# Facilitating Case Reuse in Algebra-Based Physics: Implementation of Strategies

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# Abstract

This paper summarizes the practical implications and limitations of a project that investigated students' development of problem solving schemata while using strategies that facilitate the process of using solved examples to assist with a new problem (case reuse). Over a two year span, focus group learning interviews were used to explore students' perceptions, understanding and use of several problem solving strategies. Individual clinical interviews were conducted and classroom quantitative examination data were collected to assess students' conceptual understanding, knowledge organization and problem solving performance on a variety of problem tasks.

## Introduction

Individuals, including experts of science and mathematics, commonly extrapolate information collected and stored from previous events to determine how it might be comparable to a new circumstance. Experts refine their approach to reusing cases over years of experience. This refinement includes a more sophisticated organization of knowledge elements and their associations (Jonassen, 2006). Our goal with this project was to assist novices with refining this approach early in their studies, easing both cognitive load and the perceived difficulty associated with physics problems.

With the continual decline of students choosing physical science as either a major or even a science elective, research focus has turned toward students' attitudes toward science and how the current decline might be reversed (Osborne, Simon, & Collins, 2004). This qualitatively intense study presented promising evidence of how implementing strategies that accommodate students' pre-existing problem solving methods positively affect student performance and their overall attitude towards physics problem solving. This work was not intended to be turned into a stand-alone curriculum, only a framework that faculty could assimilate into their existing teaching methodology.

This paper discusses the research methods used for each phase of the project, the results for each phase and how our promising results using limited outside intervention can have considerable implications for further research and instruction.

## Theory Meets Practice

This study, like many in science education research, remained well-informed by previous research studies and student and faculty perception of problem solving.

The pilot and three phases of this project were all built upon the same foundation: valuing worked examples (Maloney, 1993; Ward & Sweller, 1990), active reflection of case comparison (M. T. H. Chi, P.J. Feltovich, & R. Glaser, 1981; Gentner, Loewenstein, & Thompson, 2003; Graesser, Baggett, & Williams, 1996; Jonassen, 2006), emphasis on deep-structure elements within problem sets (Catrambone & Holyoak, 1989) and assessing students' development of problem solving schemata using non-traditional problem tasks. The non-traditional problem tasks used were text editing (Low & Over, 1990), problem posing (Mestre, 2002), and physics Jeopardy (Van Heuvelen & Maloney, 1999). As this project adapted, researchers continued to use and update the literature review to inform the next viable research phase. We focused our observations on measurement of schema development and collected information regarding students' perceptions of implemented strategies.

## Pilot

The study began with a short, one-time treatment of two independent research-based strategies chosen to facilitate case reuse (Mateycik, Hrepic, Jonassen, & Rebello, 2007). The problem solving strategies used in this phase of the project were chosen for their focus on organization of knowledge and their ease of accommodating case reuse.

The questioning strategy was based upon Graesser's questioning strategy template, a generated question list that solicits students to openly communicate information relevant to the question resolution (Otero & Graesser, 2001). It trains students to trigger questions with each problem that look to extract the interdependent relationships of given information as it pertains to a described event. It is not intended to force a particular process of resolution, but to incorporate quality questioning in students' problem solving framework.

The structure mapping strategy used visual representations of quantities and associations created by experts to model the appropriate mental organization of knowledge elements for a given type of physics problem. The structure maps are a type of concept map (Novak, Gowin, & Johansen, 1983), but are developed using Gentner's theoretical representations of learners' implicit cognitive associations between concepts, principles and quantities (Gentner, 1983).

For each strategy, volunteers enrolled in an algebra-based physics course were required to indicate quantities given and asked for in a work-energy problem statement, the associations between these quantities, and how these compare with another similar problem. Each strategy was used in conjunction with paired problems of similar physical principles, work and energy. The two strategies chosen were never used together. Our objective was to determine whether treatments conducted only once as extra-credit tasks, each using separate problem solving strategies, would affect student perception of problem solving strategies and/or implicitly affect student performance on solving concept-related problems. A third control group was used to identify any changes in students' examination performance. The control group participants were required to work out homework style problems as extra credit. The time on task was approximately equivalent between the three groups.

## Pilot – Results and Limitations

The one-time treatment of each strategy made no difference between treatment and control group students' average examination scores nor did individual groups perform better on any specific work-energy problem. This result was somewhat expected due to the very short treatment application. It would have been preferred to implement both strategies using multiple assignments across the semester. Unfortunately, any sizeable in-class implementation would require substantial control over the course. That level of control and course/treatment integration could not be obtained for this pilot or any other phase of this project. In fact, it was only for this pilot project that the primary instructor of the course agreed to our request for extra-credit data collection. Further data collection for subsequent studies would be done using small groups of paid volunteers.

