

THE EFFECTS OF PHYSICS RANKING TASKS
ON STUDENT UNDERSTANDING
OF CONCEPTUAL PHYSICS CONCEPTS

by

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STATEMENT OF PERMISSION TO USE

In presenting this professional paper in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the MSSE Program shall make it available to borrowers under rules of the program.

Danny Duane Mattern

July 2011

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ABSTRACT

In this research physics ranking tasks were introduced to see if they could increase students' conceptual knowledge in general and calculus based physics courses. Assessments were given both pre and post in order to calculate a class's percent gain. Although students did not seem to enjoy or appreciate these types of tasks at the beginning, analysis of the percent gain did show a remarkable increase in the conceptual concepts that were assessed due to the physics ranking tasks.

INTRODUCTION AND BACKGROUND

This research on the effects of ranking tasks was conducted at Butler Community College. Butler has several campuses across south central Kansas and serves over 13,000 students each academic year. The number of full-time equivalency students is over 6,000 each semester. The percentage of males and females for the Fall 2010 semester was 42.0% and 58.0% respectively. Seventy one percent of full-time students are Caucasian/white, 9.9% Black, 7.4% Hispanic, 5.9% Asian and 1.6% American Indian. Just over half, 52.6% of the student body are traditional college students ranging from 18 – 22 years of age. Physics classes are taught on the main campus only in El Dorado, Kansas where 21.7% of the overall enrollment of the college attends (Butler research office, <http://ir.butlercc.edu/demographics.cfm>).

Ranking tasks are unique physics problems that force students to rely more on conceptual understanding of a problem rather than traditional mathematical approaches. Traditional problems tend to be more plug and chug type questions in which students simply have to determine which mathematical equation to use and then plug in numbers to compute the solution. Ranking tasks are more conceptual in nature and are designed to improve students' problem solving and reasoning skills in physics.

This research was conducted in my General Physics 1 and Calculus-based Physics 1 courses. General Physics 1 students typically are non-science majors who are taking the course to satisfy their laboratory requirements. The calculus-based Physics 1 students are science and/or engineering majors taking the course as part of their major. I chose these

particular courses because most of the students have not had many science classes other than in high school, so their scientific knowledge and skills could benefit the most from the research.

I came to the idea of this study based on my previous work with students in my courses who could easily solve a problem mathematically, but had little to no conceptual understanding of the physics behind the problem. The more I worked to help students gain conceptual knowledge, the more I wondered about the use of ranking tasks. This led to the purpose of this study, which was to describe the effects of physics ranking tasks on developing students' conceptual knowledge in the area of general physics.

CONCEPTUAL FRAMEWORK

If a student is going to be successful in increasing their knowledge, that knowledge needs to be constructed from their own experience. Hoover (1996) writes that new students will build new knowledge upon the foundation of previous learning. This constructivist view contrasts typical lecture style courses where information is a passive transmission from the teacher to the student. The premise, says Huitt (2009), is that an individual student must actively build their own knowledge and skills. Students come to learning situations with knowledge gained from previous experience. It's that knowledge that will influence what new or modified knowledge the student will construct from a new learning experience. Furthermore, Hoover suggests that if what a student encounters is inconsistent with their current understanding, their understanding can change to accommodate the new experience. A constructivist teacher needs to change their role from being the center of the learning process to the role of a facilitator providing students with the opportunities to actively engage in the learning process. Hoover adds that since

learning is a constructive process, then instruction must be designed to provide opportunities for such construction. Huitt tells us that instruction must be concerned with the experiences and contexts that get the student ready to learn. This instruction should be structured so that it can be easily grasped by the student and should be designed to facilitate extrapolation.

Hoover (1996) and Huitt (2009), agree that an instructor using a constructivist approach must understand the prior knowledge and experience of the student to provide a method to exploit the inconsistencies between the students' current understandings and the new experience awaiting them. Suitnen (2008) says that a constructivist activity is one in which a problem has emerged and the student needs to construct various alternatives to the activity through their own thinking in such a way that a new form of the activity arises and the problem is solved.

Students in physics classes typically come in with a general idea of the basic laws of the universe. Difficulties arise with these ideas because many of these preconceived ideas are wrong. According to Cahyadi (2004), misconceptions in physics are very high among the general population. Cahyadi suggests that a goal of a physics course should be to clarify these misconceptions and show students how the physical world really works.

Cahyadi (2004), Reiner (2000), and Hestenes (1992) all agree that every student begins a physics course with an established system of beliefs derived from their own years of personal experience. Eryilmaz (2002) identifies that misconceptions are intuitive beliefs that students develop on their own before beginning the first course in physics.

He also notes that these misconceptions play a special role in the difficulties students have in physics. Cahyadi says that students hold on to these beliefs despite formal lessons from textbooks and/or teachers. Misconceptions are defined as preconceived beliefs that students have based on their own personal experience. Even pre-service teachers have many physics misconceptions as they enter the classroom (Gonen, 2008). Textbooks tend to put too much emphasis on number crunching problems in artificial situations rather than focusing on real world situations (Bryce, 2009). Classroom instruction that does not take these misconceptions into account is almost totally ineffective for the majority of the students. Hestenes adds that commonsense beliefs about motion and force are incompatible with Newtonian concepts. Physics instruction from a conventional sense provides little change in these beliefs. However, Cahyadi presented students with two contrasting situations that seemed to help student understanding of these preconceived misconceptions. He argues that considering problems from multiple perspectives may improve student understanding. Eryilmaz proves that conceptual assignments did reduce the number of student physics misconceptions. Gonen also mentions that misconceptions remain highly resistant to change by traditional methods of instruction.

The Force Concept Inventory (FCI) was created to identify these misconceptions that students' have entering a physics course, and is defined as a multiple-choice test designed to monitor students' understanding of force and related kinematics. The inventory can also be used as a diagnostic assessment tool at every level of introductory physics instruction (Savinainen, 2008). Further, the conceptual understanding of students can be assessed using the FCI (Malone, 2008).

The FCI addresses six conceptual dimensions within the domain of force and related kinematics. Savinainen (2008) defines these six areas as kinematics, Newton's First Law, Newton's Second Law, Newton's Third Law, the superposition principle, and different kinds of forces as in contact and gravitational forces. Through a series of thirty multiple choice questions, students' are evaluated on their conceptual knowledge in these main areas of focus.

Savinainen (2002) used the FCI to monitor student learning. It has been used as an assessment tool in order to determine the increase of a students' conceptual knowledge in physics due to different methods of instruction. Savinainen believes that increased learning gains can be linked to three aspects of pedagogy. One of these aspects being that the use of research based instruments, such as the FCI, enable quick and detailed formative assessments of students' learning.

After implementing the FCI, Hestenes (1992) and Savinainen (2002) report that some of the common themes are that the students' mathematical backgrounds are not a major factor in the FCI scores, pre-test scores are relatively low for beginning students, post-test scores have exhibited no relationship with students' socio-economic level, there has been no correlation identified between post-test scores and teacher competence, and no large gains from pre to post-test have been seen with conventional instruction. Hestenes summarizes that for evaluating instruction, the FCI has abundant evidence that it is a very accurate and reliable instrument.

One strategy used by physics instructors to assist student learning is *ranking tasks*. Ranking tasks are exercises that require students to compare scenarios with slightly

different configurations (Cox, 2005). Lietz (2010) adds that ranking tasks are unlike average physics textbook questions, in that they require the student to think differently. They require students to analyze a physics scenario from a conceptual standpoint. A typical ranking task will present the student with four to eight variations on a single situation. The student's task is then to rank the situation based on a single criterion from either greatest to least or least to greatest. For example, consider a ball rolling down an incline. The students might be asked to rank the velocity the ball has as it rolls off the incline from highest to lowest for different angles of inclination at, 10° , 20° , etc. These tasks seem to have a pedagogical strength of helping introduce students to the conceptual nature of physics while also limiting the so called plug and chug problems that have the students just plug numbers into a given equation to solve. Ranking tasks on the other hand require students to efficiently compare different situations of the same nature to gain an insight into the conceptual structure of the problem. Cox reasons that ranking tasks can present students with multiple representations of the same problem by having them rank graphs, vectors, or motion.

