DOES ATTITUDE MATTER?:
STUDENT EXPECTATIONS AND THEIR IMPACT ON ACADEMIC ACHIEVMENT IN INTRODUCTORY PHYSICS

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Abstract

It is often assumed that students' understanding of science and their attitudes towards science influence their academic success. This paper discusses the results of a study involving nearly three hundred students enrolled in an introductory algebra-based college physics course at the University of Wisconsin-Madison. Student expectations regarding physics and the study of physics were measured using the Maryland Physics Expectations Survey. The results of this survey were then compared to student academic achievement as indicated by an average of the students' first two exam scores. According to this study, the level of individual student agreement with expert response on the MPEX Survey is not a predictor of individual student academic achievement.

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I. Introduction

i. Physics 103: A case study

As is typical at many large research institutions, the University of Wisconsin-Madison (UW-Madison) Physics Department has large, overcrowded and much-dreaded introductory physics courses. The Physics Department offers four different introductory physics course sequences, differentiated mainly by the students' math level and major. This study examines students in their first semester of the algebra-based introductory physics course, General Physics 103. Many students taking the course enroll in order to fulfill a requirement for their major or for future enrollment in a professional school, such as medical or dental.

One of the main reasons this course was chosen for study is that student dissatisfaction with the course is high, with instructor and course ratings historically averaging below a two on a five-point scale. Instructor disillusionment with the course is also high. Professors express concerns that students do not concentrate on important physical concepts; in contrast, students get entangled in formula manipulation and arithmetic. If the students would just "study smarter," professors feel, the students would not only receive the higher grades they seek, but also develop a better understanding of physics.

Additionally, several new instructional strategies have recently been implemented in Physics 103. The UW-Madison does not support a Physics Education Group and, therefore, has relied on the Physics Education Research done at other institutions, particularly the University of Minnesota and the University of Illinois at Urbana-Champaign. Some of the strategies developed at these institutions have been implemented in Physics 103 with no test of their effectiveness at the UW-Madison.

This study represents an initial, and, hopefully, not final, attempt to quantify the success of the instructional strategies and curricula at the UW-Madison in increasing student understanding of physics. Because of the high student and instructor dissatisfaction with Physics 103 and instructor interest in improving the course, two separate studies were performed in the spring semester of 2005 by graduate physics students. Ultimately, both studies aimed to provide instructors with qualitative data regarding their students' understanding of physics and factors that influence student learning. This paper presents the results of one of those studies.

ii. The Problem/Question

In informal discussions with the course instructors, both expressed a belief that student attitudes greatly influenced student academic success in the course. Anecdotally, it seemed, those students who enjoyed physics and worked hard received the highest grades and, therefore, demonstrated the best understanding. This study attempted to quantify that feeling through the combined use of the Maryland Physics Expectations (MPEX) Survey and student achievement on course exams. The question investigated was: do student expectations with respect to physics and learning physics, as measured by the MPEX Survey, predict student performance on the course exams?

Section II discusses the history of Physics Education Research and provides a summary of previous related studies; Section III and IV describe the methods that were used to collect the data and the results, respectively; and, Section V investigates the implications of the work for Physics 103 and future studies.

II. Background and Review of Previous Work

i. Physics Education: A short history

The field of Physics Education Research (PER) has developed substantially over the past thirty years. In 1999, the Council of the American Physical Society endorsed the study of physics education research as a valid field of study by physics faculty. This endorsement indicated the community's official support for and acceptance of physics education research. Currently, there are over twenty Physics Education Research Groups (PERGs) within the United States, many at institutions with highly respected physics departments, such as the University of California at Berkeley, Harvard University, and the University of Maryland – College Park. These groups are often located within their home institution's Physics Department and function as another sub-field in which graduate students can specialize. Physics Education Research covers a range of topics, such as the teaching of specific physics concepts, curriculum development, and educational methods as they relate to teaching physics content.

Much of the pioneering work in the field was lead by Lillian McDermott at the University of Washington. She has remained a principal in the field and a great deal of the research done today reflects her work. In 2001, Dr. McDermott was awarded the Oersted Medal[1] by the American Association of Physics Teachers. In her lecture upon receipt of the award, Dr. McDermott provided a picture of physics education research today:

> Physics education research differs from traditional education research in that the emphasis is not on educational theory or methodology in the general sense, but rather on student understanding of science content. For both intellectual and practical reasons, discipline-based education research should be conducted by science faculty within science departments. There is evidence that this is an effective approach for improving student learning (K-20) in physics.[2]

PERGs inclusion in Physics Departments, instead of Education Departments, provides two main benefits. First, physicists conduct the Physics Education Research. They possess the physics content necessary to study, in depth, a particular physics problem or subject. Furthermore, they have been trained as physicists and introduce the same level of scientific rigor into physics education research as their colleagues do into more traditional sub-fields. Their adherence to the scientific method and maintenance of rigorous scientific standards helps ensure that physics education research done at one institution is applicable to another institution.

Secondly, because physics education researchers work within the Physics Department, they are able to develop strong professional relationships with other physics faculty members. For instance, a close, professional relationship can more easily be developed and maintained by colleagues in the same building, instead of a "long-distance" relationship between physicist and educators on different ends of a campus. Even though physics education research is designed so that results can be generalized and used by departments lacking PERGs, in discussions with physics education researchers during the development of this project, they mentioned close relationships with their colleagues as the most important reason why their home institution had been able to improve physics instruction. In other words, using the results of the research is not sufficient to improve general instruction; the Department must also demonstrate a commitment to improving education on an institutional level. The Physics Education researchers indicated that the creation of a Physics Education Research Group was an essential first step for any Physics Department interested in improving its own instruction.

ii. Attitudes and achievement: What has been done before

Although it is often assumed that a student's attitude towards science impacts his academic achievement in science courses, historically, the data have shown mixed results. In their study *The Relationship Between Affect and Achievement in Science*[3], for example, Rennie and Punch found that "affect is related more strongly to previous than subsequent achievement"[4] in middle-school students. In contrast, in their work with community college students, Crow and Piper demonstrated a positive relationship between a student's attitude towards science and his academic achievement.[5]

There have been few large-scale studies investigating this relationship as it relates to students in an introductory physics course. A survey of physics education group websites indicates little work has been done in this area by PERGs. As was mentioned above, physics education research tends to focus on the teaching specific physics concepts and tends to avoid studies involving educational theory. However, the University of Maryland-College Park does conduct research into "Expectation and Epistemology" and has investigated the attitude-achievement link on a small scale. A recent study by Lising and Elby, from Towson University and University of Maryland-College Park respectively, investigated the effect of epistemology on one student's learning in an introductory physics class. Through observations of the student's work and interviews, the researches concluded that the "student's epistemological stance – her tacit or explicit views about knowledge and learning – have a direct, causal influence on her physics learning."[6]

Another small-scale study relying on direct student observations and interviews demonstrated that favorable attitudes towards physics do not result in higher academic achievement. As sited by Redish et al, Hammer, in his dissertation, presented the case of two students: one with more expert expectations towards physics – a desire to understand and struggle with the conceptual framework of physics, for example - and the other with novice expectations – learning by memorization without understanding concepts.[7] In these students' introductory physics course, the student with the undesirable expectations was doing well while the other student was struggling. Only when the student with the favorable expectations changed her expectations to those of a novice was she able to succeed in the course.

III. Methods

i. Physics 103

Physics 103 is the first semester in a two-semester course of introductory physics. Concepts covered in this portion of the course include motion in one- and two-dimensions, energy, momentum, rotational motion, thermodynamics, waves, and sound. Students are required to have an understanding of algebra and trigonometry; no previous physics experience is necessary. The course's lecture component occurs twice a week for 50 minutes and is team-taught by two physics faculty. The lecture is conducted in a large lecture hall and all of the course's approximately 300 students attend the same lecture section. Discussion sections meet twice a week and are lead by graduate student Teaching Assistants. Students are divided into 16 different discussion sections, allowing for more personal contact than the lecture. Students also attend weekly laboratory meetings in small group sessions.

ii. MPEX Survey

The students' attitudes towards physics were measured using the Maryland Physics Expectations (MPEX) Survey, developed at the University of Maryland. In their rational for the development of the MPEX Survey, the authors argue that

> It is not only physics concepts that a student brings into the physics classroom. Each student, based on his or her own experiences, brings to the physics class a set of attitudes, beliefs, and assumptions about what sorts of things they will learn, what skills will be required, and what they will be expected to do. In addition, their view of the nature of scientific information affects how they interpret what they hear.[8]

This survey was chosen not only because it specifically addresses student expectations[9] towards physics (and not science in general), but also because of the extensive research that was put into its development. The researchers developed the survey over four years, using in-depth interviews with students to gauge each item's effectiveness at measuring students' expectations.