Exploration of students' perceptions of the extra-credit tasks using semi-structured interviews with eight volunteers indicated that students believed both these strategies are helpful, giving them good problem visualization and facilitating their ability to identify important information from the problem. All interview participants agreed that the purpose of the strategies was to help them work out problems, though the intended purpose of some of the questions from the questioning strategy was not clear to the students. Since the phrasing of given questions used in the questioning strategy was prone to be misinterpreted, investigators determined the structure mapping strategy would be a more effective strategy for a full semester implementation. It was impossible to study both strategies across the next semester given the limited availability of human resources.

## Phase I

Eleven student volunteers enrolled in an algebra-based physics course participated in the semester long study. These participants met in two groups of five and six students a total of nine times during the semester. During these focus group learning interviews, students were asked to solve a set of similar deep-structure problems and discuss the contrast between each of the problems. The selected problems were variations of problems asked in Physics: Principles with Applications, Giancoli, 6th Edition. Students were also introduced to structure maps or visual representations of the associations between quantities for a given broad concept. Maps were created by expert faculty and graduate students and covered several first semester algebra-based physics topics including kinematics, forces, circular motion, work and energy and waves.

Upon request, students would identify how, if at all, a given map might represent the information given or asked for in a problem statement. These 'marked' maps would then be compared between problems. Students' perceptions of the usefulness of these maps as well as the students' problem solutions and examination data were collected throughout the hour long weekly meetings with our student volunteers. Following the sixth focus group learning interview, students' feedback regarding the design of the maps was used to generate a new, more complex map.

### Phase I – Results and Limitations.

Data obtained from student solutions, examination and interviews offered no evidence of improved problem solving schema (Mateycik, Jonassen, & Rebello, 2009). The 11 contact hour study was barely sufficient time for students to become comfortable using the maps. This led researchers to believe that the strategy may not be easily assimilated into the classroom. Previous concept map research (Novak, et al., 1983) suggests that student use of concept maps requires significant training. This was something we just could not hope to achieve in a single semester at one meeting per week.

Students perceived only some of the initial maps useful. Maps that were designated as not useful were expressed to have discontinuity between how the 'given' problem quantities linked to the 'asked for' quantities. Students also determined that the redesigned maps were useful because they acted like equation sheets, but with additional information regarding the associations between quantities within individual equations. It is important to note that though the majority of students perceived the maps as useful, only three of the 11 students used the maps on their own in-class examination (with teacher approval) and only C and low B average students expressed interest in using the maps for themselves outside of the focus group.

## Phase II and III

A set of simpler strategies – case reuse and contrasting cases -- were selected for their more explicit facilitation of analogical reasoning and classroom practicality, and were used together during two more semester long focus group treatments in the final two phases of this study. These strategies included the use of a step-by-step process aimed at reducing cognitive load associated with mathematical procedure, direct reflection of principles involved in a given set of problems and the direct comparison of problem pairs designed to be void of surface similarities (similar objects or object orientations) and sharing physical principles (conservation of energy problems).

### Phase II.

For the second phase, 10 students participated in eight, 75-minute long, focus group learning interview sessions. The topics in each session followed those currently being covered in the algebra-based physics class all participants were enrolled in. Using analogical reasoning arguments for simple comparison and contrasting of cases, a protocol was designed such that worked examples were introduced alongside unsolved problems. Step-by-step guides of problem solving included active reflection of principles involved as well as similarities and differences between the worked example and the unsolved problem. Figure 3 contains screen captures of one part of a given worked example and the unsolved problem statements used for that same focus group learning interview.

Students given different unsolved problems were also asked to compare and contrast their cases and eventually pose their own problem which incorporated elements from all problems seen during the treatment for that week.

To assess the impact of participation in the group learning interviews on students' problem comparison, the students were also required to participate in two individual interview sessions, one toward the middle and the other toward the end of the semester. During the individual interviews, students were asked to rate the similarities between pairs of problems (Mateycik, Rebello, & Jonassen, 2010). Research by Chi et al. (1981) has shown that students tend to group problems based on surface features, while the experts group problems based on their deep structure. Similarly, Hardiman, Dufresne, & Mestre (1989) showed that surface similarities between problems could interfere with experts' classification of the problems. Our tasks were different from those presented by Chi in her research. Rather than ask students to categorize the problems we presented students with pairs of problems and asked them to rate the similarity of each pair on a five-point Likert scale. Each student was presented with eight pairs of problems. The problem pairs were constructed from problems that had facial similarities/differences and principle similarities/differences. The term facial similarity/difference corresponds to surface similarity/difference, while the term principle similarity/difference corresponds to deep structure similarity/difference.

All four combinations of facial/principle similarities/differences were created. These are labeled problem pair types A, B, C and D as defined in Table 1.

During these same individual interviews, students were also asked to choose two problems out of a set of six as least and most likely useful for solving a more challenging physics problem. The six problems were unsolved, but students were asked to make their selections based upon how well each speculative problem solution would be most and least useful as examples.