Students have responded to ranking tasks very well (Lietz, 2010). Most students soon realize that they can solve these problems with little or no mathematics at all. Desbien (1997) used ranking tasks in his classroom as a discussion topic for his students. The students worked on a specific ranking task and then compared similarities and differences in their rankings through in class discussions. It seems that these tasks give instructors another resource to use to combat the misconceptions that students bring to physics class with them. Using ranking tasks as the sole assignment given to students or using them as

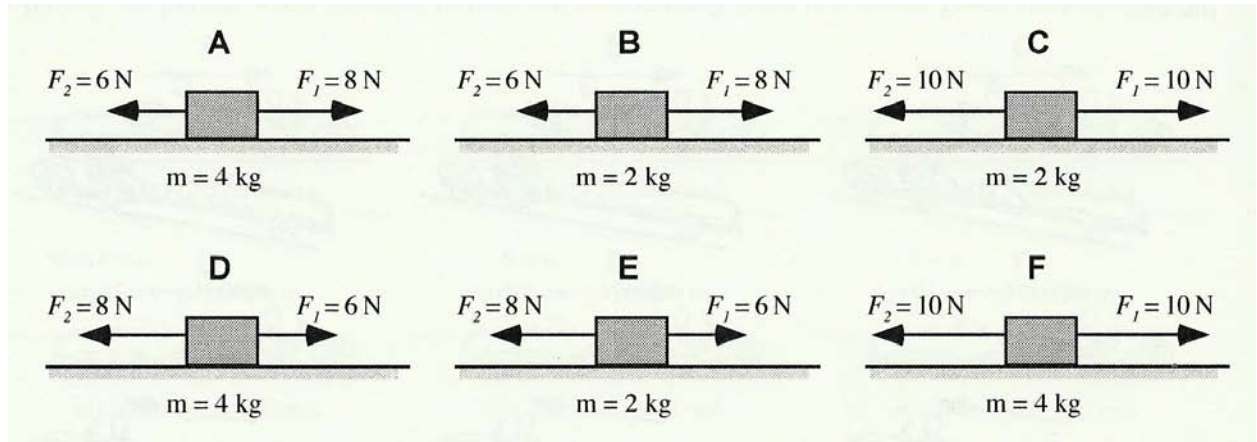
supplements to traditional problems is up to the individual instructor. Desbien and others have shown that ranking tasks do help increase the conceptual understanding of physics.

METHODOLOGY

My research project focused on methods to increase student understanding in the conceptual physics realm. The project was used with undergraduate physics courses that I instructed at the community college level. The treatment for my study consisted of students performing a variety of ranking tasks (O’Kuma, 2008) at least twice a week as we covered the mechanics unit in my physics courses (Appendix A). The FCI was given as a pre and post test to see if the ranking tasks helped to increase conceptual knowledge in physics. Each student completed eleven different ranking tasks over the course of the mechanics unit.

I used the FCI (Savinainen, 2002), as an assessment tool to gather quantitative data. The students took the FCI as a pre and post test to evaluate their progress on understanding the physics concepts. I calculated the class average on the pre FCI not recording individual scores, and then did the same for the post FCI. These scores reflect the overall class average before and after the ranking tasks were introduced. The ranking tasks did not completely replace traditional textbook problems, but they were emphasized to see if they are useful in increasing scores on the FCI. I have given the FCI as a pre and post exam over the mechanics units in both my general and calculus based physics classes over the past six semesters. In the first four semesters from Fall 2008 through Spring 2010 the homework in the courses were traditional textbook problems for the most part varying in complexity, physics ranking tasks were not used. The FCI scores for these semesters were then compared to the semesters in which I used the ranking tasks.

The methods of physics ranking tasks were introduced in the Fall 2010 and Spring 2011 semesters. A sample ranking task is illustrated in figure 1.



All Objects start at rest on a frictionless surface. Rank these situations from greatest change in velocity to least change in velocity.

Figure 1. Example Ranking Task.

Each course varied in the number of students. After comparing class averages, I went further in the numerical analysis and calculated a normalized gain for the pre and post FCI scores. The normalized gain measures the fraction of available improvement that is obtained from the data. I calculated this normalized gain by subtracting the pre FCI score from the post FCI score and then dividing by 100 minus the pre FCI score. This decimal then represents the normalized gain from the class averages of the pre and post FCI results.

Upon completion of the project, I used the Post Formal Interview of a select number of students to get their opinions of the efficacy of the project (Appendix B). This allowed individual students the opportunity to express any praises and concerns they had over the

course of the project. I analyzed the interview questions by grouping them into categories of responses by the students that were similar in nature. This allowed me to gain an understanding of what the students thought about the physics ranking task exercises.

I also used two different classroom assessment techniques to assess student's thoughts about the physics ranking tasks. The One-Minute Paper and the Muddiest Point assessments were used throughout the study to get a view of the students opinions of the ranking tasks and their understanding of the conceptual physics concepts as they progressed through the mechanics unit (Appendix C and Appendix D). These assessment activities were sorted into common themes presented from the students. I then was able to analyze common strengths and weaknesses about the physics ranking tasks from the viewpoint of the students.

The qualitative data collected from the classroom assessment techniques and interviews was analyzed and combined with the quantitative data gathered from the pre and post FCI results to evaluate the effectiveness of ranking tasks in helping to increase conceptual understanding in physics. All students who were involved in the study signed the Informed Consent Form before the data collection was started (Appendix E). The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

Combining the percent gain of the FCI as a quantitative data collection tool along with the ranking tasks provided a method to illustrate whether the ranking tasks would be an

effective measure of conceptual knowledge. The one-minute paper, muddiest point, and post formal interview provided a qualitative description of what students thought as they were performing the ranking tasks. A summary of my data collection resources is included in the following Triangulation Matrix (Table 1).

Table 1
Triangulation Matrix

Research questions	Data Source 1	Data Source 2	Data Source 3
1. Do ranking tasks increase the understanding of conceptual physics topics?	Quantitative Force Concept Inventory Pre and Post results	Post Formal Interview questions and analysis	Classroom assessment techniques: One-Minute Paper and Muddiest Point
2. Are ranking tasks used as an example of non-traditional physics problems, helpful in understanding physics?	Quantitative Force Concept Inventory Pre and Post results	Post Formal Interview questions and analysis	Classroom assessment techniques: One-Minute Paper and Muddiest Point

DATA AND ANALYSIS

The results of all of the pre/post Force Concept Inventory (FCI) administered in the Fall 2008 through the Spring 2010 semesters showed a gain of 11.05 % for general physics and 10.95 % for the calculus based physics courses (Figure 1). This group did not receive the physics ranking tasks.

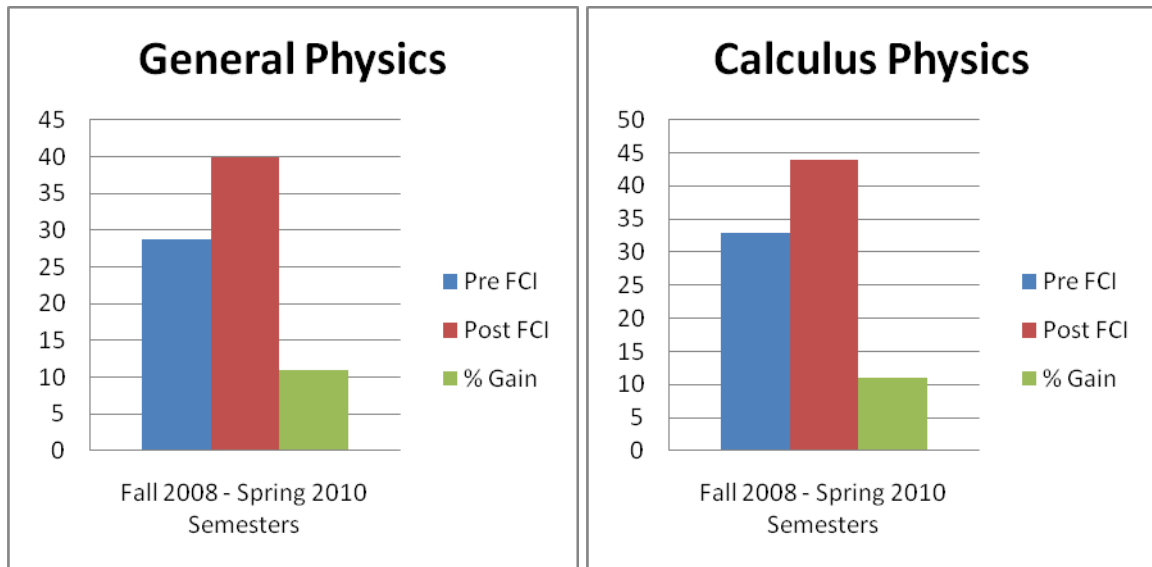


Figure 2. FCI Results for General Physics, ($N = 49$) and Calculus Physics, ($N=80$) Before Ranking Tasks.