The 34-item survey evaluated students' attitudes about, towards and relating to physics and learning – their "expectations" - in six general categories: independence, coherence, concepts, reality link, math link, and effort. Each item was a statement with which students were asked to rank their level of agreement on a Likert-scale (agree-disagree). Each item had a preferred, or favorable, response, which was determined during the Survey's development by administering the Survey to a group of experts. See Table 1 for a summary of the categories and preferred responses.

Category	Favorable Response	Unfavorable Response	MPEX Items
Independence	Takes responsibility for constructing own understanding	Takes what is given by authorities (teacher, text) without evaluation	1, 8, 13, 14, 17, 27
Coherence	Believes physics needs to be considered as a connected, consistent framework	Believes physics can be treated as unrelated facts of "pieces"	12, 15, 16, 21, 29
Concepts	Stresses understanding of the underlying ideas and concepts	Focuses on memorizing and using formulas	4, 19, 26, 27, 32
Reality Link	Believes ideas learned in physics are relevant and useful in a wide variety of real contexts	Believes ideas learned in physics has little relation to experiences outside the classroom	10. 18. 22. 25
Math Link	Considers mathematics as a convenient way of representing physical phenomena	Views the physics and the math as independent with little relationship between them	2, 6, 8, 16, 20
Effort	Makes the effort to use information available and tries to make sense of it	Does not attempt to use available information effectively	3, 6, 7, 24, 31

Table 1[10]: List of categories probed in the MPEX Survey with expert and novice responses.

Clearly, these six categories and their associated MPEX Survey items do not represent an exhaustive list of possible questions into student expectations. The Survey's developers note:

> One can imagine exploring a wide variety of characteristics ranging from whether the students like physics to whether they are

> intimidated by physics to whether they think they should take notes in lecture. In creating the MPEX survey, we have chosen to focus on issues that have an effect on how students interpret and process the physics in the class. We have not considered the student's feelings about physics, its value or its importance.[11]

In other words, this Survey was developed to be used as a tool to measure specific expectations that may impact student learning. In this project, whether these expectations do have a measurable impact on student learning was investigated. A copy of the Survey, as seen by students, can be found at the end of this paper in appendix A.

iii. Administering the Survey: Pre-Flights and computers

The survey was administered via a course "Pre-Flight." Pre-Flights were a course component that students completed regularly before each lecture. The current lecture's Pre-Flight would be posed on the course webpage and students would complete the Pre-Flight independently before the day's lecture on a computer. Generally the "Pre-Flights asked students a series of short, conceptual questions about the topics to be covered in the upcoming lecture. Student responses were then used by the instructor to gauge student understanding in preparation for the lecture. Pre-Flight questions and student responses were also used in lecture to emphasize an important concept or to help increase student understanding of a particular concept. For all Pre-Flights, students were encouraged to answer all questions and no credit was associated with the accuracy of a student's answers, only with the completion of the Pre-Flight.

The Survey was administered as the course's 18th Pre-Flight. It was due March 28, one day before the second course exam.

iv. Measuring Achievement: Structure of exams with sample questions

In order to measure the students' achievement, an average of their first two exams were used. The one-hour, twenty-question multiple-choice exams were developed by the course instructor. Both calculation-type and conceptual physics problems were given. The exams were each worth ten percent of a student's final grade. Exams were given on February 22 and March 29.

The course's first exam covered Chapters 1-4 in the course's textbook *College Physics*, 6th Ed., by R. Serway and J. Faughn. These chapters were Introduction, Motion in One Dimension, Vectors and Two-Dimensional Motion, and The Laws of Motion. These four chapters represented the students' first introduction to college-level physics and the course. The students' average score on the exam was 60%. Here two questions typical of the twenty on the exam are given:

- Calculation-type: *Question #12*
  A fireman, 50.0 m away from a burning building, directs a stream of water from a ground level fire hose at an angle of 30.0° above the horizontal. If the speed of the

stream as it leaves the hose is 40.0 m/s, at what height will the stream of water strike the building?

A. 2.5m
B. 4.9 m
C. 9.8 m
D. 18.6 m *(Correct)*
E. 37. 2m

- Conceptual: *Question #17*
  A tennis ball launching machine is to be adjusted for maximum range. What angle should the balls be launched if the launch speed remains constant?

  A. 15° above horizontal.
  B. 30° above horizontal.
  C. 45° above horizontal. *(Correct)*
  D. 60° above horizontal.
  E. 90° above horizontal.

The course's second exam covered Chapters 5-8 in *College Physics*: Energy, Momentum and Collisions, Circular Motion and the Law of Gravity, and Rotational Equilibrium and Rotational Dynamics. The students' average score on this second exam was a 56%. Here two questions typical of the twenty on the exam are given:

- Calculation-type: *Question #14*
  During a snowball fight two balls with masses of 0.4 and 0.6 kg, respectively, are thrown in such a manner that they meet head-on and combine to form a single mass. The magnitude of initial velocity for each is 15 m/s. What is the speed of the 1.0-kg mass immediately after collision?

  A. zero
  B. 3 m/s *(Correct)*
  C. 6 m/s
  D. 9 m/s
  E. none of the above

- Conceptual: *Question #1*
  Peter and Paul, who are equally massive, went up in a double chair lift to the top of Badger Mountain to ski down. Peter being the adventurous kind came down on the steep double black diamond run. Paul on the other hand took the longer and less steep blue square run down the hill. Which of the following statements are true about the physics of the situation?

  A. If the friction between the skis and the well-groomed trail is neglected, both Peter and Paul will have the same speed at the bottom of the hill.
  B. If the friction is not neglected, both Peter and Paul come down the slope such that their acceleration is: $a=g(\sin\theta - \mu\cos\theta)$, where θ is angle of the slope and μ is the coefficient of kinetic friction.
  C. If the friction is not neglected, the total energy (gravitational potential

energy and kinetic energy) of Peter is larger than that of Paul at the bottom of the hill.

D. If the friction is not neglected, the internal energy of the system (i.e., the skiers and the earth) is increased.

E. All of the above. *(Correct)*

A copy of each exam, including student responses, is included in Appendices B & C.

IV. Results

i. Expert/novice agreement

In order to determine the extent to which the students' expectations aligned with the expert, or favorable, view, an average of the students' answers on each item was taken. For each item the "Strongly Disagree" and "Disagree" responses -- representing a student response of 1 or 2 on the item -- were combined, as were the "Strongly Agree" and "Agree" responses -- representing a student response of 4 or 5. The percentage of students who chose each response was calculated for each item. The total level of student agreement with the expert view for each category was calculated and is presented in Table 2.

Category	**% Disagree/Agree with the expert view**
Independence	39/32
Coherence	33/39
Concepts	33/38
Reality Link	30/39
Math Link	40/30
Effort	35/36

Table 2: Student level of agreement with expert response

Student agreement with the expert response varied for individual items. Overall student agreement or disagreement with the expert response that was greater than 50% was considered significant. These items are presented in Table 3. A complete list of student responses and average exam scores is provided for the reader in Appendix D.