Students' problem solving performance and conceptual organization of knowledge were also assessed using traditional and non-traditional problems on their five in-class, multiple choice examinations. The last three problems on each examination were adaptations of text-editing (Low & Over, 1990), physics Jeopardy (Van Heuvelen & Maloney, 1999) and problem posing tasks (Mestre, 2002). While these tasks in the original form are open-ended, the problems included on the exams were in multiple-choice format for two reasons: first they conformed to the instructor's examination format from our previous study and second they could be graded efficiently for large numbers of students.

Text-editing tasks involved presenting a student with a problem statement and then asking the student to identify the missing, irrelevant and required information in the problem statement without first solving the problem. Low and Over (1990) point out that text -editing tasks can be a measure of schematic knowledge because they require an understanding of the deep structure of the problem. Because students are asked to complete the tasks without solving the problem, students need to know the interrelationships between various physical quantities, not in terms of equations, but at a conceptual level to be able to successfully complete the task. Figure 4 shows an example of text editing used on one of the class exams.

Physics Jeopardy tasks were first developed by Van Heuvelen and Maloney (1999). As the name indicates, these tasks require the students to work backward. Students are given a fragment of a solution to a problem and asked to identify the physical scenario that corresponds to the solution. The developers point out that these tasks require an effort to represent a physical process in a variety of ways. Because of these features, students are unable to use naïve problem solving strategies while solving Jeopardy problems.

Figure 5 shows an example of our adaptation of a Jeopardy problem that provides students with a few steps of a projectile motion. Students are asked to determine what trajectory shown corresponds to the problem. This task requires students to relate information given in the mathematical and symbolic representation to a visual or pictorial representation.

Problem posing tasks were used by Mestre and others (2002) in the context of physics problems. In the tasks presented by Mestre, students were given a scenario, typically in the form of a picture and were asked to construct a problem around the scenario that was based on certain physical principles. Mestre points out that problem posing tasks are aimed at probing students' understanding of concepts as well as assessing whether they transfer their understanding to a new context. Clearly such a task was rather open-ended with multiple possible answers. Our adaptation of this task is much more focused than Mestre's original open-ended task. It presents students with the first part of a problem statement which clearly describes a physical scenario. Students are then asked to select from a list of choices, a question, which when added to the statement will create a solvable problem that requires the use of a set of given equations. Clearly, our adaptation differs significantly from the original problem posing task designed by Mestre. First, this task clearly does have a unique correct answer. Second, it requires the knowledge of specific conceptual knowledge, represented in the form of equations. An example of our adaptation of a problem posing task is shown in Figure 6.

### Phase III.

For the third phase of this study, the focus group learning interviews were replicated using the finalized research protocol from phase II. A group of 12 students were selected from an algebra-based physics class and six focus group learning interviews were performed over the semester. Students were assessed using similar traditional and non-traditional problem solving tasks on five in-class examinations and an individual interview that was conducted at the end of the semester. The individual interview used the same protocol as the second interview from the phase II study.

## Phase II and III – Results

### Focus group learning interview results.

Students' identification of the principles and concepts involved in a problem, as well as the irrelevant information given in a problem, was done sufficiently from the very beginning of the focus group learning interviews. Students showed no marked improvement on these tasks as they were capable of successfully completing them from the very beginning. Even at the individual level, students who struggled with the task initially (within the first week) were able to complete the task by the second week (or third if the student joined the group one week late).

From observations and data collected from worksheets, it can be noted that students perceive the solved example and unsolved problems as more similar as the semester moved forward. Initially, students rated the three problems 'slightly dissimilar' to 'slightly similar.' Students' ratings progressively moved up to 'moderately similar.'

Problems posed by group pairs showed little signs of improvement in weeks where students were able to complete the task. This is not because students were unable to successfully come up with problems, but in fact, they were able from the start to create a workable problem. The most noticeable difference between weeks is the amount of creativity and thought put into the scenario of the problems. Students spent a good deal of time making sure their problems were real world specific and often made the problem personable. Often the problems involved relatives and friends of the students, references to material they just learned in other courses and detailed (but not over specified) explanations of the problem scenario. Only in the first few weeks where problems were posed in the spring, and in only the first week of the fall, do students create underspecified and over-specified problems.

### Individual interview results.

#### *Similarity ratings.*

Students' ratings of problem pairs were compared between individual interviews for Phase II and ratings of problem pairs during the end-of-semester interview were compared between semester studies. Table 1 identifies the pair types.

Before our focus group learning interviews, students in the Phase II cohort rated problems sharing prominent surface features higher than problems with different surface features. After our focus group learning interviews, students' ratings of problems sharing surface features remained high, but problems with different surface features and similar deep-structure features were also rated high. See Figure 7 for mean ratings for interviews 1 and 2 of the spring 2008 semester.

For the final interviews, students participating in our focus group learning interviews for both semesters rated problem types A and B pairs high, type C pairs highest, and type D pairs lowest. These ratings might suggest that students learn to deemphasize facial features when given problems that are not facially similar. When problems share facial similarity, the students no longer attend to the differences in principle between problems. See Figure 8 for mean ratings for the fall 2008 and spring 2008 semesters.