The normalized gain for the four semesters without the physics ranking tasks showed values for 0.155 for the general physics course to 0.163 for the calculus based physics courses (Figure 2).

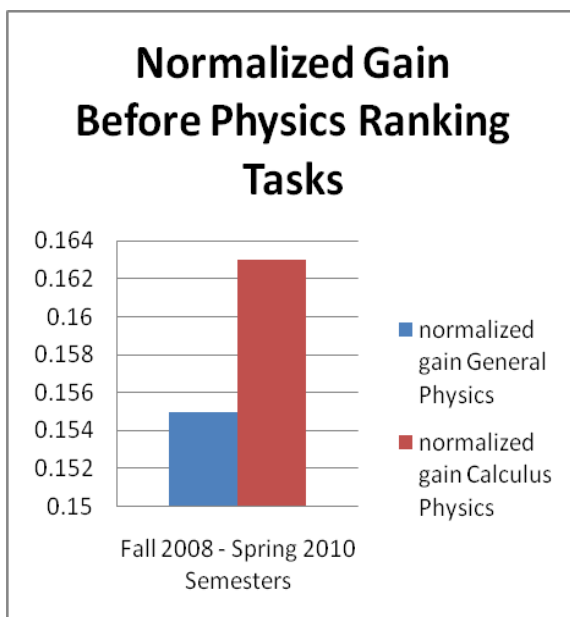


Figure 3. Normalized Gains Before Physics Ranking Tasks, $N = 49$ for General and $N = 80$ for Calculus Physics.

Physics ranking tasks were introduced during the Fall 2010 and Spring 2011 semesters into the general and calculus based physics courses. As shown previously the prior four semesters show a general trend in the percent gain between the pre and post results of the FCI around 11%. After the ranking tasks were introduced in the courses, the data revealed a large increase in percent gain on the FCI, with the Fall 2010 general course having a 20.7% gain and the calculus course a 21% gain (Figure 3). Although the class sizes were small, they did experience a high increase in the average FCI scores.

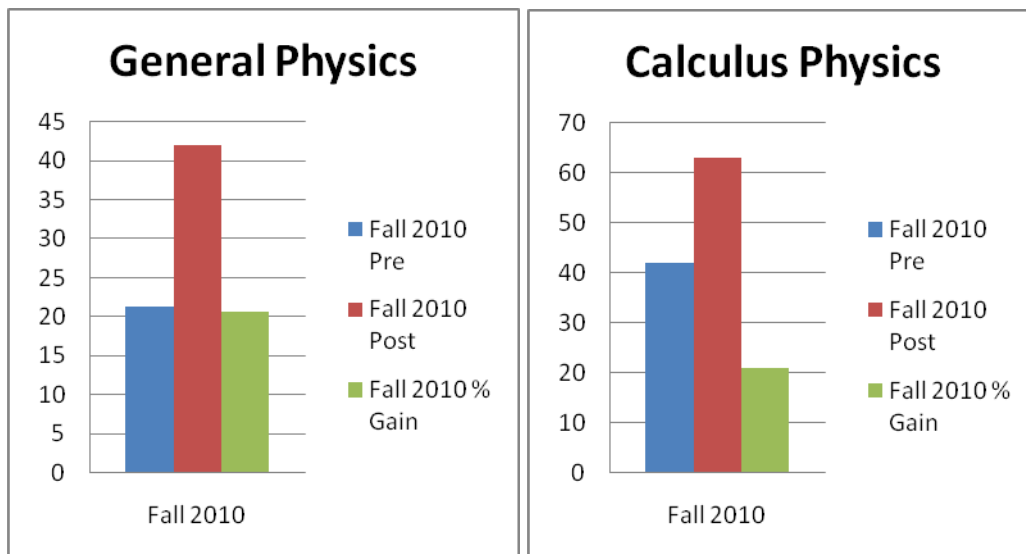


Figure 4. FCI Results for General Physics, ($N = 6$) and Calculus Physics, ($N = 16$) After Ranking Tasks Were Introduced.

The normalized gain for the Fall 2010 semester with students performing the physics ranking tasks for the first time had calculated values of 0.263 for the general physics course and 0.362 for the calculus based physics course respectively (Figure 4).

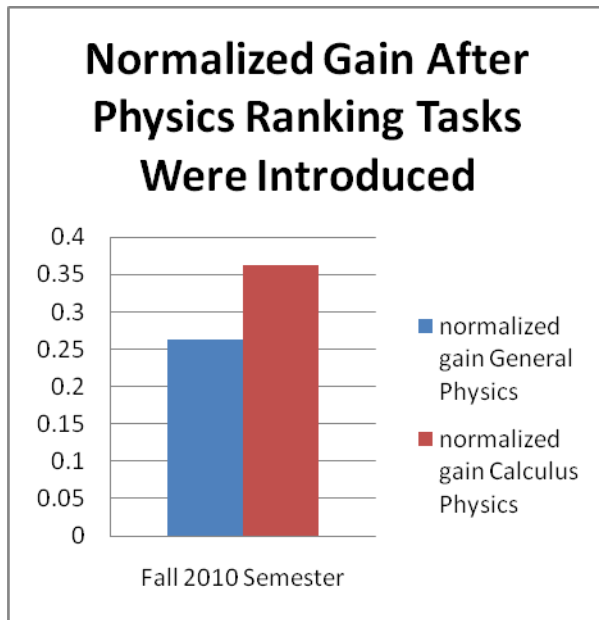


Figure 5. Normalized Gains After Physics Ranking Tasks, $N = 6$ for General and $N = 16$ for Calculus Physics.

The Spring 2011 general physics course had a gain of 19.7% while the calculus based course had a gain of 19.3% (Figure 5).

