This is to certify that the
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TECHNOLOGY'S IMPACT ON STUDENT UNDERSTANDING AND RETENTION OF MOTION AND FORCES

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Major Professor's Signature

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TECHNOLOGY'S IMPACT ON STUDENT UNDERSTANDING AND RETENTION OF MOTION AND FORCES

By

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ABSTRACT

Technology's Impact on Student Understanding and Retention of Motion and Forces

With the increasing expectations put on students by both state and federal governments, teachers nationwide are including innovative methods into their classrooms. The possible inclusion of an online experience to be added to the graduation requirements prompted this research to explore the effects of implementing an online course management system (LON-CAPA) in conjunction with the utilization of calculator based labs (CBLs) using Vernier Labpro technology.

The intention of this thesis is to explore the effectiveness of including different types of technology on student understanding and retention. These techniques were introduced to high school physical science students during the units of force and motion. The sample student body consisted of 121 total ninth and tenth grade physical science students, 97 of which consented to the use of their data for this study.

The use of LON-CAPA significantly increased the amount of time students spent completing their individualized homework problems, which resulted in higher student achievement on similar problems on assessments. The electronic whiteboard kept the students attention, and, as a result, students were much more engaged in discussions. The calculator based labs were used to aide in student comprehension of graphical analysis. While the students enjoyed using the labpro technology, students' graphical analysis skills were not found to be significantly increased.

ACKNOWLEDGEMENTS

I would like to thank both Drs. Merle Heidemann and Ken Nadler for their support and guidance during this study. My classmates, Mike Bause and Andy Moore, were invaluable in their computer knowledge, assistance and diligence, keeping me on-task. I would also like to thank my colleagues, Michele Ellis, Bill Struck, Carmen Napolitano, as well as the rest of the staff and student body at Williamston High School, without whose help, this study would not have been possible. Finally, I would like to thank my wife, Roxanne, for her patience and support.

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CHAPTER I

INTRODUCTION

Today's society is inundated with technology, with computer applications, web-based programs and multiple personal communication devices. Students need to be prepared for using technology in the workforce. The No Child Left Behind act has heightened the awareness for the importance of effectively integrating technology into the classroom (North Central Regional Educational Laboratory, 2008). Effective integration of educational technology is a necessity in all curricular areas, especially science.

There are multiple types of technology that can be integrated into the classroom setting to enhance instruction and retention of curriculum. As reported by the North Central Regional Educational Laboratory,

> "Students can learn "from" computers – where technology is used essentially as tutors and serves to increase student basic skills and knowledge; and can learn "with" computers, where technology is used as a tool that can be applied to a variety of goals in the learning process and can serve as a resource to help develop higher order thinking, creativity and research skills" (2008, p. 3).

The model that I prefer is to have students learn with computers through the use of multiple types of technology in the classroom, while encouraging students to problem solve and think critically about course content.

It is essential to use multiple formats of media to promote student learning and retention. Multiple formats of instruction increase student motivation and interest in classroom activities (NCREL, 2008). Students' use of technology in the classroom has a significant effect on learning. There is a direct correlation between the amount of time spent using technology and students' success as measured by their success and responses on surveys (Krentler and Willis-Flurry, 2005). In the physical science classroom, LON-CAPA, Calculator Based Laboratory Experiments (CBLs), and the electronic whiteboard are effective means of technology to enhance student learning and retention. "Instruction in classroom settings where technology is not often used tends to be a whole-class approach, in which students generally listen or watch the teacher. Instruction in classroom settings where technology is moderately used has much less whole-class instruction and much more independent work" (Waxman and Huang, 1996). Students in classrooms where technology was effectively used were found to be on task significantly more of the time than students in classrooms in which technology was infrequently used or in which technology was slightly used (Ibid, 1996).

