Applying a Simple Rubric to Assess Student Problem Solving

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INTRODUCTION

Problem solving skills (qualitative and quantitative) are a primary tool used in most physics instruction. Despite this importance, a reliable, valid, and easy to use quantitative measure of physics problem solving does not exist.

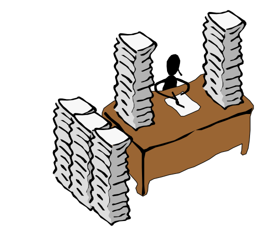
The *goal* of the project is to develop a robust, easy to use instrument to assess students' written solutions to physics problems and obtain evidence for reliability and validity. The instrument should be general (not specific to instructor pedagogy) and applicable to a range of problem types and topics.

This poster describes a test of the utility of the rubric:

- Does the rubric give more useful information about student difficulties than standard grading?
- Does the rubric give information about improving the problem statement?

ANALYSIS OF TESTS

- Calculus-based physics for science and engineering (mechanics)
- Four tests during the semester
- Problems graded by teaching assistants
- JD used the rubric to evaluate student solutions for 8 problems spaced throughout the semester (approximately 150 student solutions per problem)



PROBLEM SOLVING RUBRIC

SCORE

CATEGORY

	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.

CATEGORY DESCRIPTIONS

*Categories are based on problem solving research[1-4] and past research at the University of Minnesota[5-6].

USEFUL DESCRIPTION: summarize essential problem information visually, symbolically, and/or in writing

PHYSICS APPROACH: select appropriate physics concepts & principles to use

SPECIFIC APPLICATION: apply physics to the specific conditions in the problem

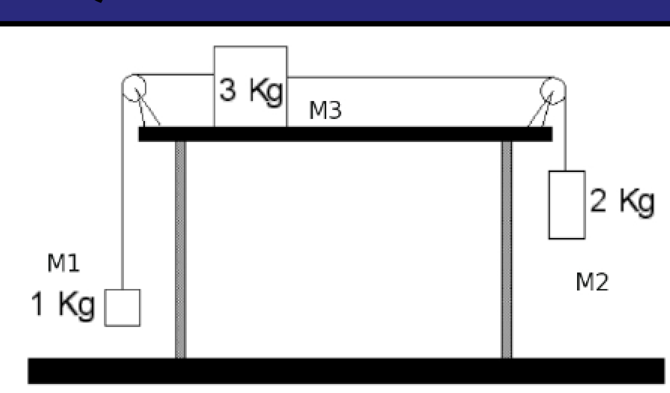
MATHEMATICAL PROCEDURES: follow appropriate mathematical rules and procedures during the solution execution

LOGICAL PROGRESSION: (overall) the solution progresses logically; it is coherent, focused toward a goal, and consistent

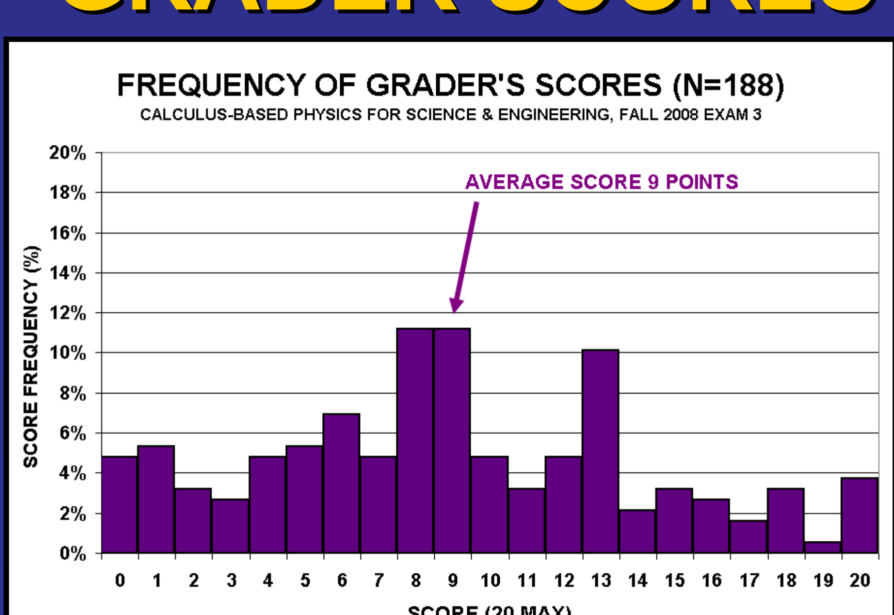
EXAMPLE TEST QUESTION

Problem 1. Show all work! The system of three blocks shown is released from rest. The connecting strings are massless, the pulleys ideal and massless, and there is no friction between the 3 kg block and the table.