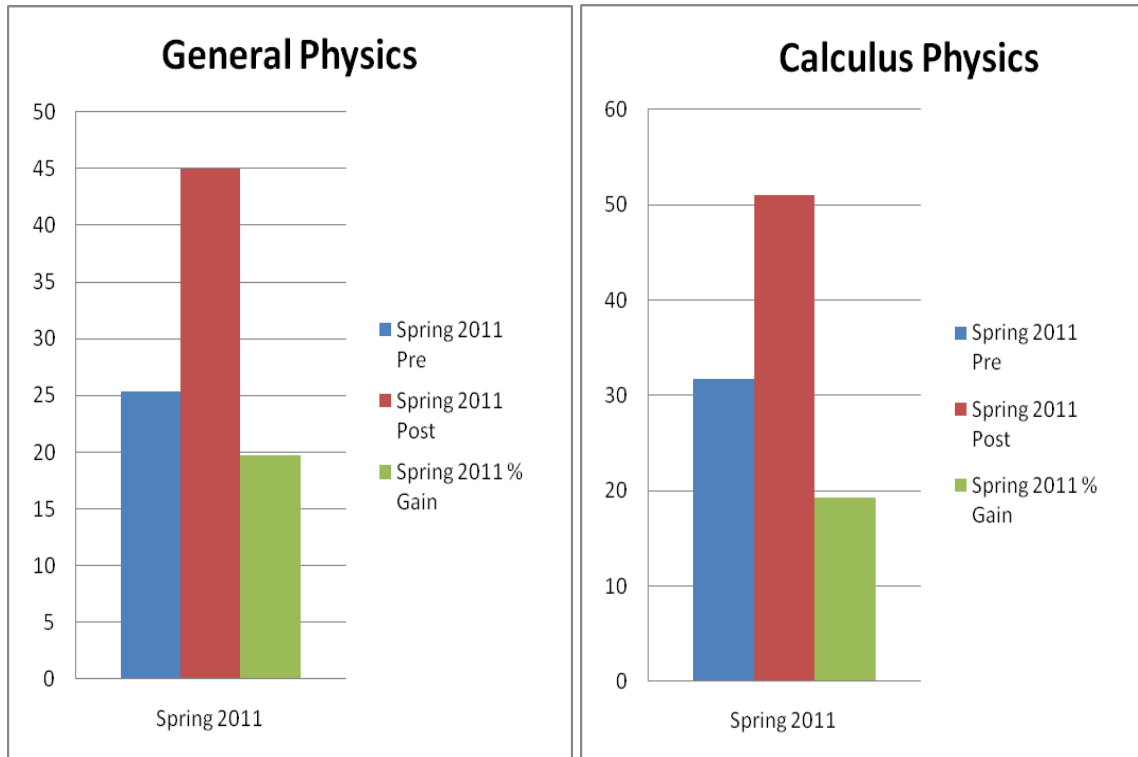


Figure 6. FCI Results for General Physics, ($N = 23$) and Calculus Physics, ($N = 25$) After Ranking Tasks Were Introduced.

The normalized gain for the Spring 2011 semester with students performing the physics ranking tasks for the second time had calculated values of 0.263 for the general physics course and 0.283 for the calculus based physics course respectively (Figure 6).

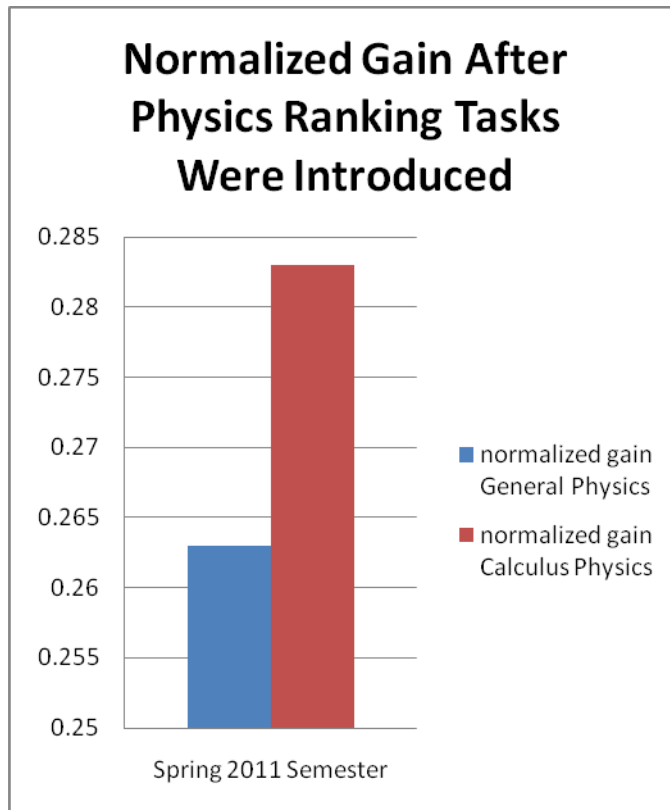


Figure 7. Normalized Gains After Physics Ranking Tasks, $N = 23$ for General and $N = 25$ for Calculus Physics.

The data collected from the semesters while using the physics ranking tasks does show that they can increase the conceptual knowledge of physics students in the study of mechanics. The percent gain was over two times greater than previous semesters in both the general physics course and the calculus based physics courses for both semesters in which ranking tasks were introduced. Another thing to note about the data is to notice the very high pre FCI score of the calculus based course during the Fall 2010 semester. A pre score of 42% was close to the post scores of the previous semesters of data collection. Yet they still had a gain of 21%, doubling the previous four semesters.

Students struggled with the idea of the ranking tasks at first. One student commented during the post formal interview, “these problems are confusing, they make me think a lot more about what is going on.” Many students didn’t like the conceptual approach that

the physics ranking tasks are geared to, one student in particular said during the post formal interview, “just let me use my calculator so that I do not have to think about the situation.” I even had one student from the calculus based course in the spring comment, “these things make my head hurt.” But from an instructor point of view, I think that is a good thing at times. A student noted on a final One-Minute Paper assessment when I asked them to summarize their thoughts on ranking tasks that, “Although they were painful at first, the ranking tasks did help me think in a different way about physics. It hit home that physics is not just about mathematical equations.” This was a very good insight, I couldn’t have said it better myself.

INTERPRETATION AND CONCLUSION

As I analyzed the results of my research it seems that my main area of focus was confirmed from all of the data that was collected. My goal was to see if ranking task types of problems could increase the students’ conceptual understanding in physics and the data does indeed confirm that they do. The increase in the pre and post FCI scores show a dramatic increase in the semesters that I used the physics ranking tasks from the previous semesters when I did not.

A couple of things that I might change if I were to do this again would be to analyze the FCI scores differently. I think it might be interesting to analyze each question individually or at least by topic. For example I would look at the questions involving just free-fall motion, or questions that focus on linear momentum and see how the specific topics changed from pre and post rather than looking at the class average of the entire assessment. This would give more insight into what specific areas I could focus the

physics ranking tasks to help in. Furthermore, if one particular topic was very low on the pre test I could include more ranking tasks on that topic to help strengthen the area of weakness.

I could also add another assessment along with the FCI to get a wider range of questions. There are many conceptual assessments that could be of value to give another set of pre and post scores to analyze. This could give more credit to the research using two different assessments to see if there was an increase on both rather than relying on the FCI alone.

Another topic I might address in future research is to evaluate how many students actually changed their misconceptions throughout their work in a course. It would be interesting to have a list of obvious misconceptions each student had upon entering the course, and then have them update that list at the end of the semester to see how and why they changed their thinking. Would a student be able to explain the correct viewpoint from a physical sense and explain why their initial misconceptions were wrong? I think that could be a very interesting study. This would have to be done on an individual basis rather than as a group, but it might shed some light into why students come in to class with so many of these misconceptions while others may not.

VALUE

The most obvious outcome of this study was that physics ranking tasks help students gain a conceptual understanding of physics concepts. One outcome of this is that I will keep using these ranking tasks in my future courses in to ensure that those students have the same opportunity to increase their conceptual knowledge in the area of general

physics. I think that the type of activities presented in this research can be implemented by any classroom instructor fairly easily. I'm quite certain that in most physics classrooms, instructors want their students to gain a firm understanding of both the conceptual and mathematical laws of physics. Any instructor who struggles with their students' understanding of conceptual problems would benefit from this research. These ranking tasks and other similar types of problems would be a benefit for anyone willing to change their method of instruction just a little to get students to think and solve a different type of physics problem. I am not trying to put down traditional physics instruction, but I think some instructors do get set in their methods of teaching and are afraid or just unwilling to try something a little different. The physics ranking tasks have shown that they can increase the conceptual knowledge of students in the study of mechanics.

It is always a challenge each semester to fight some of the misconceptions that physics students bring with them to class. The ranking tasks are a great opportunity for the students to challenge their own personal beliefs to see how the universe really works. Some students seem to struggle with these initial misconceptions all semester, so introducing them early on and often will help them battle the misconceptions they brought in to the class at the beginning.