Item	**Disagree/ Agree**	**Expert Response**
#2*: All I learn from a derivation or proof of a formula is that the formula obtained is valid and that it is OK to use it in*	16/52	D

problems.		
***#10**: Physical laws have little relation to what I experience in the real world.*	56/14	D
***#11**: A good understanding of physics is necessary for me to achieve my career goals. A good grade is not enough.*	53/18	A
***#15**: In doing a physics problem, if my calculation gives a result that differs significantly from what I expect, I'd have to trust the calculation.*	63/14	D
***#19**: The most crucial thing in solving a physics problem is finding the right equation to use.*	19/58	D
***#24**: The results of an exam don't give me any useful guidance to improve my understanding of the course material. All the learning associated with an exam is in the studying I do before it takes place.*	19/52	D
***#31**: I use the mistakes I make on homework and on exam problems as clues to what I need to do to understand the material better.*	18/51	A
***#32**: To be able to use an equation in a problem (particularly in a problem that I haven't seen before), I need to know more than what each term in the equation represents.*	11/62	A
***#34**: Learning physics requires that I substantially rethink, restructure, and reorganize the information that I am given in class and/or in the text.*	12/55	(A)

Table 3: Items on which student responses were greater than 50% in agreement or disagreement with the expert view. The percentage of students that chose "ambivalent" can be found via subtraction. () mean less than 80% of experts agreeing.

ii. Achievement

The achievement of the students, as measured by an average of their first two exam scores, showed no statistical correlation to student expectations as measured by the MPEX Survey. Individual items and category totals were both examined, with no individual item or category demonstrating a statistically significant difference in achievement between those students who agreed with the expert view and those students who did not. As was mentioned above, a complete list of student responses and average exam scores is provided for the reader in Appendix D.

iii. Student Comments

Although not analyzed as part of this investigation, student comments were provided in an open-ended question included with the survey as well as in the course's last Pre-Flight, a survey created and administered by the course's instructor. A sample of representative comments is provided here as additional insight into student expectations about the course that may or may not have been addressed with the MPEX Survey.

In response to the Survey's question "What are your goals for this course?" students had the following type of responses:

- **Grade-related**: many students articulated goals related to the overall grade they would receive in the course, such as "Not to fail"; "to pass"; or, "get a B or better". Most of the students expressed some form of grade-related goal.
- **Survival**: students also expressed their desire to do well in the course combined with a negative comment on their experience in the course, such as "get a B and not die"; "to pass and to not go insane from how unbelievably bad this class is run"; "Just to pass!!!! I have hated this class more than anyother (sic) class that I have taken in my whole life!!"
- **Conceptual**: some students also expressed views that better aligned with that of their instructors – to develop a conceptual understanding of physics. These students had comments such as "understand concepts to help me understand the world that I live in"; "My goal for this course is to truly understand the concepts of physics so I can have a good basis for deciding my major"; "to learn and understand the most that I can."

Of course, not all responses fell into these categories, but they provide some insight into how students felt about the course and what they wanted to gain from completing the course.

Additional insight can be gained from the comments offered by students in response to the instructor's item "Enter your comments about this course", given on the course's last Pre-Flight. The students who chose to answer this item generally expressed strong feelings and opinions about the course. Again, the comments were grouped into general categories:

- **Exams**: many students expressed frustration with the format of the course exams, with the difficulty level of the exams being a common complaint. For example, students commented: "I felt that the time I put into studying did not accurately reflect my test grades"; "exams were too hard! (not enough time to complete and material covered in the course didn't help me for all of it.)"; and, "For some reason I did terrible on all the tests and it really hurt me even though I studied a lot."
- **Disillusionment**: student disillusionment with the course – as well as with physics in general – was expressed repeatedly in comments. Some students held extreme views, such as "it was painful" or "i (sic) hated it." Other comments reflected the students' frustration with their level of achievement in the course, for example "Main thing I learned during this course: I'm not very good at Physics."
- **Suggestions**: many students used this item to offer suggestions on how to improve the course in the future. Some typical suggestions were "…given that the tests are concepts based, it might be useful to make some of the homework concepts based as well. This would probably boost test scores."; "the tests should not be multiple choice, rather, partial credit should be given out for showing work."; "I felt the course cover[ed] a lot of material in a short time. I also felt the lectures were rushed and not very

helpful in learning the material. Lectures should be more concise and clear."

- **Praise**: not all of the comments were negative. Students also expressed enjoying the course and the subject matter: "This course was excellent. The material I learned will definitely be helpful in the near future. [The instructor and my Teaching Assistant] are assets to the University."; "It was fine, looking forward to next year."; "I enjoyed the course, and I hope that 104 is very similar."

V. Conclusion

i. Summary

The MPEX Survey was used to measure student expectations in an introductory, college-level, algebra-based physics course at the University of Wisconsin. Although the students displayed a variety of favorable and unfavorable views about the study and learning of physics, an individual student's expectations were not an indicator of that student's academic success in the course.

ii. What does it mean?: The future for Physics 103

As can be seen from the student comments, student dissatisfaction and disillusionment with Physics 103 is high. However, the data suggest that student attitudes and opinions about learning physics do not impact their achievement in the course. Hopefully, this result does not cause despair among the course's instructors and prevent any further research into physics education at the University of Wisconsin. On the contrary, this result should spur more research into improving instruction because of what the results demonstrate, possibly, about the course itself.

If the MPEX Survey accurately reflects student expectations in the course, then it would be desirable for students who hold expert views to do better in the course than students who hold novice views. The instructors of Physics 103 strive to teach students a conceptual framework in which to ponder physics concepts. That is, they would like students to be able to describe the physics of a situation, not just choose the correct equation and "plug-and-chug." If this type of higher-order learning is occurring, then a student who holds the unfavorable expectations listed in Table 1 should be unable to succeed without changing his or her views. The fact that there is no relationship between a student's expectations and his achievement on exams suggests that the course's exams are an insufficient measure of students' conceptual understanding of physics.

Many students expressed frustration about the exams when asked to provide comments about the course, including comments about the exams' inability to accurately measure their knowledge. Some representative comments are:

- "I feel that my exam scores do not reflect what i (sic) have learned or what i (sic) thought i (sic) understood [.]"

- "The exams are worded in a strange way and the questions don't test your knowledge of physics that well in my opinion."
- "The tests were very frustrating to take because I felt that I was not able to show any knowledge I had learned. It would be much better as a written test, where students can show their work and at least gain partial credit."
- "The exams were not a good means of testing our knowledge of the subject matter."

Although student comments should not be taken as proof that Physics 103 exams do not accurately measure students' conceptual knowledge, the comments indicate that further investigation into the structure of the course exams and the course's assessment in general is necessary. Questions to be examined are:

- What are the goals of the course?
- How are these goals conveyed to the students?
- What is the structure of an exam question that addresses a particular goal? (For example, if a goal is for students to be able to accurately identify the direction and relative strength of forces acting on a body undergoing circular motion, then, what does a question "look like" that assesses a student's level of mastery of that goal?)
- What is the best format for the exams? (Many factors, obviously, come into consideration here: the number of students in the course, the location of the course, the amount of time required to write and grade exams, the necessity for consistency in grading.)
- If an expert view is desirable, how does one teach students to change their novice views to expert views and how does one assess if this change has occurred?

Of course there are many more questions that could be investigated, all that require significant time and effort. Improving student understanding of physics is a monumental task that has been undertaken by many Physics Departments across the country and progress has been made. Unfortunately, the University of Wisconsin-Madison has not yet developed a Physics Education Research Group to assist in this important research. As was stated earlier, individual interest in and use of physics education research will not transform the instruction in a department. Only an institutional commitment to physics education research can create changes within a department. A department's creation of a Physics Education Research Group not only provides a opportunity for collaboration between colleges, but it also demonstrates a valuing of physics education in general and physics education research specifically. This support for physics education research has an intangible, yet immensely positive effect on the department and instruction. Hopefully, this investigation represents only a first step in the development of a thriving and field-leading Physics Education Group at the University of Wisconsin-Madison.

iii. Student Expectations and Learning

Although it was found that student expectations do not impact student learning, these expectations should still be addressed in introductory physics courses. Currently, physics courses may be unintentionally influencing student expectations in a negative way. For example, in the MPEX study done by the University of Maryland, overall, students changed their views from more expert to more novice in the course of the semester[12]. This result indicates, first of all, that the problems faced by the University of Wisconsin-Madison are not unique; and, secondly, that physics education as it is currently occurring in the United States is actually creating undesirable student outcomes with respect to learning.

Changing student expectations while teaching physics concepts should be consciously integrated into a course's curriculum. Encouraging these changes in students may be a more important course goal than the physics content itself, particularly in a course like Physics 103. In these types of introductory courses for non-physics majors, thinking skills are often what is valuable to students in their current academic and future non-academic careers. Helping students develop favorable expectations about physics will encourage their higher-order thinking and problem-solving skills. The importance of these skills to student and their future employers should not be dismissed. On the contrary, they should be directly addressed by physics departments and their curriculum. Only by consciously adopting research-based methods to support changes in student expectations and learning can physics departments improve conceptual understanding of physics.