When compared with the previous semester, it can be seen that the ratings of the different pair types are very close. It is also important to note that like the previous semester, students are rating problem pair type B high. These pairs are ones in which there are structural similarities between problems and significant surface feature differences. In hindsight, it might have been preferable to collect a mid-semester interview as was done with the previous study. This would enable us to determine whether a similar pattern between mid-semester and end-semester ratings might emerge between the two different sets of focus group learning interview participants.

### *Usability ranking.*

Assessing the usability rankings simply by looking at problem rank numbers was challenging as no real pattern emerges in any of the individual interviews. However, since the usability ranking task was done over a semi-structured interview, researchers were given the opportunity to ask students how they chose problems to rank. The reasoning in all interviews remained similar. In the event that the participant presents feelings of discomfort with a given object associated with a given principle, those problems are chosen as high ranking, possibly important examples. An example would be selecting a 'spring problem' because those are 'harder' than 'pendulum problems.' In the circumstance that students do not share information regarding their comfort level with given objects or their orientations, high ranking problems are associated with mathematical complexity. In other words, if the problem requires many steps to complete, then its solution may be useful for a larger variance of problems.

### *Examination results.*

We compared the performance of our cohort group with the rest of the class on all of the traditional problems using an ANOVA single factor test with an $\alpha=0.10$ level of significance. Students in our fall 2008 (Phase III) cohort performed better than the rest of the class on three of five examinations: the second, third, and fourth examination which took place while students were being treated. This is different from the spring 2008 (Phase II), as students did not perform statistically better or worse on the traditional examination problems. It is important to make a distinction between the types of traditional problems given between the two semesters. The spring 2008 semester used multiple-choice problems that were likely to be answered using simple plug and chug methods. The Fall 2008 semester used word problems that were more context rich and dependent on conceptual understanding. These problems looked more like difficult homework problems. Table 2 shows positive statistical significant differences between the Phase II and Phase III treatment groups and their respective classmates.

On each exam we also compared the performance of our cohort group with the rest of the class on each non-traditional problem based on a logistics test using a binomial model. Our fall (Phase III) cohort performed better on specific non-traditional problem solving tasks after examination 1. There was statistically significant difference (at the 0.1 level of significance) between our cohort and the rest of the class on their performance on text editing problems given on examinations 2, 4 and 5. There was statistically significant difference (at the 0.1 level of significance) between our cohort and the rest of the class on their performance on the physics Jeopardy task given on examination 4 (p value = 0.0879). There was statistically significant difference (at the 0.1 level of significance) between our cohort and the rest of the class on their performance on problem posing tasks on exams 3, 4 and 5 (p value = 0.01 on exam 3, 0.001 on exam 4, and 0.038 on exam 5). A univariate split plot analysis was also used to determine that though our fall student cohort performed significantly better on individual non-traditional tasks on specific examinations, their overall average performance on all five examinations does not significantly differ in improvement as compared with the rest of the class.

Our spring (Phase II) cohort also performed better on specific non-traditional problems and showed significant improvement on problem posing tasks as compared to the rest of the class. There was statistically significant difference (at the $\alpha=0.1$ level of significance) between our cohort and the rest of the class on their performance on the physics Jeopardy task on exam 5 (p value = 0.0635). There was statistically significant difference (at the 0.1 level of significance) between our cohort and the rest of the class on their performance on problem posing tasks on exams 4 and 5 (p value = 0.0012 on exam 4 and 0.0821 on exam 5 respectively). A univariate split plot analysis was used to determine whether there existed a significant difference at $\alpha=0.10$ between instruction on traditional or non-traditional problem scores on the examinations. Statistically significant differences between the baseline and treatment groups instruction on problem posing problems were observed through mean examination scores. Since the individual exam 4 and 5 scores for the problem posing task and the average over all five examinations is significantly different between the cohort and the rest of the class, there is no contradiction between our two separate statistical analyses. In Table 3 the statistically significant differences between treatment group performance and the rest of the class is outlined by semester. The 'TE' represents text-editing, 'PP' represents problem posing and 'PJ' represent physics Jeopardy. The 'S' represents statistical significance while '-' represents no statistical significance. Cells that are highlighted represent examinations which were administered after students had undergone full treatment for one or more weeks.

We also compared exam-by-exam and exam-by-treatment interactions using data from only those students who completed all of the exams. These analyses resulted in a loss of about 42 participants per semester out of a total of 253 participants per semester and a loss of one of our 12 students in the treatment group. These results are broad, relating general trends in mean scores. For both Phase II and Phase III, at an alpha level of 0.10, statistically significant exam-by-treatment interactions were observed between the baseline and treatment group scores. The traditional, problem posing, and text editing tasks for Phase III participants, and physics Jeopardy for Phase II participants were shown to have significantly higher mean scores when compared to the rest of the class. This suggests that our fall student cohort obtained overall higher averages and does not suggest dependence on treatment. For both Phase II and Phase III, at an alpha level of $\alpha=0.10$, there also existed a statistically significant exam-by-exam interaction between problem score averages on the class examinations. Unfortunately, we also observed that the significant difference is not always positive. That is, the average scores for a given problem type are statistically different between examinations, but the averages don't always improve as the semester progresses. This exam-by-exam ANOVA analysis also does not distinguish between the baseline and treatment groups as it uses the average scores for the total class population.