During the Post Formal Interview it was very evident that early on students did not appreciate working on the Physics Ranking Tasks. However, after working through several of the tasks some students did show some appreciation into why they were doing them. Not all students appreciated them, but some did like the extra challenge. I do not know if this would be appreciated with younger students, but at the college level they did

value the problems that made them think on a different level. If I did this again I would put some additional questions into the Post Formal Interview to get the thoughts of the students on a particular ranking task or two that they found the most beneficial or the most difficult.

This research really made me think about what I want students to get out of the classes that I teach. I think it is very important for students to learn to think about science and be able to explain scientific principles in their own words. I still think they need to be able to calculate answers to scientific problems as well, but I see a greater need for students to be able to think and reason through scientific principles. I used to assign problems solely on a mathematical basis where if they knew the equations they could get the correct answer. However after reading through a lot of previous research to prepare for my own project I saw the need for students to gain a conceptual understanding of the scientific concepts as well as the mathematical components of them. This led to my research of using ranking tasks in my physics courses. After analyzing the results I was very pleased that I had tried this. The results have really motivated me to try other non-traditional strategies in my courses in the future. I have realized that a quality instructor cannot be afraid to try new things. If it works keep it, if not try something different next time. This was a very challenging philosophy for me to incorporate but I think my students will benefit from it in the long run. Furthermore, I have learned the value of educational resources. I have always tried to stay on top of new and exciting things in physics research, but I have learned that I need to do this in the education field as well. Reading literature and seeing what other educators have done has helped me grow professionally. To be the best instructor I can be, I need to keep up to date on what new methods might

work from published research, and then be able to create and implement lessons in my courses based upon it.

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APPENDICES

APPENDIX A

PHYSICS RANKING TASKS

Appendix A

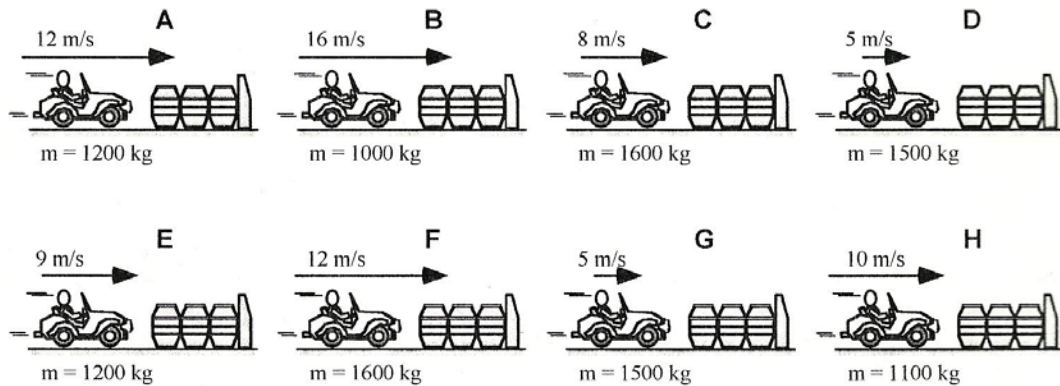
Physics Ranking Tasks

Physics Ranking Task 1

Basic Instructions for ranking tasks: Each item will have a number of situations. Your task is to rank the items in a specific order. After ranking you will need to identify the basis you used for the ranking and the reasoning behind your choice.

Shown below are eight cars that are moving along horizontal roads at specified speeds. Also given are the masses of the cars. All of the cars are the same size and shape, but they are carrying loads with different masses. All of these cars are going to be stopped by plowing into barrel barriers. All of the cars are stopped over the same distance.

Rank these situations from greatest to least on the basis of the strength of the forces that will be needed to stop the cars in the same distance. That is, put first the car on which the strongest force will have to be applied to stop it in x meters, and put last the car on which the weakest force will be applied to stop the car in the same distance.



Greatest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ Least

Or, all cars require the same force. _____

Please carefully explain your reasoning.

How sure are you on your ranking? Circle One

Basically Guesses

Sure

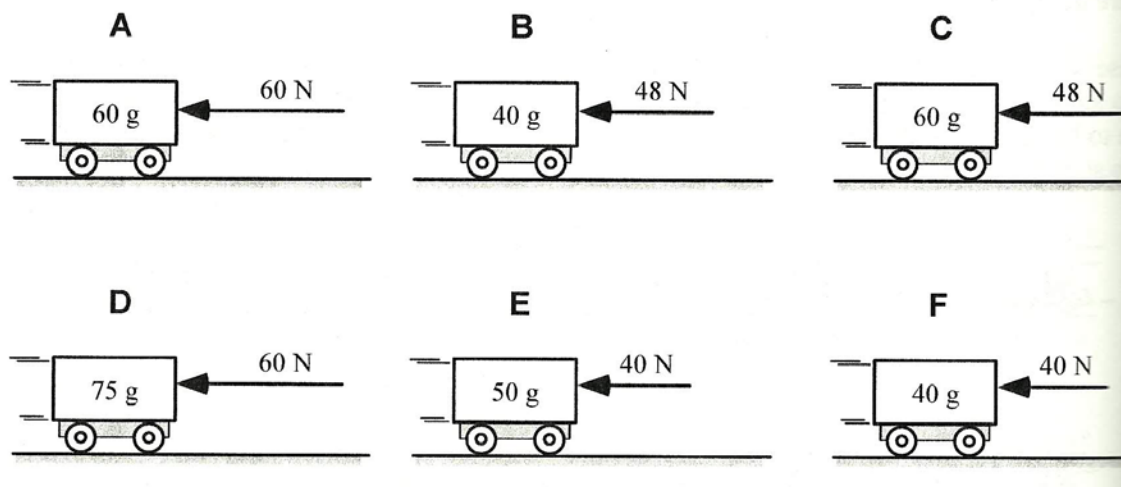
Very Sure

1 2 3 4 5 6 7 8 9 10

Physics Ranking Task 2

Shown below are six situations where a cart, which is initially moving to the right, has a force applied to it such that the force will cause the cart to come to a stop. All of the carts have the same initial speed, but the masses of the carts vary, as do the forces acting upon them.

Rank these situations from greatest to least on the basis of how long it will take each cart to come to a stop.



Greatest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Least

Or, all cars require the same time to stop. _____

Please carefully explain your reasoning.

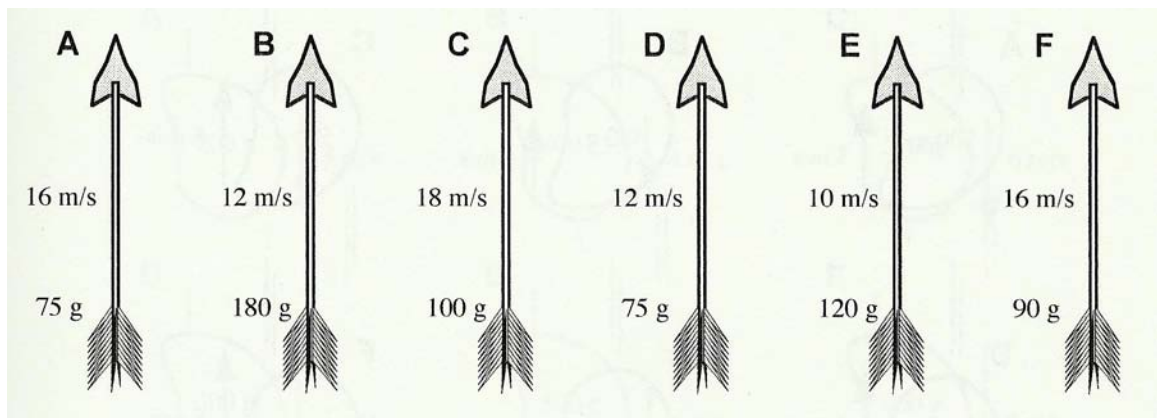
How sure are you on your ranking? Circle One
Basically Guesses Sure

1 2 3 4 5 6 7 8 9 10 Very Sure

Physics Ranking Task 3

The six figures below show arrows that have been shot in the air. All of the arrows were shot straight up and are the same size and shape. The arrows are made of different materials so they have different masses, and they have different speeds as they leave the bows. The values for each arrow are given in the figures. (We assume for this situation that the effect of air resistance can be neglected.) All arrows start from the same height.