Learning Online Computer Assisted Personalized Approach (LON-CAPA)

LON-CAPA offers personalized or individualized computer-generated problems for students to solve. "Students are given instant feedback and relevant hints via the internet and may correct errors without penalty prior to an assignment's due date" (Kortemeyer, 2003). Each student receives similar yet different problems to solve, which leads to student-collaboration rather than student plagiarism of work. Brush (1998), indicated that "unique problem sets are an effective means for encouraging cooperative learning among the students while still maintaining individual accountability on the students' part, a key role to the success of cooperative learning among groups of students". The problems can be completed within the walls of the classroom or as meaningful homework, since students may access the internet-based LON-CAPA from any computer at home or in an after-school computer or homework lab setting. Though studies have shown positive reactions from students to on-line homework problems, no significant gains have been shown over problem sets assigned on paper (Kashy et. al. 1993). From a survey given to students at Williamston High School, over 93% of students surveyed have internet access at home (Appendix A). In addition, Williamston High School, where this study took place, has access to three wireless laptop carts so that a portable computer lab can be brought into any classroom.

I was first introduced to the LON-CAPA system by a colleague who implemented the course management system into his chemistry classes. In several conversations with this teacher, he noted the increased effort put forth by the students to seek outside help. In my previous five years of teaching at Williamston High School, I would occasionally have a former student come to me for assistance in chemistry, but when the LON-CAPA system was introduced, I immediately witnessed an increase in the number of students that were coming to me before and after school seeking help. Through interviews with the students that came for assistance I learned students were looking to one another, not just for answers, but for understanding. I realized the power of this system and, as part of this research, attended the LON-CAPA training course at Michigan State University, which was facilitated by one of its creators, Ed Kashy. The main purpose of this research was to integrate technology into my classroom and measure the effects on student achievement, thus the inclusion of the LON-CAPA system seemed to be a perfect platform.

In this study, the LON-CAPA system was used as a web-based, home-work application which allows instructors to assign individualized problem sets for each and every student. These problems can be one of many different types, including multiple-choice, true/false, calculations, or even essays. Course instructors are given the choice of authoring their own problems, or sharing problems with other teachers within the LON-CAPA system. One particularly helpful site within the system is THE DUMP (Teachers Helping Everyone Develop User Materials & Problems). The growing number of participating instructors ensures that there are thousands of ready made questions available to any level of instructor new to using the system. You are able to construct your own problems, or import any of the public access problems that have been published by colleagues. Each problem developed within the system is coded in XML or Perl if the problem deals with a numerical calculation. The author of the problem is able to set up certain elements to be randomized so the same problem will produce different answers for each individual student. For example, when developing a total distance problem, I randomized three different speeds and times. For each element, I had the system randomize a speed between 10 and 50 miles per hour, in 0.1 increments so the resulting speed would be 10.1, 10.2, 10.3 and so on to 50.0 miles per hour. I then instructed, or coded, the problem to use the individual quantities, to find the correct answer using those values instead of just a single correct answer.

The randomization within each problem is a wonderful tool for assessment. Because each value in the problem is random, no two problems will be alike in their answer. This eliminates the problem of students simply copying the correct work and answer from a fellow student. Students do collaborate on problems. However, instead of giving the answers to each other, they are teaching and learning the processes of completing the problems from one another.

Another parameter of these online problems which can be controlled by the instructor is the number of attempts each student will have to correctly answer the problems. These attempts can be increased depending upon the difficulty of the question. Most multiple choice or true/false type questions can be assigned just one or two attempts, while the more difficult calculation problems can be assigned multiple tries, with hints that can be given to the students after a predetermined number of attempts.

The LON-CAPA system has a message board that instructors can utilize if they wish. Students are able to post questions online to which either the instructor can answer, or other students can answer by describing how they were able to calculate their problem correctly. The messages can be posted at the bottom of each problem so the students are able to ask specific questions pertaining to that individual problem. The individual nature of these problems encourages cooperative learning, while retaining accountability for every student (Brush, 1998).

Calculator Based Labs (CBLs)

The generation and interpretations of graphs, tables and diagrams is a key activity of scientists. Learning to produce, read and critique these graphs should therefore be an ingredient in any science classroom (Bowen, et. al, 1999). The use of CBLs is a quick and efficient way for students to collect and analyze data for a given experiment. Unfortunately, students are not utilizing this technology in most high school science classrooms, especially in the area of Physical Science (Vernier, 2006). Even though it has been suggested that the implementation of CBLs holds promise for enhancing and enriching learning opportunities for students (Aarstad, 1997; Colman and Colman, 2003; Graham and Smith, 2004), CBLs have not become a permanent fixture in the science curriculum of most middle schools and high schools (Vernier, 2006).