VI. Acknowledgements

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Finally, thank you to all those involved in Physics 103: the students, the instructors and the teaching assistants. This project would not have been possible without their involvement

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[1] An award that, according to the group's website, "recognizes notable contributions to the teaching of physics." (http://www.aapt.org/Grants/oersted.cfm)
[2] L.C. McDermott, Oersted Medal Lecture 2001: "Physics education research: The key to student learning," *Am.J. Phys.* **69** (11) 1127 (2001).
[3] L. J. Rennie and K. F. Punch, "The relationship between affect and achievement in science," J. Res. Sci. Teaching **28 (2)**, 193-209 (1991).
[4] *Ibid*, pg. 193.

[5] L. W. Crow and M. K. Piper, "A study of the perceptual orientation of community college students and their attitudes toward science as they relate to science achievement," J. Res. Sci. Teaching **20 (6)**, 537-541 (1983).
[6] Laury Lising and Andrew Elby, "The impact of epistemology on learning: a case study from introductory physics" to be published in *Proceedings of the Varenna Summer School, "Enrico Fermi" Course CLVI*, (Italian Physical Society, 2004).
[7] E. Redish, J. Saul and R. Steinberg, "Student expectations in introductory physics," Am. J. Phys. **66** (3), 212-224 (1998).
[8] *Ibid*.
[9] *Ibid*: The authors use "expectations" to describe the "set of attitudes, beliefs, and assumptions" students bring to the learning of physics and the term will be used in the same way in this paper.
[10] Adapted from E. Redish et al., "Student Expectations in Introductory Physics"
[11] *Ibid*.
[12] *Ibid*.

VII. Appendices

i. Appendix A: MPEX Survey[1]

For the questions below select, 1 for Strongly Disagree, 2 for Disagree, 3 for Ambivalent, 4 for Agree and 5 for Strongly Agree

1) All I need to do to understand most of the basic ideas in this course is just read the text, work most of the problems, and/or pay close attention in class. 1 2 3 4 5

2) All I learn from a derivation or proof of a formula is that the formula obtained is valid and that it is OK to use it in problems. 1 2 3 4 5

3) I go over my class notes carefully to prepare for tests in this course. 1 2 3 4 5

4) Problem solving in physics basically means matching problems with facts or equations and then substituting values to get a number. 1 2 3 4 5

5) Learning physics made me change some of my ideas about how the physical world works. 1 2 3 4 5

6) I spend a lot of time figuring out and understanding at least some of the derivations or proofs given either in class or in the text. 1 2 3 4 5

7) I read the text in detail and work through many of the examples given there. 1 2 3 4 5

8) In this course, I do not expect to understand equations in an intuitive sense -- they just have to be taken as givens. 1 2 3 4 5

9) The best way for me to learn physics is by solving many problems rather than by carefully analyzing a few in detail. 1 2 3 4 5

10) Physical laws have little relation to what I experience in the real world. 1 2 3 4 5

11) A good understanding of physics is necessary for me to achieve my career goals. A good grade in this course is not enough. 1 2 3 4 5

12) Knowledge in physics consists of many pieces of information each of which applies

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[1] Adapted from E. Redish, J. Saul and R. Steinberg, "Student expectations in introductory physics," Am. J. Phys. **66** (3), 212-224 (1998).

primarily to a specific situation. 1 2 3 4 5

13) My grade in this course is primarily determined by how familiar I am with the material. Insight or creativity has little to do with it. 1 2 3 4 5

14) Learning physics is a matter of acquiring knowledge that is specifically located in the laws, principles, and equations given in class and/or in the textbook. 1 2 3 4 5

15) In doing a physics problem, if my calculation gives a result that differs significantly from what I expect, I'd have to trust the calculation. 1 2 3 4 5

16) The derivations or proofs of equations in class or in the text has little to do with solving problems or with the skills I need to succeed in this course. 1 2 3 4 5

17) Only very few specially qualified people are capable of really understanding physics. 1 2 3 4 5

18) To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed. 1 2 3 4 5

19) The most crucial thing in solving a physics problem is finding the right equation to use. 1 2 3 4 5

20) If I don't remember a particular equation needed for a problem in an exam there's nothing much I can do (legally!) to come up with it. 1 2 3 4 5

21) If I came up with two different approaches to a problem and they gave different answers, I would not worry about it. I would just choose the answer that seemed most reasonable.(Assume the answer is not in the back of the book.) 1 2 3 4 5

22) Physics is related to the real world and it sometimes helps to think about the connection, but it is rarely essential for what I have to do in this course. 1 2 3 4 5

23) The main skill I get out of this course is learning how to solve physics problems. 1 2 3 4 5

24) The results of an exam don't give me any useful guidance to improve my understanding of the course material. All the learning associated with an exam is in the studying I do before it takes place. 1 2 3 4 5

25) Learning physics helps me understand situations in my everyday life. 1 2 3 4 5

26) When I solve most exam or homework problems, I explicitly think about the

concepts that underlie the problem. 1 2 3 4 5

27) Understanding physics basically means being able to recall something you've read or been shown. 1 2 3 4 5

28) Spending a lot of time (half and hour or more) working on a problem is a waste of time. If I don't make progress quickly, I'd be better off asking someone who knows more than I do. 1 2 3 4 5

29) A significant problem in this course is being able to memorize all the information I need to know. 1 2 3 4 5

30) The main skill I get out of this course is to learn how to reason logically about the physical world. 1 2 3 4 5

31) I use the mistakes I make on homework and exam problems as clues to what I need to do to understand the material better. 1 2 3 4 5

32) To be able to use an equation in a problem (particularly in a problem I haven't seen before), I need to know more than what each term in the equation represents. 1 2 3 4 5

33) It is very possible to pass this course (get a 'C' or better) without understanding physics very well. 1 2 3 4 5

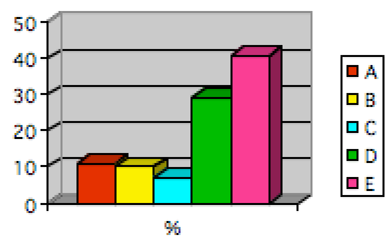
34) Learning physics requires that I substantially rethink, restructure, and reorganize the information that I am given in class and/or in the text. 1 2 3 4 5

ii. Appendix B: Exam 1

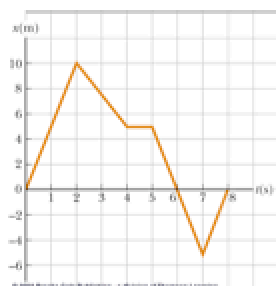
Physics 103, Midterm Exam 1, Spring 2005

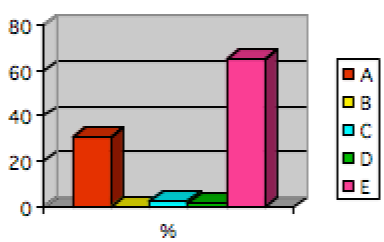
Solution

1) Tiger Woods and Vijay Singh tee off at Augusta by striking their golf balls. The balls first hit the course at exactly the same spot and then make it into the hole. From this observation we can conclude that:
   A. The speeds at which their golf balls left the club are identical.
   B. The angles at which their golf balls left the club are identical.
   C. The maximum heights their golf balls reached are identical.
   D. The vertical components of the velocities with which the golf balls left the club are identical.
   E. None of the above.



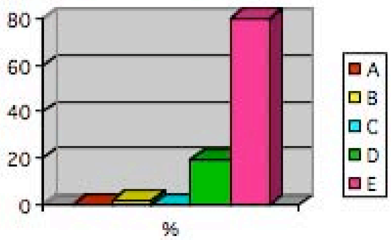
2) The position versus time for a particle is shown in the figure below. During which period is the acceleration positive?
   A. 0.1s to 1.9s
   B. 2.1s to 3.9s
   C. 4.1s to 4.9s
   D. 5.1s to 6.9s
   E. Acceleration is zero during all the periods A-D





3) The drivers of an 18-wheeler (10000 kg), a pickup truck (2000 kg) and a VW bug (1000 kg) are driving along neck-to-neck on a straight road at 120 km/h on a three lane highway, when they see a road block. If all three drivers slam on the breaks simultaneously and come to stop within 1 meter of the roadblock, what can you conclude?