Rank these arrows, from greatest to least, on the basis of the acceleration of the arrows at the top of their flight.



Greatest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Least

All arrows have the same acceleration but not zero. _____

The acceleration at the top is zero for all arrows. _____

Please carefully explain your reasoning.

How sure are you on your ranking? Circle One

Basically Guesses

Sure

Very Sure

1

2

3

4

5

6

7

8

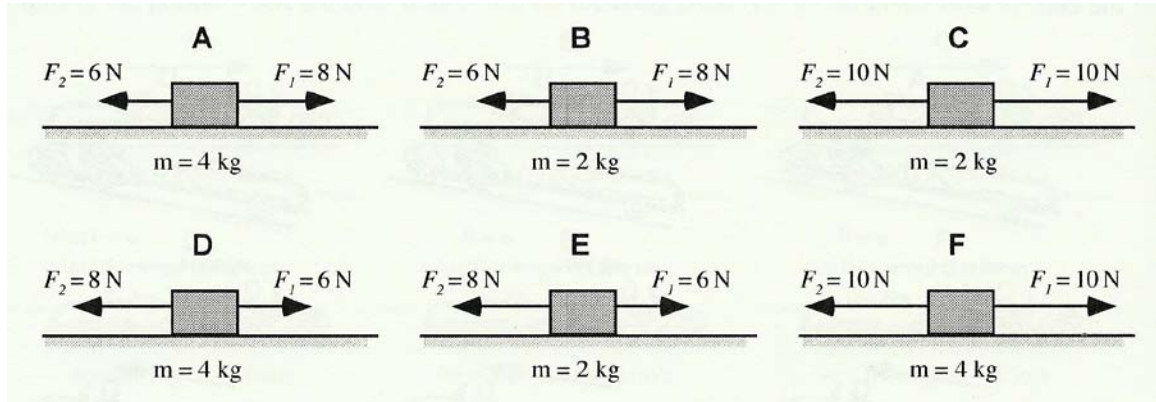
9

10

Physics Ranking Task 4

All Objects start at rest. Two forces act on an object that is on a frictionless surface, as shown below.

Rank these situations from greatest change in velocity to least change in velocity. (Note: All vectors directed to the right are positive, and those to the left are negative. Also, $0 \text{ m/s} > -10 \text{ m/s}$).



Greatest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Least

Or, the change in velocity is the same in all cases. _____

Or, the velocity will not change in any of these situations. _____

Please carefully explain your reasoning.

How sure are you on your ranking? Circle One

Basically Guesses

Sure

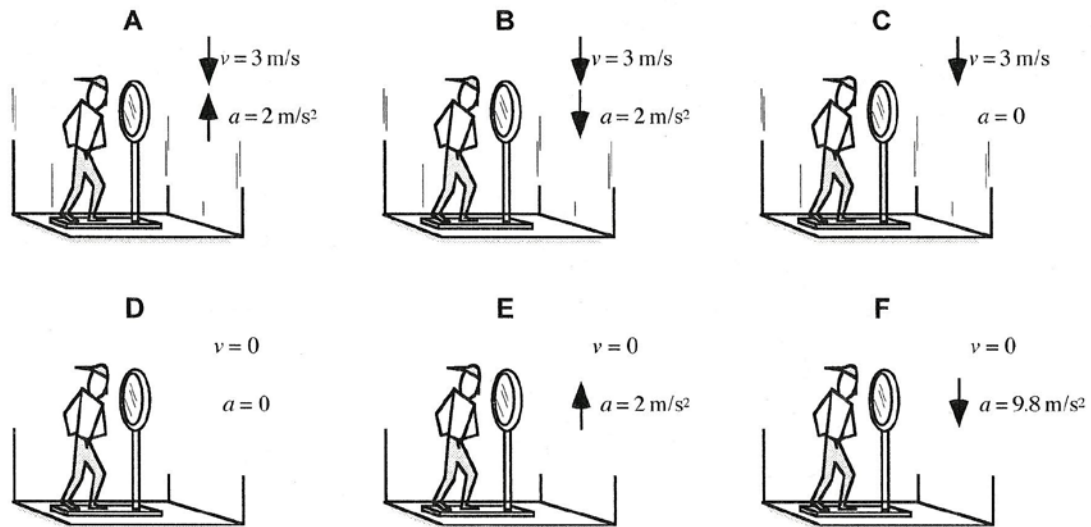
Very Sure

1 2 3 4 5 6 7 8 9 10

Physics Ranking Task 5

The figures below depict situations where a person is standing on a scale in six identical elevators. Each person weighs 600 N when the elevators are stationary. Each elevator now moves (accelerates) according to the specified arrow that is drawn next to it. In all cases where the elevator is moving, it is moving downward.

Rank the figures, from greatest to least, on the basis of the *scale weight* of each person as registered on each scale. (Use $g = 9.8 \text{ m/s}^2$.)



Greatest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Least

Or, all of the scales read the same weight. _____

Or, all of the scales read zero weight. _____

Please carefully explain your reasoning.

How sure are you on your ranking? Circle One

Basically Guesses

Sure

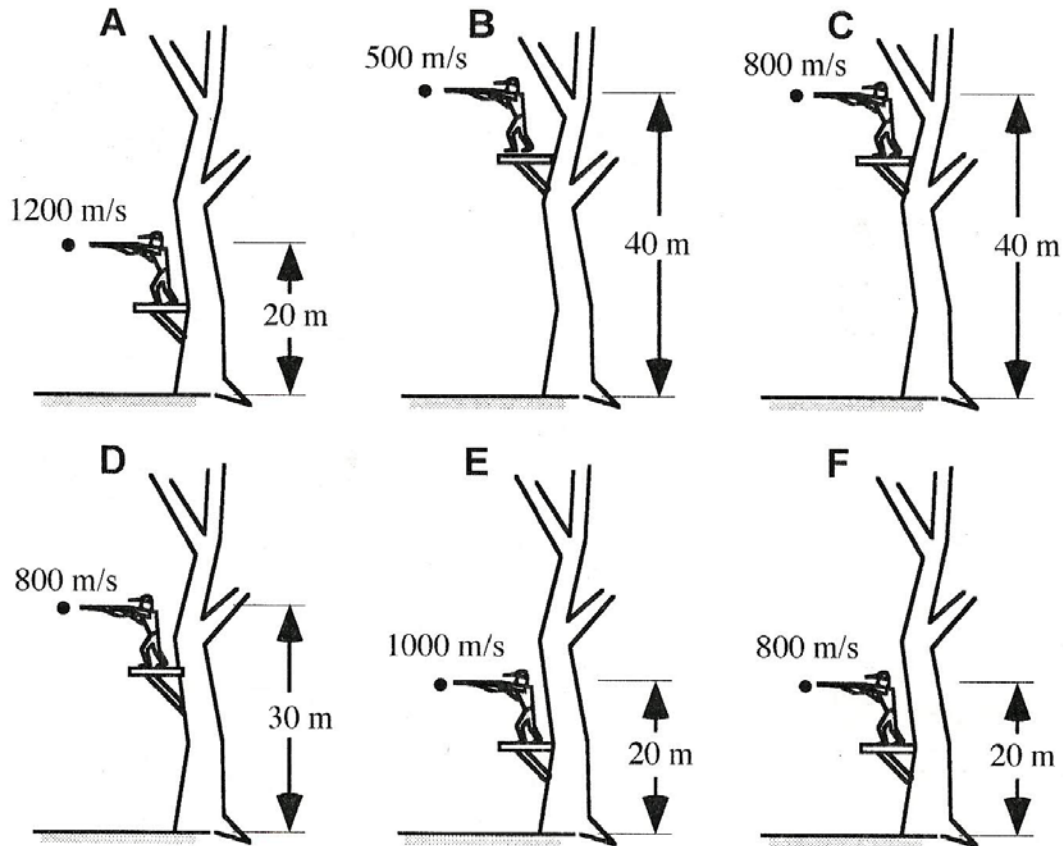
Very Sure

1 2 3 4 5 6 7 8 9 10

Physics Ranking Task 6

The six figures below show rifles that are being fired horizontally, i.e. straight out, off platforms. The bullets fired from the rifles are all identical, but the rifles propel the bullets at different speeds. The specific speed of each bullet and the height of the platform are given. All of the bullets miss the targets and hit the ground.