### Phase II & III – Limitations

Important caveats in interpreting these data should not be overlooked. The topical content of material covered between individual interviews 1 and 2 and on each of these exams was very different. The level of difficulty of the non-traditional problems and traditional problems on each exam was also different. Therefore any differences between usability and similarity ratings or scores on traditional or non-traditional problems on exams could also be the result of these differences, rather than a result of the participation of our cohort groups in the focus group learning interviews. There is also the possibility that the ANOVA used on examination data revealed false positives, though there would be no way to discern whether this was true without replicating our study with a much larger population of students. The alpha value was chosen to reduce probability of high Type 1 and Type 2 errors with small (<30 participants per bin) group analysis.

## General Implications

The instructors for the algebra-based physics courses agreed to place additional extra-credit problems on their examinations at the request of the project investigators, but these faculty were unwilling to allow more significant implementation in lab or on homework. It is believed that more regular communication between education researchers and instructor stakeholders may have alleviated some reluctance in those that were unaware or ill-advised as to the intent and importance of this research. This study was restricted to outside interventions using small focus group learning interviews and volunteers were selected and paid to participate each week. Small convenience samplings, additional problem solving practice and uncontrollable changes in classroom instructors semester to semester all add dependent variability to this project which cannot be accounted for in our analysis. However, the results above are not wholly diminished by these limitations.

Simply put, there exists great promise in these strategies and assessments and every result from every assessment opens new windows of opportunity for research and teaching practices. This study has identified a framework for facilitating case reuse using deep-structure similarity, contrasting cases and active reflection upon the usability of examples. This work was never intended to be turned into a standalone curriculum. Future work could include integration of explicit case contrasting in homework and/or in lab settings, replication of the focus group learning interviews with new populations and/or different levels of physics students or specific assessments like the similarity ratings task could be further developed to include wider variances in similarities and differences.

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Table 1

*Problem pairs for the similarity rating task*

| | Facial Similarity (**FS**) | Facial Difference (**FD**) |
|---|---|---|
| Principle Similarity (**PS**) | **A** | **B** |
| Principle Difference (**PD**) | **C** | **D** |

Table 2

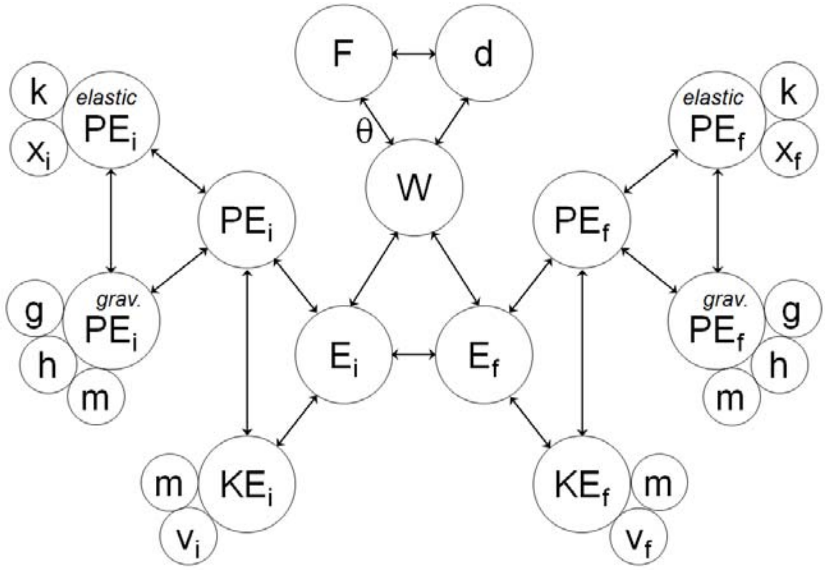
*Statistically significant differences between the treatment cohort and the rest of the class in performance on traditional problems*

| **Traditional Problems ONLY** | Spring 2008 (Phase II) | Fall 2008 (Phase III) |
|---|---|---|
| Examination 1 | Not Significant | Not Significant |
| Examination 2 | Not Significant | Significant |
| Examination 3 | Not Significant | Significant |
| Examination 4 | Not Significant | Significant |
| Examination 5 | Not Significant | Not Significant |