Microcomputer-based laboratories were first introduced in the early 1980s, making data acquisition quicker and more accurate (Eisele, 1982). The "CBL system consists of a small hand-held unit to which different probes may be attached" (Arnold, 1998). This probeware is becoming less expensive, "and improvements in hardware and software have made it more accessible to students and teachers" (Hisim, 2005). Due to the success of their predecessors, in the early 1990s, sophisticated graphing calculators were developed, which allowed interfacing between sensors, the calculator, software programs and the computer (Texas Instruments, 1995).

Students hold a multitude of graphing misconceptions such as treating a graph as a picture (Barclay, 1985), and many others have difficulty making real world connections with physical concepts and graphs (Goldberg and Anderson, 1989). Real-time graphing technology incorporated into these CBLs can enhance graphical understanding. Providing the students with a kinesthetic experience makes these labs effective. Students manipulate physical lab materials, as in this study, a basketball or coffee filters, and use their own physical movements to produce data (Kwon, 2002).

Graphs are important tools, enabling students to predict relationships between variables. They also help make the nature of these relationships concrete

(McKenzie & Padilla, 1984). "Monk (1994) claimed that large numbers of students have little or no basis for arriving at an understanding between a graph and a real-life situation. In choosing or constructing a graph to describe a given aspect of a physical situation, students frequently favored a graph that resembles a "picture" of a situation, rather than a graph that adequately illustrates the behavior of the variables involved" (Clement, 1989; McDermott, Rosenquist, and van Zee, 1987).

> "The use of CBL activities allow for frequent repetition and numerous opportunities in experiencing graphing physical phenomena. These activities might reinforce students' concepts of different shapes of graphs representing different classes of motion events" (Kwon, 2002).

Also, "real-time data collection seems to be the most effective way to connect a graph with the real-world experiences of the student" (Brassell, 1987).

Use of Technology in the Classroom for Instruction

Electronic whiteboards systems, which include a computer, a projector and the whiteboard, are "often referred to by such brand names as Smartboard® or Mimio Board®. They look very similar to the traditional whiteboards or chalkboards teachers use to display information to their students" (Education World, 2007).

> However, "the electronic versions have capabilities far beyond those of their low-tech predecessors. In addition to simply displaying information, they also allow teachers to save what they have written or drawn and send it to students' computers, to navigate computer files and Web sites, and to interact with online information with a touch of the finger" (Education World, 2007).

While 80% of teachers in America use computers for administrative functions, only half of them are integrating computers into their daily curriculum (Rother, 2005).

> "One of the major reasons for the lack of use of this technology is that most educators feel that they have not received enough training to make the most of the technology in their classrooms" (Rother, 2004).

Currently, instructors rely most heavily on a few relatively low-end and well-established technologies: the overhead projector, the DVD player and the PowerPoint® presentations (Brill and Galloway, 2007).

> "Electronic whiteboards, educators report, assist in lesson planning, support diverse learning styles, and provide a needed tool for graphic representation in math, science, and art classes. Most importantly, they engage students, particularly when the learning is student-driven" (Education World, 2007).

The "interactive electronic whiteboard is great for demonstrations. Because the presenter can run the application from the board, using his finger like a mouse, it is easy to show the important features of particular software. The ability to mark on the board by writing with the stylus or using one's finger makes it possible to point out important features of the demonstration. The board can accommodate different learning styles. Tactile learners can benefit from touching and marking at the board, audio learners can have the class discussion; visual learners can see what is taking place as it develops at the board" (Bell, 2002). The interactive nature of the electronic whiteboard creates the most excitement for both staff and students. Students are very enthusiastic and want to have a hands-on role (Smith and Fellows, 2000).

> "Teachers need on-going support, especially if time elapses between the initial training and the teacher's "turn" with the board. All teachers need time to practice with the board and its accessories. They need to acquaint themselves with presentation software, and develop contexts for its effective use" (Smith, 1997).