Rank these bullets, from longest to shortest, on the basis of how long it takes a bullet to hit the ground. That is, put first the bullet that will take the longest time from being fired to hitting the ground, and put last the bullet that will take the shortest time.



Longest 1 _____ 2 _____ 3 _____ 4 _____ 5 _____ 6 _____ Shortest

Or, all of the bullets reach the ground at the same time. _____

Please carefully explain your reasoning.

How sure are you on your ranking? Circle One

Basically Guesses

Sure

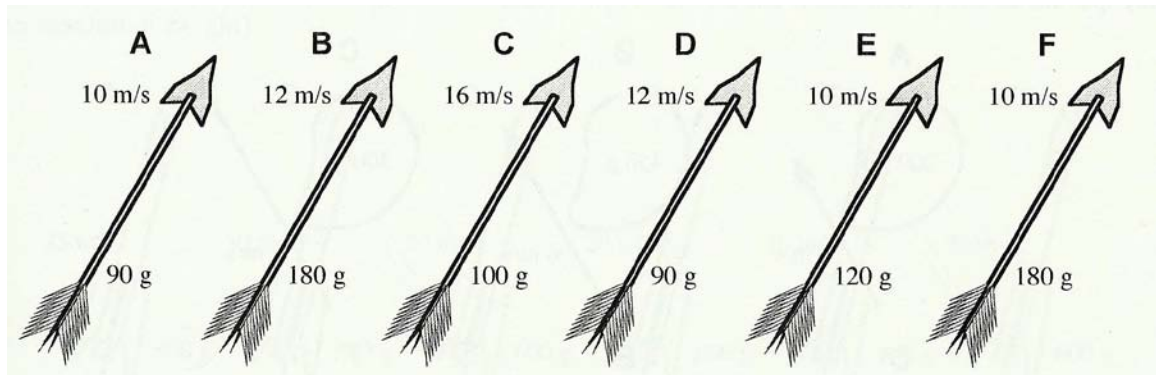
Very Sure

1 2 3 4 5 6 7 8 9 10

Physics Ranking Task 7

The six figures below show arrows that have been shot into the air. All of the arrows were shot at the same angle and are the same size and shape. The arrows are made of different materials so they have different masses, and they have different speeds as they leave the bows. The values for each arrow are given in the figures. (We assume for this situation that the effect of air resistance can be ignored.) All arrows start from the same height.

Rank these arrows from greatest to least on the basis of the maximum heights the arrows reach.



Greatest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Least

Or, all of the arrows reach the same height. _____

Please carefully explain your reasoning.

How sure are you on your ranking? Circle One

Basically Guesses

Sure

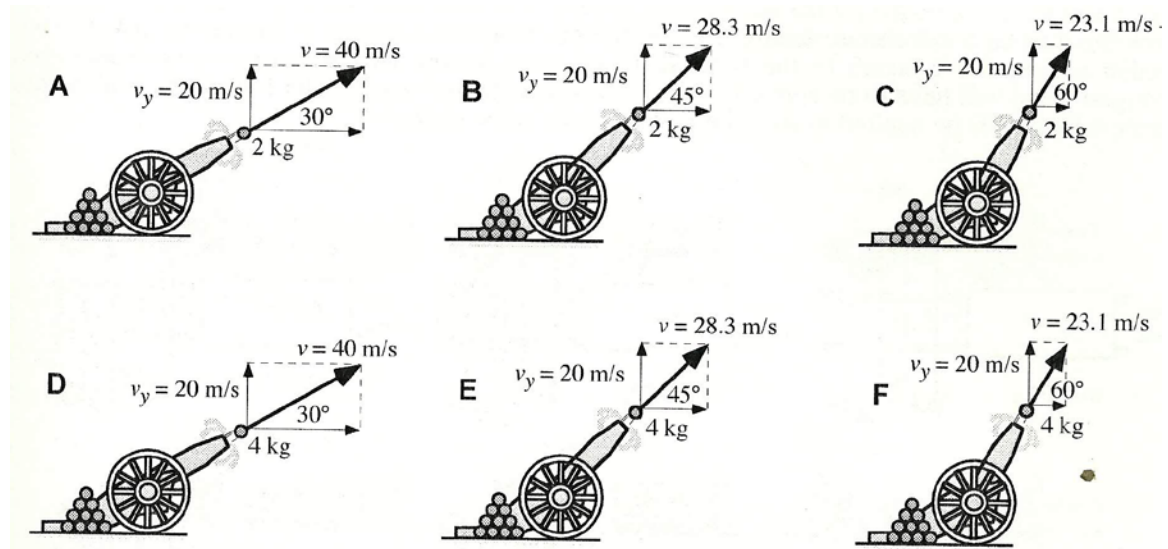
Very Sure

1 2 3 4 5 6 7 8 9 10

Physics Ranking Task 8

The pictures below depict cannonballs of two different masses projected upward and forward. The cannonballs are projected at various angles above the horizontal, but all are projected with the same vertical component of velocity.

Rank these situations from largest to smallest according to the time the balls are in the air.



Largest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Smallest

All times are the same. _____

Please carefully explain your reasoning.

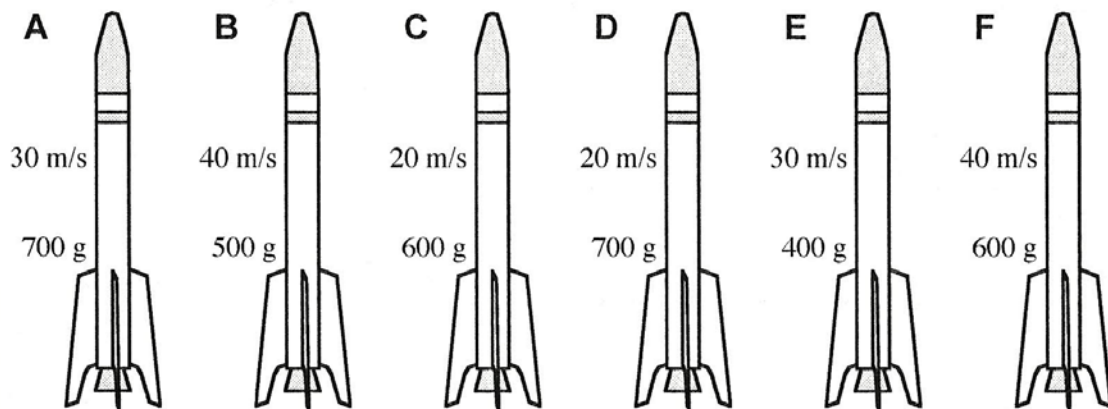
How sure are you on your ranking? Circle One
Basically Guesses Sure

1 2 3 4 5 6 7 8 9 10 Very Sure

Physics Ranking Task 9

The six figures below depict six model rockets that have just had their engines turned off. All of the rockets are aimed straight up, but their speeds differ. All of the rockets are the same size and shape, but they carry different loads, so their masses differ. The mass and speed for each rocket are given in each figure. (In this situation we are ignoring any effect air resistance may have on the rockets.) At the instant when the engines are turned off, the rockets are all at the same height.

Rank these rockets from greatest to least on the basis of the kinetic energy they have at the top of their flights.



Greatest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Least

Or, all of the rockets have the same kinetic energy. _____

Please carefully explain your reasoning.