Table 3

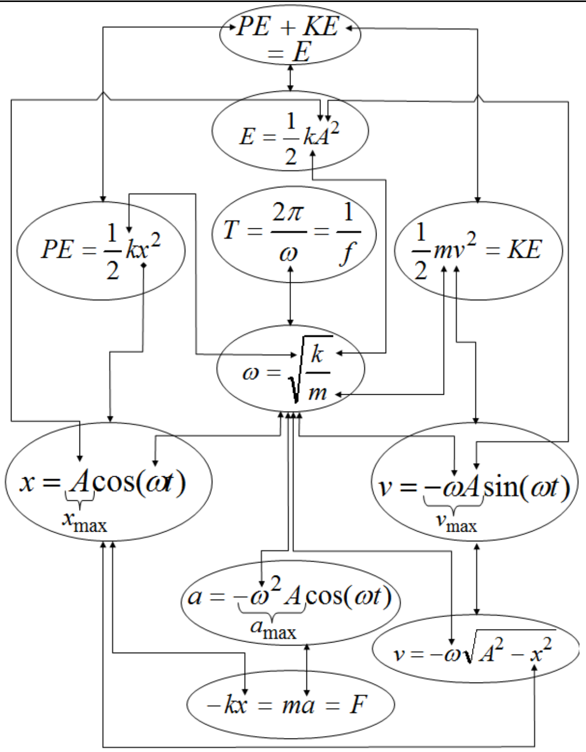
*Statistically significant differences between the treatment cohort and the rest of the class in performance on traditional problems*

| **Non-traditional Problems ONLY** | Spring 2008 (Phase II) | | | Fall 2008 (Phase III) | | |
|---|---|---|---|---|---|---|
| | TE | PP | PJ | TE | PP | PJ |
| Examination 1 | - | - | - | - | - | - |
| Examination 2 | - | - | - | S | - | - |
| Examination 3 | - | - | - | - | S | - |
| Examination 4 | - | S | | S | S | S |
| Examination 5 | - | S | S | S | S | - |



| | |
|---|---|
| **Problem 1:**<br>A 0.10 kg arrow is fired from a bow whose string exerts an average force of 110 N on the arrow over a distance of 0.8 m. What is the speed of the arrow as it leaves the bow? | **Problem 2:**<br>A 0.10 kg arrow is fired from a bow with a speed of 50 m/s over a distance of 0.8 m. What is the average force exerted on the arrow by the bowstring? |
| **Problem 3:**<br>A 0.14 kg baseball exerts an average force of 300 N on a fielder's glove, moving the glove backward 0.25 m when the ball is caught. What is the speed of the ball? | **Problem 4:**<br>A 1200 kg car rolling on a horizontal surface has speed of 18 m/s when it strikes a horizontal coiled spring and is brought to rest in a distance of 2.2 m. What is the stiffness constant of the spring? |

*Figure 1.* Work-Energy structure map and problem set used during a focus group learning interview

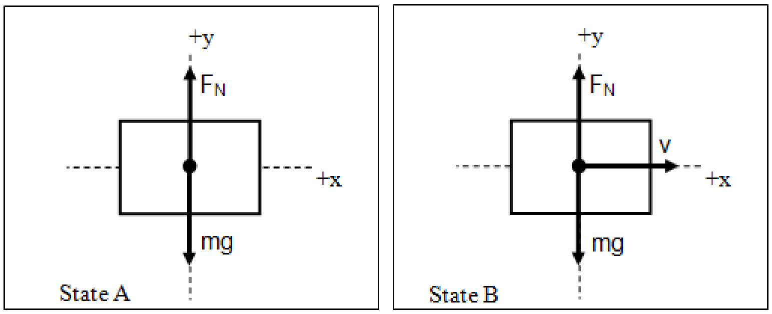


| | |
|---|---|
| **Problem 1:**<br>A pumpkin with mass 3.0 kg is attached to a spring with stiffness constant k = 280 N/m and is executing simple harmonic motion. When the pumpkin is 0.020 m from its equilibrium position, it is moving with a speed of 0.55 m/s. Calculate the maximum velocity attained by the pumpkin. | **Problem 2:**<br>A pumpkin with mass 3.0 kg attached to a spring is executing simple harmonic motion. When the pumpkin is 0.020 m from its equilibrium position, it is moving with a speed of 0.55 m/s. The amplitude of motion is 0.060 m. Calculate the correct spring stiffness constant. |
| **Problem 3:**<br>A spring of a toy popgun is compressed 0.200 m to “load” a 0.180 kg ball. Assuming the spring has a stiffness constant k = 110 N/m and leaves the gun with a speed of 0.25 m/s, what is the maximum velocity attained by the ball? | **Problem 4:**<br>A 0.60 kg mass vibrates according to the equation x=0.45 cos (6.40t), where x is in meters and t is in seconds. Determine<br>(a.) amplitude,<br>(b.) frequency,<br>(c.) total energy,<br>(d.) how far away from equilibrium the ball is after 0.20 s, and<br>(e.) the velocity of the mass after 0.20 s. |

*Figure 2.* Vibration & waves structure map and problem set for a focus group learning interview

### Problem C (Example Problem)

Joshua pushes a 1.85 kg box along a flat horizontal table applying an average force of 39.0 N. The box starts at rest and reaches a velocity of 12.0 m/s. Neglecting friction, how far did Joshua push the box?