The purpose of this study is to determine the impact of using several types of instructional technology, introduced above, on student understanding and retention in the motion and force unit in physical science classes.

Context: Physical Science

I introduced the LON-CAPA system, the CBLs, and the electronic whiteboard to all of my physical science classes at Williamston High School during the 2006-2007 school year. Williamston, with a population of approximately 3,500 people, is a rural bedroom community, and is located approximately 15 miles east of Lansing, Michigan. Williamston High School has approximately 670 students, primarily Caucasian and middle class. Over ninety-three percent of the students are white, 3.0% Hispanic, 2.1% Asian/Pacific Islander,1.2% African American, and 0.3% Native-Americans. The average household income in Williamston is $51,000. Only 7% of the students are classified as economically disadvantaged. The State of Michigan average is 35.2% (School Matters, 2007).

The Physical Science course at Williamston High School, taught during the 2006-2007 school year, is an introduction to both chemistry and physics, with a review of Earth History during the last ten weeks. I taught five sections of Physical Science, with a total of one hundred and twenty-one students. Williamston was in the process of moving Physical Science from a required tenth grade class to a ninth grade class during the study year. Because of this, 52.9% of the students were from the ninth grade while the remaining 47.1% were from tenth grade. Of the one hundred twenty-one students in my classes, ninety-seven gave permission for me to use their data in this study. All students at Williamston High School are required to take Physical Science so the demographic of the classes is the same as the entire school.

The Force and Motion unit was taught early in the second semester, at the beginning of the introduction to physics portion of the curriculum.

CHAPTER II

IMPLEMENTATION

One of the goals of this study was to incorporate the use of technology into the motion and force unit. This was accomplished by including, in all classes, different activities that used CBLs, along with the standard activities that I had used in previous years. A second goal was to determine whether the use of the electronic whiteboard had any effect on student performance. To study this, two classes, out of five, were selected to receive instruction, such as content notes, using the traditional methods. These methods included lecture and notes written on a chalk board and demonstrations done by the instructor in the front of the classroom. The three other classes were given the same instruction, lecture notes, and demonstrations , but utilizing the electronic whiteboard. Out of the ninety-seven total students participating in this study, forty were in the classes selected to receive instruction on the chalk board and traditional methods, the remaining 57 students received instruction on the electronic whiteboard. Prior to this study, students were introduced to the LON-CAPA homework system. Lap-top computers were brought into the classroom and students were instructed how to access the system and how to navigate through the on-line course materials and answer their assigned homework problems.

All classes at Williamston High School during the study year were 55 minutes in length and met five times per week.

Tables 1 and 2 summarize the motion and force unit, indicating what topics were covered for the particular day, which objectives of the unit were being addressed (Appendix A), and the assessments used to measure student understanding.

Week/Day	Topic/Activity	Objectives	Assessment
Week 1 / Day1	Motion and Force Pre-Test, Intro to Speed and Velocity, Frame of Reference	Understand motion and how it relates to a frame of reference.	Speed Calculations Worksheet, LON-CAPA Motion Problems
Week 1 / Day 2	Review Speed, Velocity, Frames of Reference. Review Motion Problems. Introduce Motion Lab	Calculate average speed given a change in position and time.	Motion Calculations
Week 1 / Day 3	Introduce Lab Pros with Palm Pilots. Motion Lab	Create line graphs.	Lab Write Up
Week 1 / Day 4	Review Motion Lab Acceleration, Acceleration due to gravity.	Create and analyze motion graphs, solve velocity and constant acceleration problems.	Speed/Velocity/Acceleration Calculations, LON-CAPA Acceleration problems
Week 1 / Day 5	Acceleration Lab	Describe and analyze the motion that a position-time graph represents.	Lab Write Up
Week 2 / Day 1	Complete Acceleration Lab, LON-CAPA in class. Describing Motion with Graphs	Given a graph, describe and analyze the motion that a velocity-time graph represents.	Describing Motion with Graphs Hand Out
Week 2 / Day 2	Review Labs, Speed and Acceleration Calculations, Units	N/A	Determining Speed(Velocity), Acceleration Calculations
Week 2 / Day 3	Air Resistance Lab	Determine force of friction of air, terminal velocity	Lab Write Up
Week 2 / Day 4	Review for Quiz, Review LON-CAPA Motion Problems	N/A	