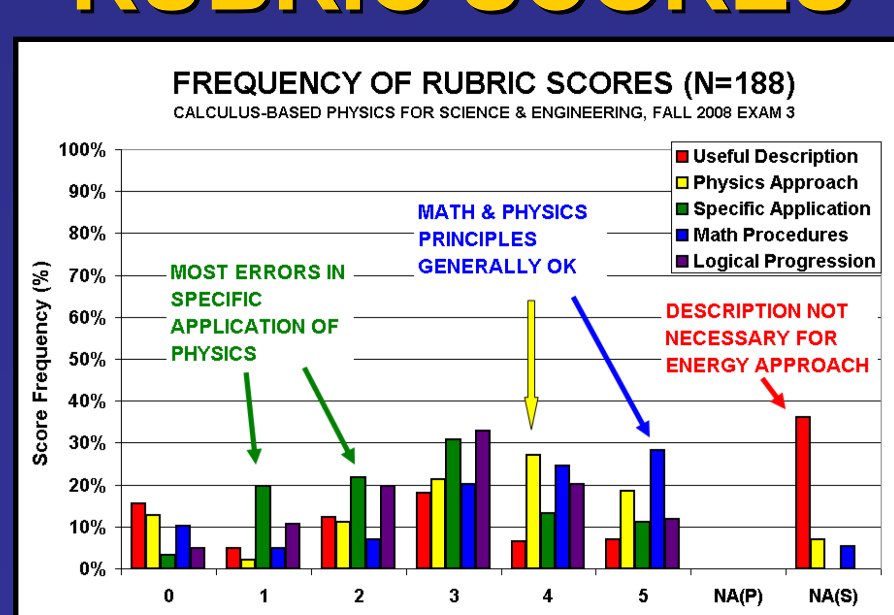
(A) At the instant M_3 is moving at speed v, how far (d) has it moved from the point where it was released from rest? (answer in terms of M_1, M_2, M_3, g and v.) [10 points]



GRADER SCORES



RUBRIC SCORES



PROBLEM FEATURES

Some problem characteristics that could bias problem solving behavior:

DESCRIPTION	MATH	PHYSICS
• Picture given • Familiarity of context • Prompts symbols for quantities • Prompts procedures (i.e. draw FBD)	• Symbolic vs. numeric question • Mathematics too simple (i.e. one-step problem) • Excessively lengthy or complex math	• Prompts physics • Cue focuses on a specific object

COMMON RESPONSES

CORRECTLY APPLIED CONSERVATION OF ENERGY: $\frac{1}{2}(M_1+M_2+M_3)v^2 = M_2gd - M_1gd$	6%
CORRECTLY APPLIED NEWTON'S 2ND LAW: $T_1 - M_1g = M_1a$, $M_2g - T_2 = M_2a$, $T_2 - T_1 = M_3a$; $d = \frac{v^2}{2a} = \frac{(M_1+M_2+M_3)v^2}{2g(M_2-M_1)}$	11%
APPLIED ENERGY WITH ONLY VELOCITY OF M_3: $\frac{1}{2}M_3v^2 = M_2gd - M_1gd$	25%
OTHER ERRORS IN ENERGY CONS. APPLICATION: $\frac{1}{2}(M_1+M_3)v^2 = M_2gd$, or cancel all masses, etc.	21%
APPLIED NEWTON'S SECOND LAW TO M_3 WITH T=MG: $T_2 - T_1 = M_3a \Rightarrow M_2g - M_1g = M_3a$	8%
APPLIED NEWTON'S SECOND LAW WITH T=MG: $a = \frac{\sum F}{M_{total}} = \frac{T_2 - T_1}{M_{total}} = \frac{M_2g - M_1g}{M_1+M_2+M_3}$	7%
MINOR ERRORS ONLY (SIGN)	5%
OTHER APPROACHES (MOMENTUM, ETC.)	7%
NO ATTEMPT / INDETERMINATE	10%

TABLE STATEMENTS IN RED SUGGEST STUDENTS FOCUSED ON M3 WHICH WAS CUED IN THE PROBLEM STATEMENT.

FINDINGS

The rubric indicates areas of student difficulty for a given problem. For example, the most common student difficulty involves specific application of physics whereas other categories are adequate.

For more detailed information for coaching and problem writing, examine the solutions for specific application of physics (see the table of common student responses).

The rubric responds to different problem features. For example, in this problem visualization skills were not measured.

REFERENCES

[1] J.H. Larkin, J. McDermott, D.P. Simon, and H.A. Simon, "Expert and novice performance in solving physics problems," Science 208 (4450), 1335-1342.

[2] F. Reif and J.I. Heller, "Knowledge structure and problem solving in physics," Educational Psychologist, 17(2), 102-127 (1982).

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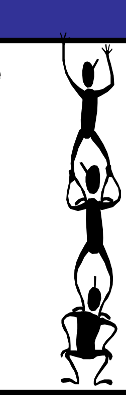
[4] A.H. Schoenfeld, *Mathematical problem solving* (Orlando, FL: Academic Press, Inc., 1985).

[5] J.M. Blue, *Sex differences in physics learning and evaluations in an introductory course*, Unpublished doctoral dissertation, University of Minnesota, Twin Cities (1997).

[6] T. Foster, *The development of students' problem-solving skills from instruction emphasizing qualitative problem-solving*, Unpublished doctoral dissertation, University of Minnesota, Twin Cities (2000).



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