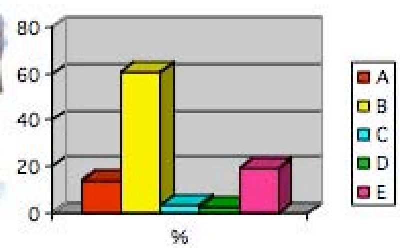
   A. The magnitude of acceleration of the 18-wheeler is the greatest.
   B. The magnitude of acceleration of the pickup truck is less than that of the 18-wheeler but more than that of the VW bug.
   C. The magnitude of acceleration of the VW bug is the least.
   D. A, B and C are true.
   E. The magnitude of acceleration of all three vehicles is the same



4) The same force F is exerted in the two cases (a) and (b) shown below. Which of the following statements is true?

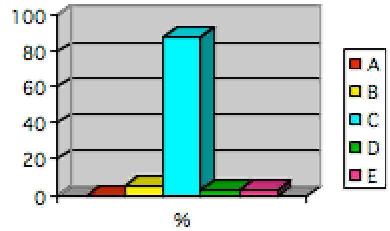
   A. The normal force and the frictional forces exerted by the ground on the sled, are the same for both cases (a) and (b).
   B. The normal force and the frictional forces exerted by the ground on the sled, are higher for the case (a) compared to the case (b).
   C. The normal force and the frictional forces exerted by the ground on the sled, are smaller for the case (a) compared to the case (b).
   D. The normal force is the same for both cases but the frictional force is smaller for the case (a) compared to the case (b).
   E. The normal force is the same for both cases but the frictional force is higher for the case (a) compared to the case (b).

(a) (b)



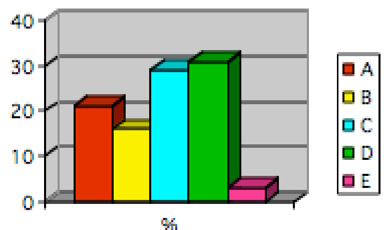
5) The severity of injury depends on the speed at which one strikes the ground. If on the Earth a person can safely land jumping unaided from 10 feet up, from how high can the same person jump when he/she is on the Moon (Acceleration due to gravity on the surface of Earth is six times that on the Moon).

A. 10 feet
B. 30 feet
C. 60 feet
D. 120 feet
E. 360 feet



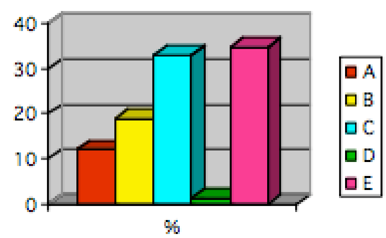
6) A projectile of mass M and another of mass 5M were launched at the same time at 15° and 75° with respect to the ground, at the same speed. Which of the following statements is true?

A. Projectile with mass M strikes the ground 5 times sooner than the one with mass 5M
B. Projectile with mass M strikes the ground 5 times farther than the one with mass 5M
C. Both projectiles strike the ground at the same time.
D. Both projectiles strike the ground at the same distance.
E. The answer depends on the mass and speed



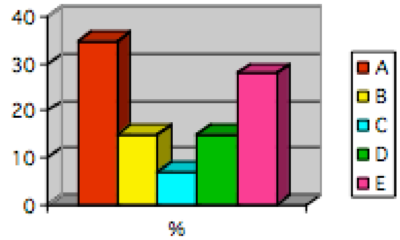
7) A skier of mass 50 kg is coming down a hill with varying slope. At what point is his frictional force half as much as it will be when he reaches the hoizontal surface near the ski lift?

A. When the slope is 30° to the horizontal
B. When the slope is 45° to the horizontal
C. When the slope is 60° to the horizontal
D. At the top of the hill
E. The frictional force is the property of the surfaces and will remain the same all the way down the hill.



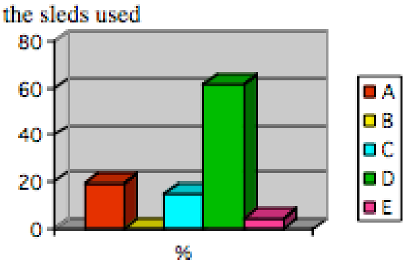
8) A tightrope walker is at the center of the rope tied between two poles. The rope makes an angle of 4.8° with respect to the horizontal. The tension in the string will be

A. equal to one half the weight of the tightrope walker.
B. equal to the weight of the tightrope walker.
C. equal to twice the weight of the tightrope walker.
D. equal to six times the weight of the tightrope walker.
E. not possible to determine without knowing the distance between the poles.



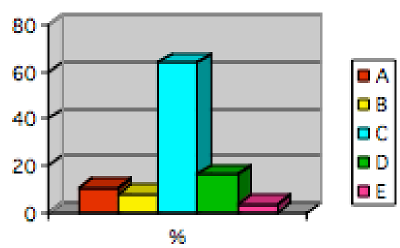
9) Three children Aaron (20 kg), Beth (25 kg) and Charlie (30 kg) take off on sleds at the same speed from the top of a hill. Who will reach the bottom first? ($\mu_k = 0.15$)

A. Aaron
B. Beth
C. Charlie
D. All of them reach the bottom at the same time
E. Answer depends on the unknown mass of the sleds used



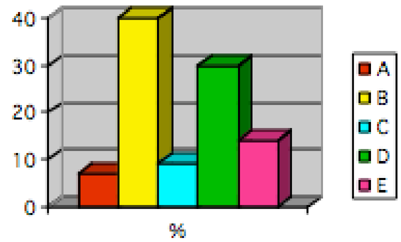
10) Bob has two balls. He releases one ball from a platform of height H. Just as that ball strikes the ground, he releases the next ball from the same height. Assuming that the first ball bounces perfectly,(*i.e.*, reversing only the direction of its velocity when it strikes the ground), at what height from the ground do the balls strike each other?

A. H/4
B. H/3
C. H/2
D. 3H/4
E. None of the above



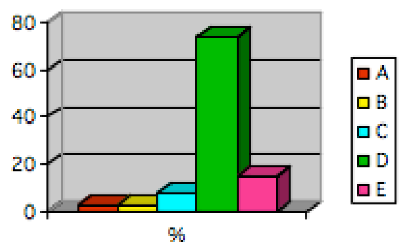
11) A massive wooden crate (M) is on a wooden floor. A horizontal force is exerted on the crate till the static frictional force is just overcome. If that force is maintained for a period of time (t), how far is the crate displaced? (Coefficients of static and kinetic friction are μ_s and μ_k. Acceleration due to gravity is g.)

A. $\frac{1}{2}gt^2$
B. $\frac{1}{2}\mu_k gt^2$
C. $\frac{1}{2}\mu_s gt^2$
D. $\frac{1}{2}(\mu_s - \mu_k)gt^2$
E. $\frac{1}{2}(\mu_k - \mu_s)gt^2$



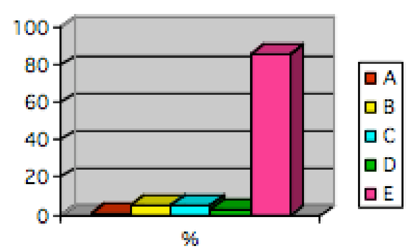
12) A fireman, 50.0 m away from a burning building, directs a stream of water from a ground level fire hose at an angle of 30.0° above the horizontal. If the speed of the stream as it leaves the hose is 40.0 m/s, at what height will the stream of water strike the building?