Table 1 – Overview of Motion Unit

Week/Day	Topic/Activity	Objectives	Assessment
Week 2 / Day 5	Motion Quiz, Forces Introduction, Newton's Laws	Identify forces between objects	Motion Quiz, Force LON-CAPA Problems open
Week 3 / Day 1	Review Forces, Friction	Identify the basic forces in everyday interactions	Force and Friction Problems
Week 3 / Day 2	Friction Lab	Calculate forces on an object on an inclined plane.	Lab Write Up
Week 3 / Day 3	Net Forces and Acceleration	Calculate net force acting on an object. Force equal mass times acceleration	Working with Forces
Week 3 / Day 4	Forces and Motion Review	N/A	LON-CAPA Problems
Week 3 / Day 5	Forces Review LON-CAPA help	N/A	
Week 4 / Day 1	Force and Motion Review	N/A	
Week 4 / Day 2	Force and Motion Unit Test	N/A	
Week 4 / Day 3	Force and Motion Post-Test	N/A	

Table 2 – Overview of Force Unit

Description of Activities

For all lab activities, students were randomly assigned to a group of four students. Each lab, students worked with different lab partners, and each student turned in their own set of data tables, graphs and answers to questions. During the each lab, students took turns doing each of the tasks required in the activity such as the timer, the data collector, etc.

New material and demonstrations presented to the students in the selected three classes was delivered on the electronic white board while material in the other two classes was presented on the chalk board and demonstration were performed by the instructor in the front of the classroom. With the electronic white boards, lecture notes were developed on the computer and displayed using an overhead projector. These lecture notes were saved and printed for any student who was absent for that particular class. Students absent in the two classes not receiving instruction on the electronic white board were given copies of student notes. When students were asked to share problem calculations with the rest of the class, in the three selected classes, they were allowed to present their solutions using the electronic white board while students in the remaining two classes wrote their solutions with chalk on the black board.

LON-CAPA problem sets were assigned on the first day of motion instruction and the first day of force instructions. Students were allowed thirteen days to complete the motion problems and seven days to complete the force problems. On calculations problems, students were allowed five attempts, and two attempts were allowed on the multiple choice questions. In previous LON-CAPA problem sets assigned to the students, no more than five attempts were usually needed by the students to correctly answer the calculation problems, and any more than two attempts at a multiple choice question seemed to allow the students to guess at the correct answer instead of working for understanding. When students entered an answer into LON-CAPA, the system would provide immediate feedback by displaying a red box informing the student they were incorrect. Students are allowed to view previous answers they have entered before attempting the problem again. When a student enters a correct answer, the system informs them using a green box. Students that did not have internet access at home, which was less than 10% (n=9), were allowed to go to the computer lab and print out their problem sets to complete their calculations.

They were then able to enter their answers during class when the lap-top computers were available.

The mastery of the motion and force objectives (Appendix B) was measured using the same assessment as a pre-test and post-test (Appendix C-1). The pre-test was given to students before instruction to assess the students' prior knowledge of the material. The same test was given post instruction to determine which objectives the students had mastered. The test was comprised of twenty questions. Two questions were on graphical analysis, both describing motion of an object on a given graph, and construction of graphs given an object's motion. Six questions were calculations involving motion and force (three motion problems and three force problems). The remaining twelve questions were short answer type questions covering the material presented on motion and forces.

Daily Activities

Day 1: The Motion and Forces Pre-Tests (Appendix C-1) were administered. Students were then introduced to the topics of speed and velocity and how both are related to a frame of reference. Sample speed calculation problems were performed and practice problems were handed out as homework (Appendix C-2). Students were also informed that their motion LON-CAPA problems (Appendix C-3) were open and that they would have two weeks to complete the online set. The LON-CAPA problem sets were due by 11 pm the night before the motion quiz(Appendix C-8) and motion and force unit test (Appendix -C11).

Day 2: Students wrote out solutions to the motion homework problems on the board to check for understanding. The last half of the class was used to introduce the CBL equipment (the Lab-Pro®, the Palm Pilot® and the sonic motion detector) that was to be used with the Motion Lab (Appendix D-1) on the following day. Motion Labs (Appendix D-1) were given to the students so they were able to read the lab protocol before class.