We may express the work done by Joshua on the box in terms of two quantities:

$$W = \vec{F}_{Box}\vec{d}_{covered} \qquad (1)$$

i. The force applied on the box by Joshua
ii. The distance covered while Joshua applied the force

This expression (1) may be rewritten in terms of the magnitudes of the force and distance travelled.

$$W = F_{Box} d \cos\theta \qquad (2)$$

where θ is the angle between the directions of the displacement and the force.

### Problem A

**A 0.10 kg arrow is fired from a bow. The bow is pulled back a distance of 0.8 m so that the arrow is released with a speed of 50 m/s as it leaves the bow. The arrow travels 25.0 m before hitting its target. What is the average force exerted on the arrow by the bowstring?**

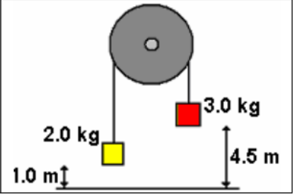
### Problem B

A Yankees batter hits a 0.14 kg baseball sending it off into left field, 40 m away from the batter's box. The baseball lands in a Royals fielder's glove, exerting an average force of 300 N, moving the glove backward 0.25 m before coming to rest. What is the speed of the ball just before it is caught?

*Figure 3.* Worked example and unsolved problems for one focus group learning interview

You are given a problem below.

A 2.0 kg mass initially 1.0 m above the ground is attached to thin cord that passes over a frictionless pulley to a second 3.0 kg mass which is initially 4.5 m above the ground. Both masses are initially at rest. Find the final velocity of the 3.0 kg mass right before it hits the ground.

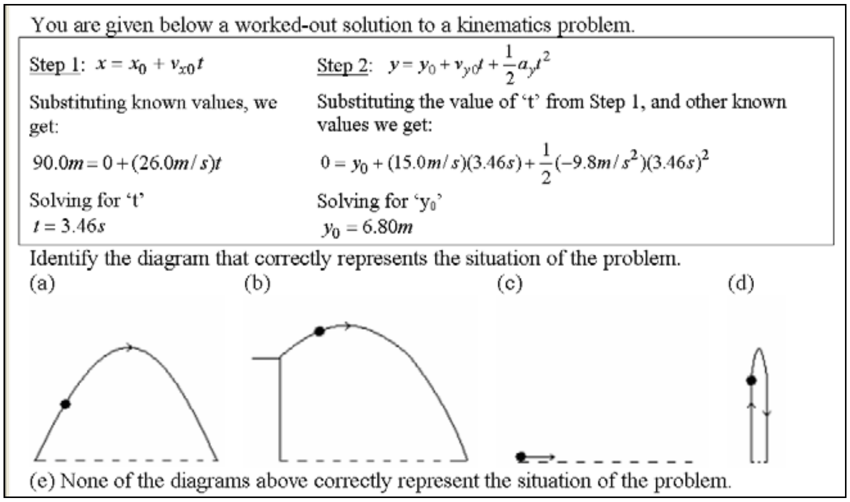


In the problem statement above, specify which, if any, of the following quantities are ***not*** relevant for solving the problem.

(a) 2.0 kg mass (b) 3.0 kg mass (c) 4.5 meters (d) 1.0 meters

(e) None of the above. You need all the information given to solve the problem.

*Figure 4.* Example of a multiple choice adaptation of a text-editing task



You are given below a worked-out solution to a kinematics problem.

Step 1: $x = x_0 + v_{x0}t$

Substituting known values, we get:

$90.0m = 0 + (26.0m/s)t$

Solving for ‘t’

$t = 3.46s$

Step 2: $y = y_0 + v_{y0}t + \frac{1}{2}a_y t^2$

Substituting the value of ‘t’ from Step 1, and other known values we get:

$0 = y_0 + (15.0m/s)(3.46s) + \frac{1}{2}(-9.8m/s^2)(3.46s)^2$

Solving for ‘$y_0$’

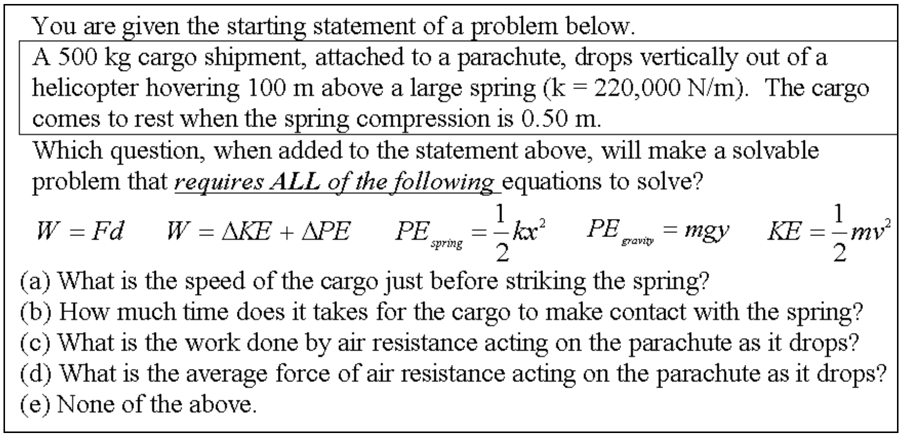
$y_0 = 6.80m$

Identify the diagram that correctly represents the situation of the problem.