A. 2.5 m
B. 4.9 m
C. 9.8 m
D. <u>18.6 m</u>
E. 37.2 m



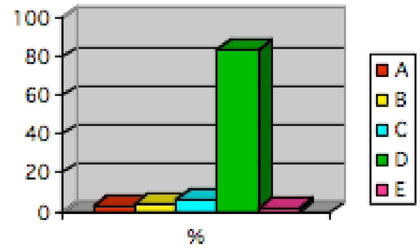
13) A boy uses a slingshot to propel a stone of mass 0.1 kg upwards at 45^0 with respect to the horizontal across a river. Neglecting any air resistance, about 1 second after the stone leaves the slingshot, the direction of its acceleration is

A. $> 45^0$ to horizontal
B. $< 45^0$ to horizontal
C. along the direction of its motion
D. opposite the direction of its motion
E. <u>downwards</u>



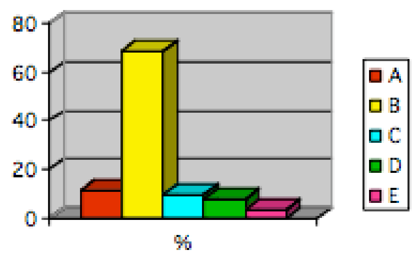
14) A driver slams on the brakes as soon as he sees a roadblock on a highway. If he is traveling at 60 mph and comes to a stop in 3 s, how far did the car move before coming to a full stop?

A. 10 m
B. 20 m
C. 30 m
D. 40 m
E. 50 m



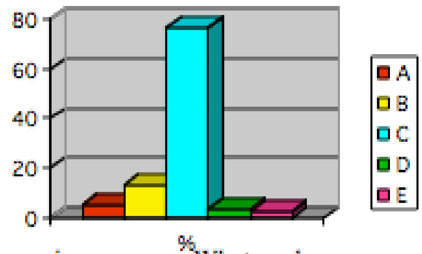
15) Ann, Beth and Carly can swim equally fast. In a competition to swim across a river that is flowing twice as fast as the girls can swim, Ann heads 45° upstream, Beth heads straight across and Carly points 45° downstream, all doing the best job that they can. Which of the following statements is true?

A. Ann reaches the opposite bank directly across the starting point.
B. Ann and Carly reach the opposite bank, at different places, at the same time, but later than Beth.
C. The order in which they reach the opposite bank is Ann, Beth and Carly.
D. The order in which they reach the opposite bank is Carly, Beth and Ann.
E. Ann, Beth and Carly reach the opposite bank at the same time.



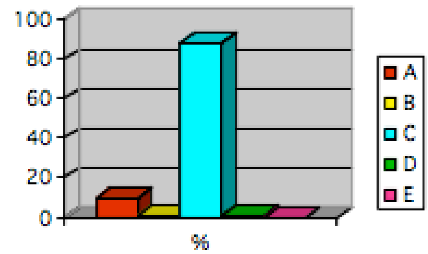
16) Peter throws a 1-kg rock 10 m vertically up while standing on a ladder at a height of 10 m. Paul throws a 2-kg rock vertically upward, from the ground level, to twice the distance as Peter did. The speed of Peter's rock compared to Paul's rock when they eventually land on the ground in their free fall is,

A. quarter as much.
B. half as much.
C. <u>the same</u>
D. twice as much
E. four times as much



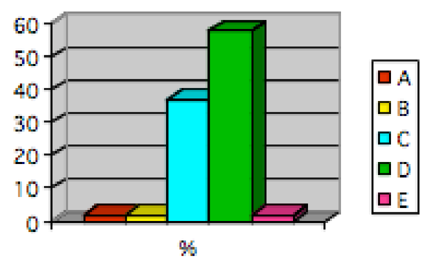
17) A tennis ball launching machine is to be adjusted for maximum range. What angle should the balls be launched if the launch speed remains constant?

A. 15° above horizontal.
B. 30° above horizontal.
C. <u>45° above horizontal</u>
D. 60° above horizontal
E. 90° above horizontal



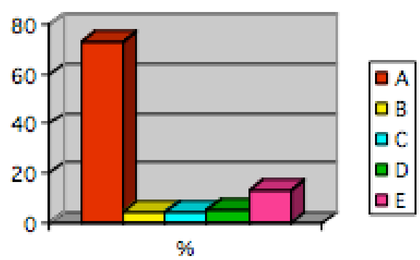
18) A car has a maximum acceleration of 3 m/s^2. What would its maximum acceleration be while towing a second car with twice its mass?

A. 2.5 m/s^2
B. 2.0 m/s^2
C. 1.5 m/s^2
D. <u>1.0 m/s^2</u>
E. 0.5 m/s^2



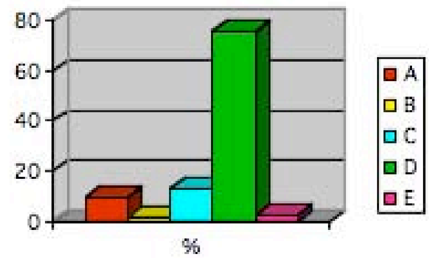
19) A cheetah can run at approximately 100 km/hr and a gazelle at 80.0 km/hr. If both animals are running at full speed, with the gazelle 70.0 m ahead, how long before the cheetah catches its prey?

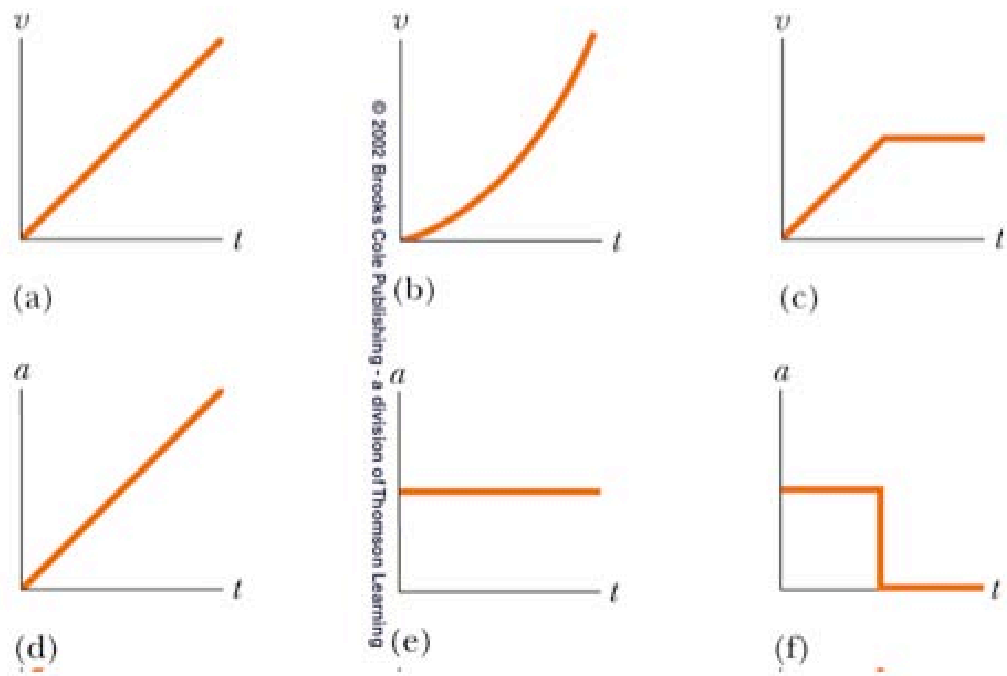
A. <u>12.6 s</u>
B. 25.2 s
C. 6.30 s
D. 10.7 s
E. None of the above



20) In the picture below (a), (b) and (c) represent velocity versus time graphs and (d), (e), and (f) represent acceleration versus time graphs. Which of the following graph pairs are matching correctly?