How sure are you on your ranking? Circle One

Basically Guesses

Sure

Very Sure

1

2

3

4

5

6

7

8

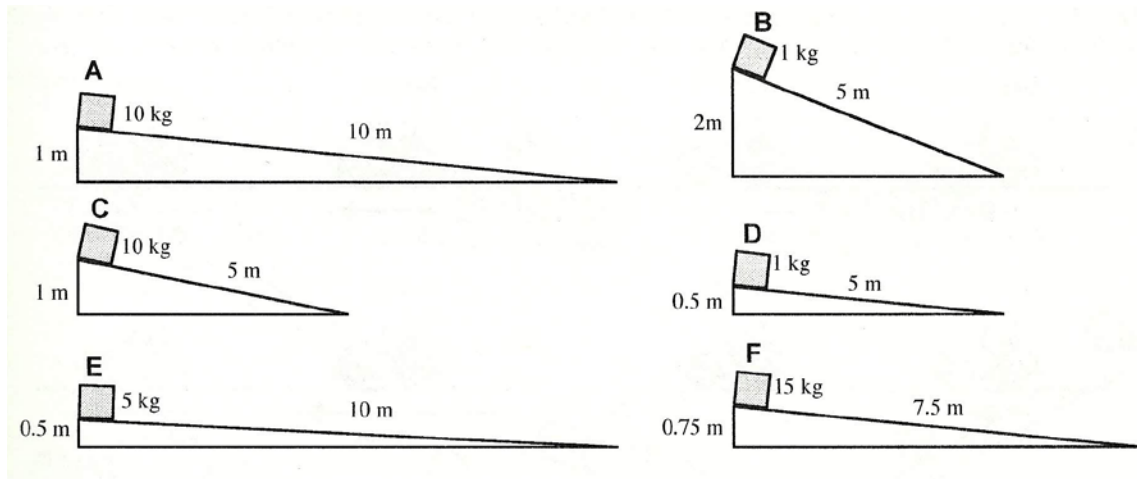
9

10

Physics Ranking Task 10

For the figures below, all surfaces are frictionless. All masses start from rest at the top of the incline.

Rank in order from greatest to least the change in gravitational potential energy of the sliding masses from the top of the incline to the bottom of the incline.



Greatest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Least

Or, all masses have the same change in gravitational potential energy. _____

Please carefully explain your reasoning.

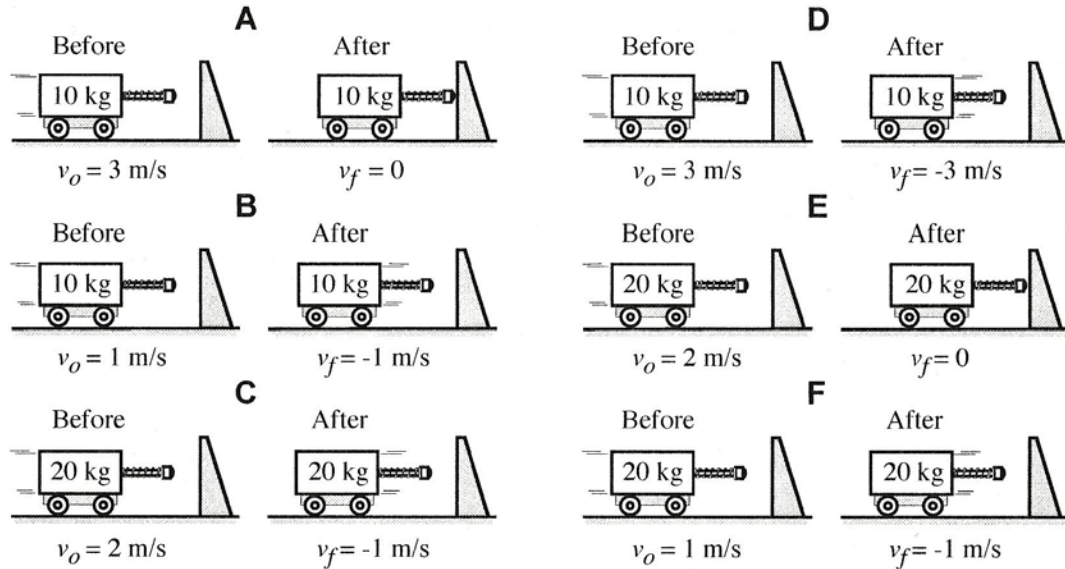
How sure are you on your ranking? Circle One
Basically Guesses Sure

1 2 3 4 5 6 7 8 9 10 Very Sure

Physics Ranking Task 11

A cart with a spring plunger runs into a fixed barrier. The mass of the cart, its velocity just before impact with the barrier, and its velocity right after collision are given in each figure.

Rank the change in momentum for each cart from the greatest change in momentum, to the least change in momentum (+ direction is to the right and – to the left with $-4 < 2$).



Greatest 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ Least

Or, all the changes in momentum are the same. _____

Please carefully explain your reasoning.

How sure are you on your ranking? Circle One

Basically Guesses

Sure

Very Sure

1 2 3 4 5 6 7 8 9 10

APPENDIX B

POST FORMAL INTERVIEW

Appendix B
Post Formal Interview Questions

- 1) Do you find ranking tasks helpful? Why or Why not?
- 2) How do you think ranking tasks compare to traditional physics problems? Are they easier or more difficult?
- 3) Do ranking tasks help you get a better picture of conceptual physics ideas? Can you think of any specific examples of topics to illustrate this?
- 4) How do you think you did on the Force Concept Inventory Assessment? Were the questions what you expected for a physics exam?
- 5) Which problems seem tougher to you, the mathematical problems or conceptual problems?
- 6) Describe your idea of the problem solving process for me.
- 7) Do you follow your problem solving process for all of the problems that you do?
- 8) Is there anything else you would like me to know?

APPENDIX C

ONE-MINUTE PAPER

Appendix C
One-Minute Paper

One-Minute Paper

In a short summary respond to the following:

What physics concept did the ranking task focus on?

What did you learn about this concept?

Was the ranking task helpful in learning this physics concept?

APPENDIX D

MUDDIEST POINT

Appendix D

Muddiest Point

Muddiest Point

In a short summary please respond to the following statement:

What was the muddiest point in the ranking task you just completed, i.e. what did you not understand or what is still unclear about the physics concept it covered?

APPENDIX E
CONSENT FORM

Appendix E Consent Form

SUBJECT CONSENT FORM FOR PARTICIPATION IN HUMAN RESEARCH AT MONTANA STATE UNIVERSITY

The purpose of this research project entitled "The Use of Physics Ranking Tasks on Conceptual Understanding of Physics," examines the effectiveness of a non-traditional problem task on developing an understanding of physics in basic mechanics topics. For this project, students will be asked to complete a series of physics ranking tasks. All of these data collection instruments fall within the area of common classroom assessment practices.

Identification of all students involved will be kept strictly confidential. Most of the students involved in the research will remain unidentified in any way, and their levels of environmental interaction will be assessed and noted. However, six to ten students will be selected at random for interviews. Nowhere in any report or listing will students' last name or any other identifying information be listed.

There are no foreseeable risks or ill effects from participating in this study. All treatment and data collection falls within what is considered normal classroom instructional practice. Furthermore, participation in the study can in no way affect grades for this or any course, nor can it affect academic or personal standing in any fashion whatsoever.

There are several benefits to be expected from participation in this study. Students will gain an understanding of common misconceptions in physics and be able to reason why and how these misconceptions exist. This project will also help the instructor in identifying some of the reasons behind these misconceptions and ways in which to correct them.

Participation in this study is voluntary, and students are free to withdraw consent and to discontinue participation in this study at any time without prejudice from the investigator.

Please feel free to ask any questions of Danny Mattern 316-322-3233 or dmattern@butlercc.edu should you require more information on the research study. For questions regarding your rights as a human subject, contact Mark Quinn, IRB chair at 406-994-4706 or mquinn@montana.edu.

AUTHORIZATION: I have read the above and understand the discomforts, inconvenience and risk of this study. I, _____ (*name of subject*), agree to participate in this research. I understand that I may later refuse to participate, and that I may withdraw from the study at any time. I have received a copy of this consent form for my own records.

Signed: _____

Investigator: _____

Date: _____