(a) (b) (c) (d)

(e) None of the diagrams above correctly represent the situation of the problem.

*Figure 5.* Example of a multiple choice adaptation of a physics Jeopardy task



You are given the starting statement of a problem below.

A 500 kg cargo shipment, attached to a parachute, drops vertically out of a helicopter hovering 100 m above a large spring (k = 220,000 N/m). The cargo comes to rest when the spring compression is 0.50 m.

Which question, when added to the statement above, will make a solvable problem that *requires ALL of the following* equations to solve?

$$W = Fd \qquad W = \Delta KE + \Delta PE \qquad PE_{spring} = \frac{1}{2}kx^2 \qquad PE_{gravity} = mgy \qquad KE = \frac{1}{2}mv^2$$

(a) What is the speed of the cargo just before striking the spring?
(b) How much time does it takes for the cargo to make contact with the spring?
(c) What is the work done by air resistance acting on the parachute as it drops?
(d) What is the average force of air resistance acting on the parachute as it drops?
(e) None of the above.

*Figure 6.* Example of a multiple choice adaptation of a problem posing task

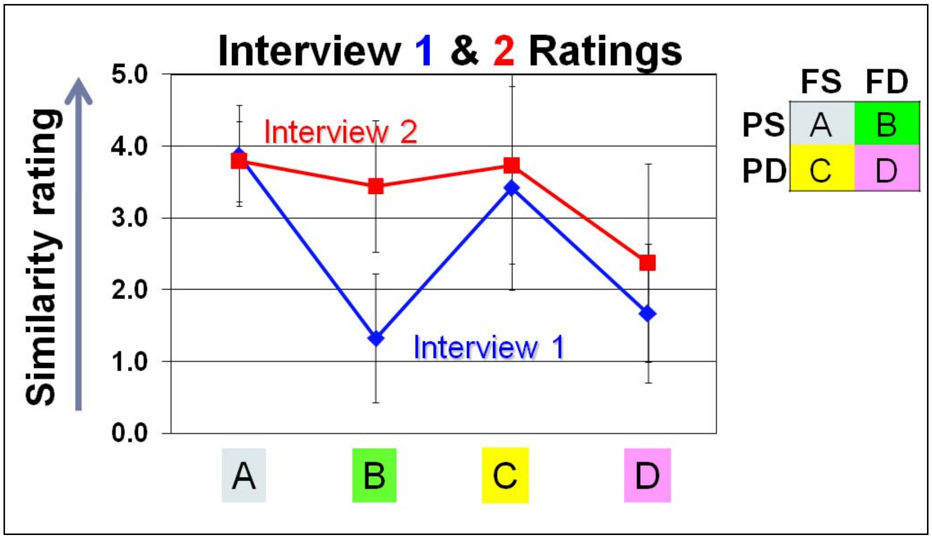


*Figure 7.* Mean ratings for interviews 1 and 2 for the spring 2008 semester

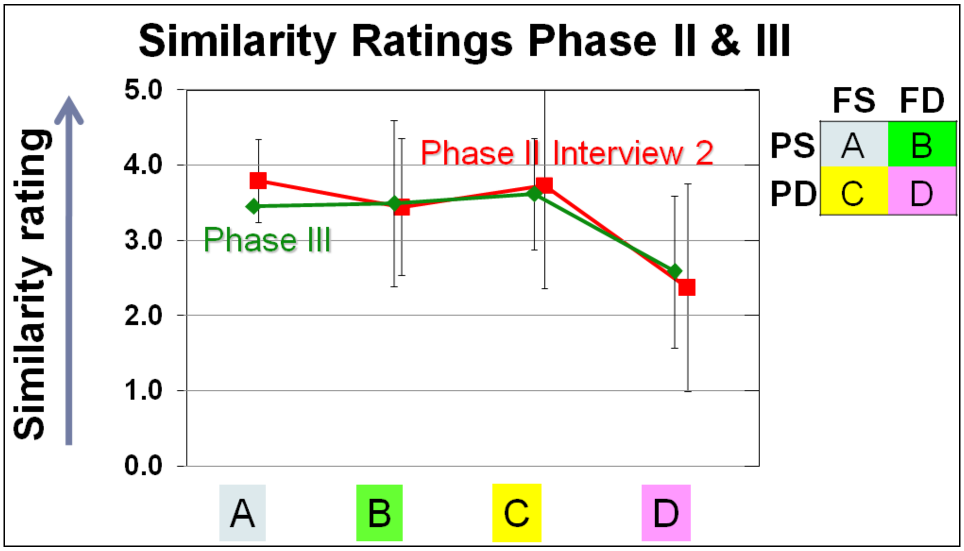


*Figure 8.* Similarity ratings for Fall 2008 mapped on top of Spring 2008 ratings