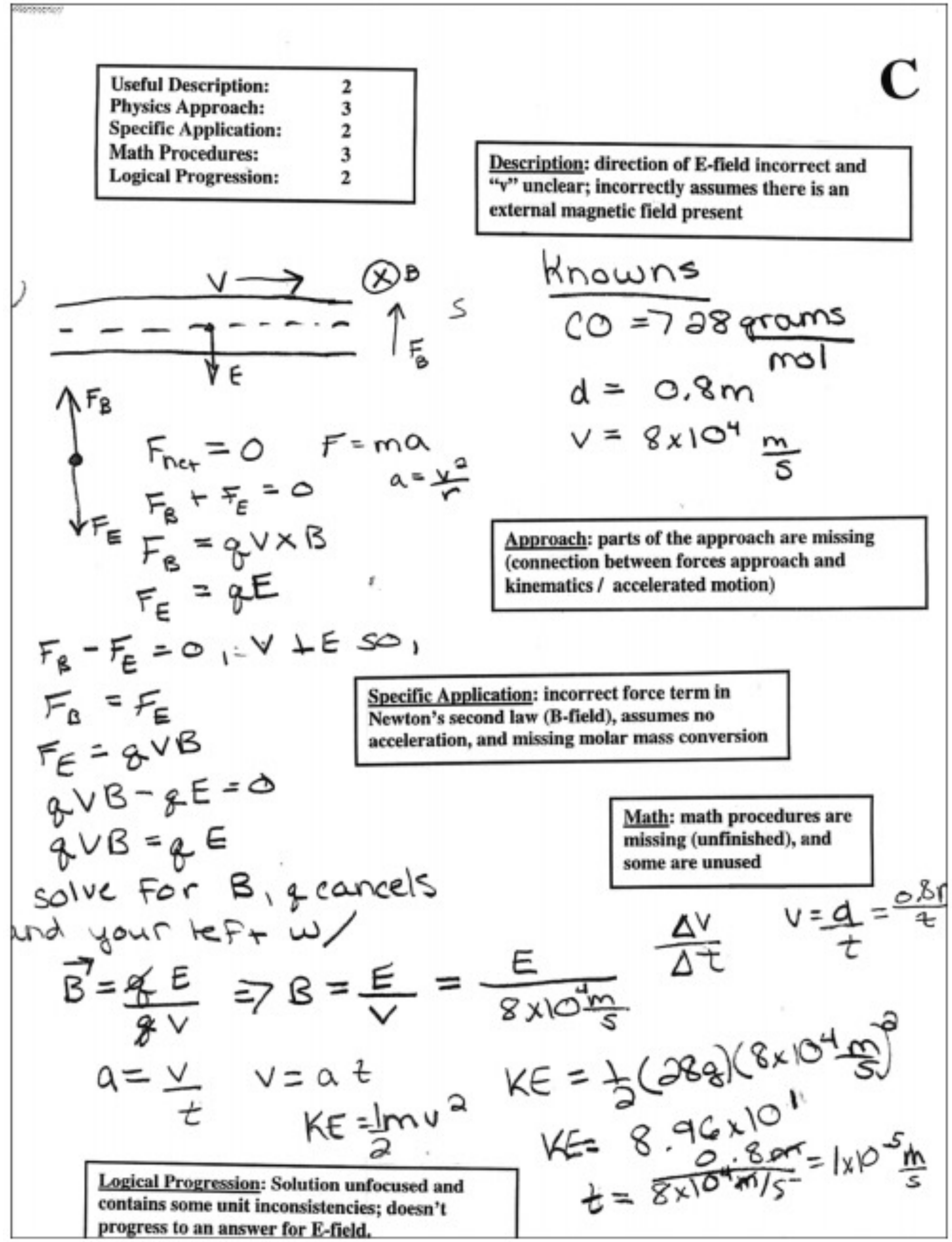
units of E = N/C

big but reasonable considering the high velocity it must obtain

Math: minor algebra mistake (factor of 2) when solving for E

Figure 2: Rubric application 1[2]

Example 2



C

Useful Description:	2
Physics Approach:	3
Specific Application:	2
Math Procedures:	3
Logical Progression:	2

Description: direction of E-field incorrect and "v" unclear; incorrectly assumes there is an external magnetic field present

Knowns

$CO = 28 \frac{grams}{mol}$

$d = 0.8m$

$v = 8\times10^4 \frac{m}{s}$

$F_{net} = 0$ $F = ma$

$a = \frac{v^2}{r}$

$F_B + F_E = 0$

$F_B = qV \times B$

$F_E = qE$

Approach: parts of the approach are missing (connection between forces approach and kinematics / accelerated motion)

$F_B - F_E = 0$ ∴ V ⊥ E so,

$F_B = F_E$

$F_E = qVB$

$qVB - qE = 0$

$qVB = qE$

solve for B, q cancels and your left w/

$\vec{B} = \frac{qE}{qV} \Rightarrow B = \frac{E}{V} = \frac{E}{8\times10^4 \frac{m}{s}}$

Specific Application: incorrect force term in Newton's second law (B-field), assumes no acceleration, and missing molar mass conversion

Math: math procedures are missing (unfinished), and some are unused

$\frac{\Delta V}{\Delta t}$ $v = \frac{d}{t} = \frac{0.8m}{t}$

$a = \frac{V}{t}$ $V = at$

$KE = \frac{1}{2}mv^2$

$KE = \frac{1}{2}(28g)(8\times10^4 \frac{m}{s})^2$

$KE = 8.96\times10^{11}$

$t = \frac{0.8m}{8\times10^4 m/s} = 1\times10^{-5} \frac{m}{s}$

Logical Progression: Solution unfocused and contains some unit inconsistencies; doesn't progress to an answer for E-field.

Figure 3: Rubric application 2[2]

Post Rubric Analysis

- Compare the performance of students in computer-based vs. paper-based exams
- Analyze the relationship between students' performance and students' background information, such as:
  - GPA
  - SAT score
  - Grade in prerequisite course
  - Transfer/non-transfer
  - Major/minor
  - Number of times students have taken the course

Expected outcomes

- Insights into the effectiveness of the different exam delivery methods
- Understanding factors affecting student exam performance:
  - To improve students' experience in the computer-based exam
  - To infer possible predictors of students' performance

Limitations

- The study is limited to a single institution and may not be generalizable to other populations
- The study does not investigate the potential effects of other external factors on student performance, such as:
  - Test anxiety
  - Testing environment

Conclusion & Summary/Research Plan

- Analysis of students' written work using Docktor-Heller's Rubric
  - PHYS 1301 Spring 2017 – Fall 2018
- Analysis of relationships between student performance metrics and student background information

References

1.Docktor, Jennifer, and Kenneth Heller. *Development and Validation of a Physics Problem-Solving Assessment Rubric a DISSERTATION SUBMITTED to the FACULTY of the GRADUATE SCHOOL of the UNIVERSITY of MINNESOTA by in PARTIAL FULFILLMENT of the REQUIREMENTS for the DEGREE of DOCTOR of PHILOSOPHY*. 2009.

2.Docktor, Jennifer L., et al. "Assessing Student Written Problem Solutions: A Problem-Solving Rubric with Application to Introductory Physics." *Physical Review Physics Education Research*, vol. 12, no. 1, 11 May 2016, https://doi.org/10.1103/physrevphyseducres.12.010130.

3.Stokes, Donna, et al. *FULL PROTOCOL TITLE: Analyzing Student Engagement and Performance in Introductory Physics Courses*. 23 May 2018.