A. (a) and (e)
B. (b) and (d)
C. (c) and (f)
D. ***<u>All of the above</u>***
E. None of the above



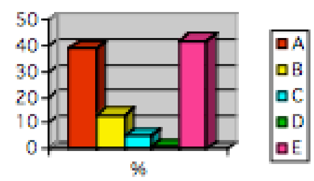


iii. Appendix C: Exam 2

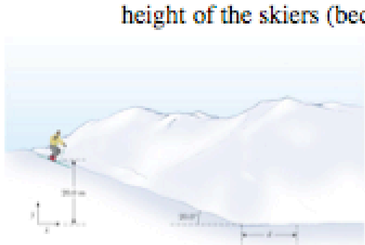
Physics 103, Midterm Exam 2, Spring 2005

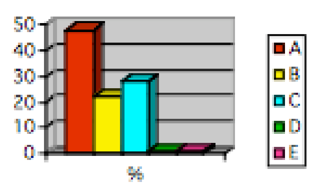
Answer Key

1) Peter and Paul, who are equally massive, went up in a double chair lift to the top of Badger Mountain to ski down. Peter being the adventurous kind came down on the steep double black diamond run. Paul on the other hand took the longer and less steep blue square run down the hill. Which of the following statements are true about the physics of the situation?
   A. If the friction between the skis and the well-groomed trail is neglected, both Peter and Paul will have the same speed at the bottom of the hill.
   B. If the friction is not neglected, both Peter and Paul come down the slope such that their acceleration is: $a = g(\sin\theta - \mu\cos\theta)$, where θ is angle of the slope and μ is the coefficient of kinetic friction.
   C. If the friction is not neglected, the total energy (gravitational potential energy and kinetic energy) of Peter is larger than that of Paul at the bottom of the hill.
   D. If the friction is not neglected, the internal energy of the system (i.e., the skiers and the earth) is increased.
   E. ***All of the above***



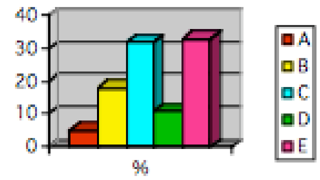
2) A family of skiers Dad (150 lbs), Mom (100 lbs) and their Child (50 lbs) come down the same green circle run, parallel to each other, starting off at the same time from rest. Their skis are of the same type and are waxed in an identical fashion, such that the small coefficient of friction (μ_k) between the ice and skis is the same for all three skiers. A picture of Dad is shown below. Which of the following statements is true? (Assume that the poles were not used by any of the three skiers during their descent.)
   A. ***The family skis down abreast of each other all the way down the slope to stop at the same distance d from point (B) shown: $d_{Dad} = d_{Mom} = d_{Child}$***
   B. The distance *d* traveled by the skiers is not the same: $d_{Dad} < d_{Mom} < d_{Child}$
   C. The distance *d* traveled by the skiers is not the same: $d_{Dad} > d_{Mom} > d_{Child}$
   D. The distance *d* traveled by the skiers cannot be specified without knowing the length and width of the skis used by the three skiers.
   E. The distance *d* traveled by the skiers cannot be specified without knowing the height of the skiers (because it determines their center of gravity).





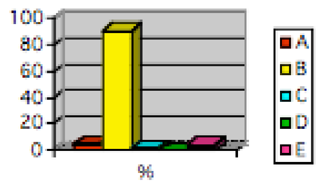
3) Two ice skaters John and Jane (John is twice as massive as Jane), "push off" against each other on smooth level ice, where friction is negligible. What is the relationship between the kinetic energy and momentum of the skaters after they start traveling apart from each other?

A. $K.E._{john} = K.E._{jane}$ & $p_{john} = p_{jane}$
B. $K.E._{john} = K.E._{jane}$ & $p_{john} = -p_{jane}$
C. $K.E._{john} = 2\ K.E._{jane}$ & $p_{john} = -p_{jane}$
D. $K.E._{john} = 0.5\ K.E._{jane}$ & $p_{john} = p_{jane}$
E. $K.E._{john} = 0.5\ K.E._{jane}$ & $p_{john} = -p_{jane}$



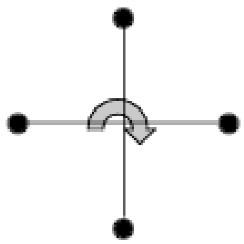
4) A student is initially standing still on frictionless ice rink. Her friend throws a ball directly toward her. After which of the following cases will the student be sliding on the ice with the greatest speed:

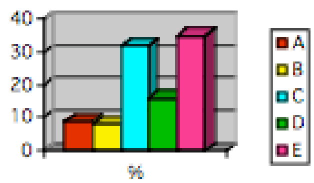
A. The student catches and holds on to the ball
B. The student catches the ball and then throws it back to her friend
C. The student catches the ball and then drops it (to reduce the total mass)
D. The student catches the ball and throws it in a direction away from her friend
E. The speed gained by the student is the same for all the cases above



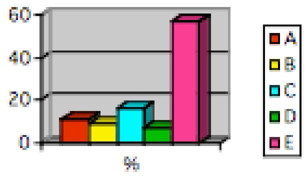
5) What is the moment of inertia of the system of four balls, with mass M and negligible radius, attached as shown in the figure below with two rods of negligible mass and length L, if it is spinning about the axis running through the center, perpendicular to the plane in which balls are located.

A. $0.25\ ML^2$
B. $0.5\ ML^2$
C. ML^2
D. $2\ ML^2$
E. $4\ ML^2$

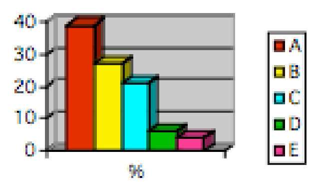




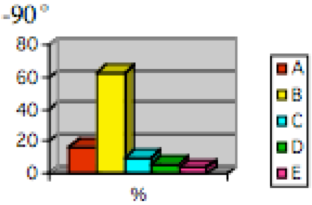
6) A physics professor makes a demo for his class on rotational motion. He ties a knot at the end of a 1-m long string, strings a 50-g nut (A) to that end. He ties another knot 0.1 m from nut A, and strings a second 50-g nut (B). He then sets an electric motor to spin the string with nuts at 10 revolutions per second. Unfortunately, during the class demo, the central knot tightens due to tension in the string, and the nut B slides to the nut A. What will happen to the angular velocity and angular momentum if the power output of the electric motor is unchanged during this process?
   A. Angular velocity and angular momentum will increase
   B. Angular velocity and angular momentum will decrease
   C. Both angular velocity and angular momentum remain unchanged
   D. Angular velocity increases and angular momentum remains constant
   E. Angular velocity decreases and angular momentum remains constant

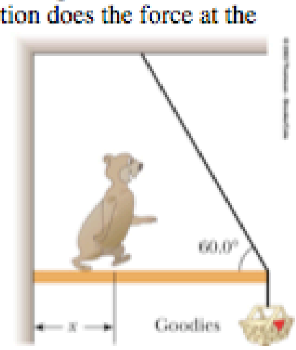


7) For the situation described in problem 6, ignore the size of the nuts and the mass of the string, and estimate the angular velocity of the string + nuts system in the steady state after the nut B slides to nut A:
   A. 9.0 revolutions per second
   B. 9.5 revolutions per second
   C. 10 revolutions per second
   D. 10.5 revolutions per second
   E. 11 revolutions per second



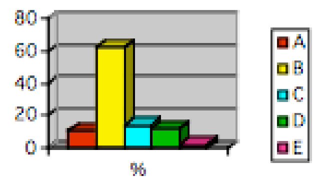
8) Consider the situation shown in the figure below. Use the coordinate system in which the origin is at the support of the wooden plank, the bear is walking in +X direction to the goodies, and vertically up is +Y direction. In which direction does the force at the support of the wooden plank point?
   A. 90°, i.e., along +Y
   B. Above 0° but below 90°
   C. 0°, i.e., along +X
   D. Below 0° but above -90°
   E. -90°, i.e., along -Y



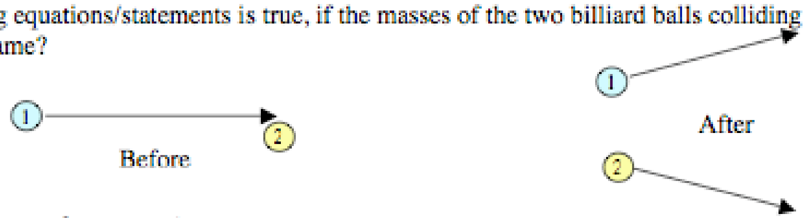


9) An astronaut of mass M is floating in the environment of her spacecraft and is initially at rest at the center of the spacecraft. She decides to get to the far end of the spacecraft by throwing the spacecraft operations manual (mass m) at her fellow astronaut who is at the controls at the head of the spacecraft. If the speed of the operations manual is v, at what speed does she strike the far end of the spacecraft?

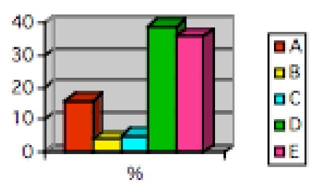
A. v
B. $v\, m/M$
C. $v\sqrt{\frac{m}{M}}$
D. $v\, m/(M+m)$
E. The astronaut will remain at the center of the spacecraft



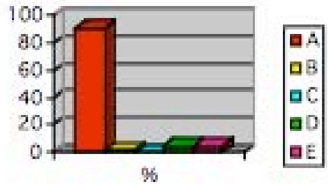
10) A billiard ball (labeled 1) collides with a stationary billiard ball (labeled 2) as shown in the figure. The collision is elastic but not head-on, and the balls roll off making angles θ and ϕ with the original direction in which ball 1 was traveling. Which of the following equations/statements is true, if the masses of the two billiard balls colliding are the same?

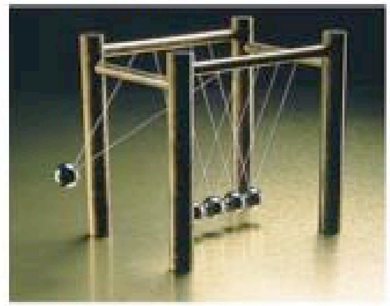


A. $v_{1f}\cos\theta + v_{2f}\cos\phi = v_{1i}$
B. $v_{1f}\sin\theta + v_{2f}\sin\phi = 0$
C. $v_{1f}^2 + v_{2f}^2 = v_{1i}^2$
D. Only A and B
E. A, B and C



11) The picture below depicts an *executive stress-reliever*. If the CEO of MicroScrap Inc. lifts one of the steel balls up and lets go and to strike the remaining four which were initially stationary with speed *v*, which of the following can happen? Assume that all the steel balls are of the same mass and collisions are elastic.

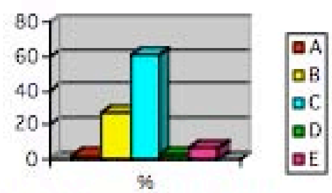




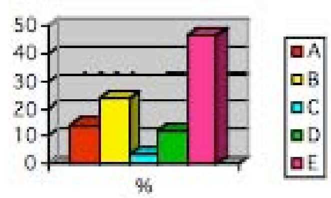
A. ***The right most steel ball moves with speed v, while the striking ball stays stationary after the collision***
B. The right most two steel balls move with speed *v/2*, while the striking ball stays stationary after the collision
C. The right most three steel balls move with speed *v/3*, while the striking ball stays stationary after the collision
D. All four stationary steel balls move with speed *v/4*, while the striking ball stays stationary after the collision
E. All five steel balls move with speed *v/5*.

12. A professional skier reaches a speed of 56 m/s on a 30° ski slope. Ignoring friction, what was the minimum distance along the slope the skier would have had to travel, starting from rest?

a. 110 m
b. 160 m
c. 320 m
d. 640 m
e. None of the above

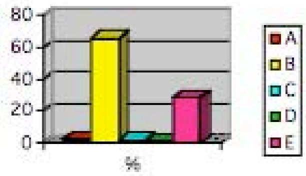


13. When an object is dropped from a tower, what is the effect of the air resistance as it falls?
a. does no work
b. does positive work
c. increases the object's kinetic energy
d. increases the object's potential energy
e. None of the above



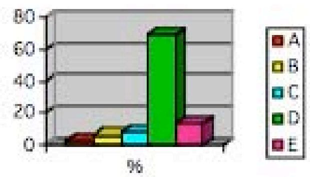
14. During a snowball fight two balls with masses of 0.4 and 0.6 kg, respectively, are thrown in such a manner that they meet head-on and combine to form a single mass. The magnitude of initial velocity for each is 15 m/s. What is the speed of the 1.0-kg mass immediately after collision?

a. zero
b. 3 m/s
c. 6 m/s
d. 9 m/s
e. none of the above



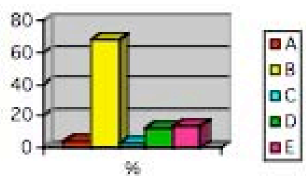
15. A machine gun is attached to a railroad flatcar that rolls with negligible friction. If the railroad car has a mass of 6.25×10^4 kg, how many bullets of mass 25 g would have to be fired at 250 m/s off the back to give the railroad car a forward velocity of 0.5 m/s?

a. 400
b. 2 000
c. 3 000
d. 5 000
e. none of the above



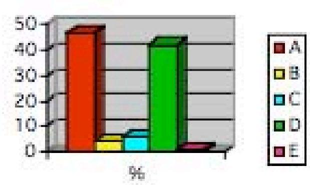
16. A railroad freight car, mass 15 000 kg, is allowed to coast along a level track at a speed of 2.0 m/s. It collides and couples with a 50 000-kg loaded second car, initially at rest and with brakes released. What percentage of the initial kinetic energy of the 15 000-kg car is preserved in the two-coupled cars after collision?

a. 14%
b. 23%
c. 86%
d. 100%
e. none of the above



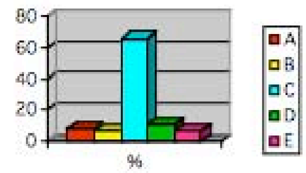
17. Of the nine known planets in our solar system, the innermost is Mercury. When compared to the other planets in the system, Mercury has the:

a. greatest centripetal acceleration.
b. greatest period of revolution.
c. smallest angular velocity.
d. smallest tangential velocity.
e. highest density



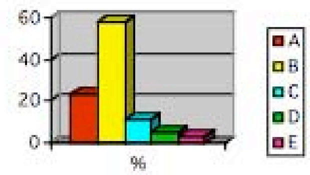
18. At what angle (relative to the horizontal) should a curve 52 m in radius be banked if no friction is required to prevent the car from slipping when traveling at 12 m/s? ($g = 9.8$ m/s^2)

a. 28°
b. 32°
c. 16°
d. 10°
e. none of the above



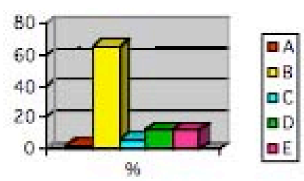
19. If a non-zero net torque and zero net force are applied to an object, that object will experience:

a. a constant angular speed, but does not experience any translation
b. an angular acceleration, but no linear acceleration
c. an increasing angular acceleration, but no linear acceleration
d. an increasing angular and linear acceleration
e. none of the above



20. A turntable has a moment of inertia of 3.00×10^{-2} kg·m^2 and spins freely on a frictionless bearing at 25.0 rev/min. A 0.300-kg ball of putty is dropped vertically onto the turntable and sticks at a point 0.100 m from the center. What is the new rate of rotation of the system?

a. 40.8 rev/min
b. 22.7 rev/min
c. 33.3 rev/min
d. 27.2 rev/min
e. none of the above



iv. Appendix D: Table of Student Responses & Average Exam Scores

Item #	% of Students who Disagreed/Agreed with Item[2]	Average Exam Score for Students who Disagreed/Agreed with Item[3]
1	**42**/35	53.5/62.9
2	**16**/52	57.9/58.0
3	29/**41**	59.7/56.9
4	**44**/30	56.0/57.3
5	36/**34**	56.3/58.5
6	49/**25**	59.4/56.0
7	26/**46**	59.6/57.3
8	**34**/34	60.8/55.4
9	**30**/40	56.9/58.8
10	**56**/14	57.6/60.0
11	53/**18**	57.8/58.0
12	**15**/49	58.5/56.4
13	**25**/47	57.4/58.3
14	**19**/48	57.1/57.6
15	**63**/14	58.1/57.9
16	**38**/31	56.1/60.1
17	**40**/35	60.9/54.1
18	32/**43**	56.6/58.7
19	**19**/58	60.9/56.3
20	**36**/32	60.8/54.8
21	**37**/41	60.4/57.8
22	**29**/37	57.2/56.6
23	**27**/40	55.4/60.0
24	**19**/52	56.6/57.0
25	39/**28**	55.5/59.3
26	31/**30**	57.4/58.7
27	**33**/33	56.2/58.7
28	**36**/37	58.8/55.8
29	**43**/28	59.2/55.2
30	28/**39**	56.0/60.1
31	18/**51**	54.5/59.0
32	11/**62**	56.1/57.5
33	**45**/28	55.5/59.9
34	12/**55**	56.2/56.8

[2] For each item, the choice that agreed with the expert view is bolded. Items 7, 9, & 34 had less than 80% expert agreement. The percent of students who chose "Ambivalent" can be calculated via subtraction from 100.

[3] All apparent differences in average exam scores for an item were statistically insignificant as measured by each average's standard deviation.