Day 3: Students had their first CBL experience (Appendix D-1). Students produced motion graphs by walking away from the sonic motion detector at a constant velocity. They then produced a distance vs. time graph and a velocity vs. time graph for some type of non-uniform motion that the lab groups were to decide upon.

Day 4, 5 and 6: The topic of acceleration was introduced. Lecture notes were presented and examples demonstrated. Speed, velocity and acceleration problems (Appendix C-4) were given to the students to complete at home. The following day, students performed an acceleration CBL (Appendix D-2). Students dropped a large ball from a height of 2 meters underneath the sonic motion detector. Students were then to developed graphs generated by the sonic motion detector. The student lab groups of four were to develop their own procedure that would yield distance vs. time graphs showing constant velocity of an object and another showing an accelerating object. Next, students produced velocity vs. time graphs for the same situations. Students had some difficulty completing the acceleration lab, so they completed the lab on day 6. The wireless laptop computers were brought in after completion of the lab in order to give students the opportunity to have some in class time to complete the motion LON-CAPA problems. Also, while correcting the previous labs and homework, I noticed that the students were having problems making their own graphs and interpreting graphs. Another practice sheet for students to describe motion with graphs was developed for students to complete (Appendix C-5).

Day 7: As a class, we discussed the "describing motion with graphs worksheet" (Appendix C-5), and the acceleration lab (Appendix D-2). Students were having difficulty with assigning the correct units to their answers, so additional practice problems were assigned (Appendices C-6 and C-7). After a few selected problems were demonstrated by students, the Air Resistance Lab (Appendix D-3) was distributed for the students to prepare for the following day.

Day 8: Students performed the air resistance lab (Appendix D-3). They determined an object's terminal velocity as well as an experimental determination of the acceleration due to gravity. This was achieved by dropping a coffee filter from height of 4 meters underneath the sonic motion detector. The acceleration due to gravity was experimentally determined by calculating the slope of the line produced by the hand held Palm Pilot®.

Day 9: As a class, we reviewed motion for a quiz (Appendix C-8). LON-CAPA questions were answered and more sample problems were worked as a class. The LON-CAPA questions were due by this evening. Students were encouraged to have all of the questions attempted before the quiz the next day.

Day 10: The motion quiz (Appendix C-8) was administered. Students were quizzed over simple motion problems, including speed, velocity, acceleration and momentum. After the motion quiz, forces and Newton's laws were introduced. The LON-CAPA force problems (Appendix C-9) were opened at this time.

Day 11: The class began with a review of forces and example problems were performed and friction was introduced. Practice force and friction problems (Appendix C-10) were done in class and students wrote out the solutions on the electronic white board or the black board. The friction lab (Appendix D-4) was given to the student to prepare for the lab on the next day.

Day 12: Student performed the friction lab (Appendix D-4) by pulling wood blocks up an inclined plane using a scale. The scale registered the amount of force necessary to move the block up the plane. Students calculated the force of static and sliding friction for one and two blocks of wood. Williamston High School does not have the force probes to use the CBLs so hand-held spring scales were used.

Day 13: The concept of net forces and how unbalanced forces will cause a mass to accelerate was introduced. The worksheet, "Working with Forces and Friction", (Appendix C-11) was assigned for homework.

Day 14: Again, as a class, we reviewed forces and friction. LON-CAPA questions were brought up and time was spent going over examples of force and friction problems. Students displayed calculations on the electronic white board and black board.

Day 15: All objectives for the motion and force unit were reviewed. Sample problems were worked as a class on the electronic white board and the black board.

Day 16: The motion and forces unit test (Appendix C-12) was administered and the pre and post test (Appendix C-1) was given on the following day.

CHAPTER III

RESULTS

Assessment of this study were obtained by administering a pre-test prior to instruction to gauge prior knowledge, and a post-test immediately after the unit was completed.

Pre and Post-Test Scores

The average score on the pre-test was 9.6% while the average score on the post-test was 73.9%. Figure 1 illustrates how students performed on each test item.

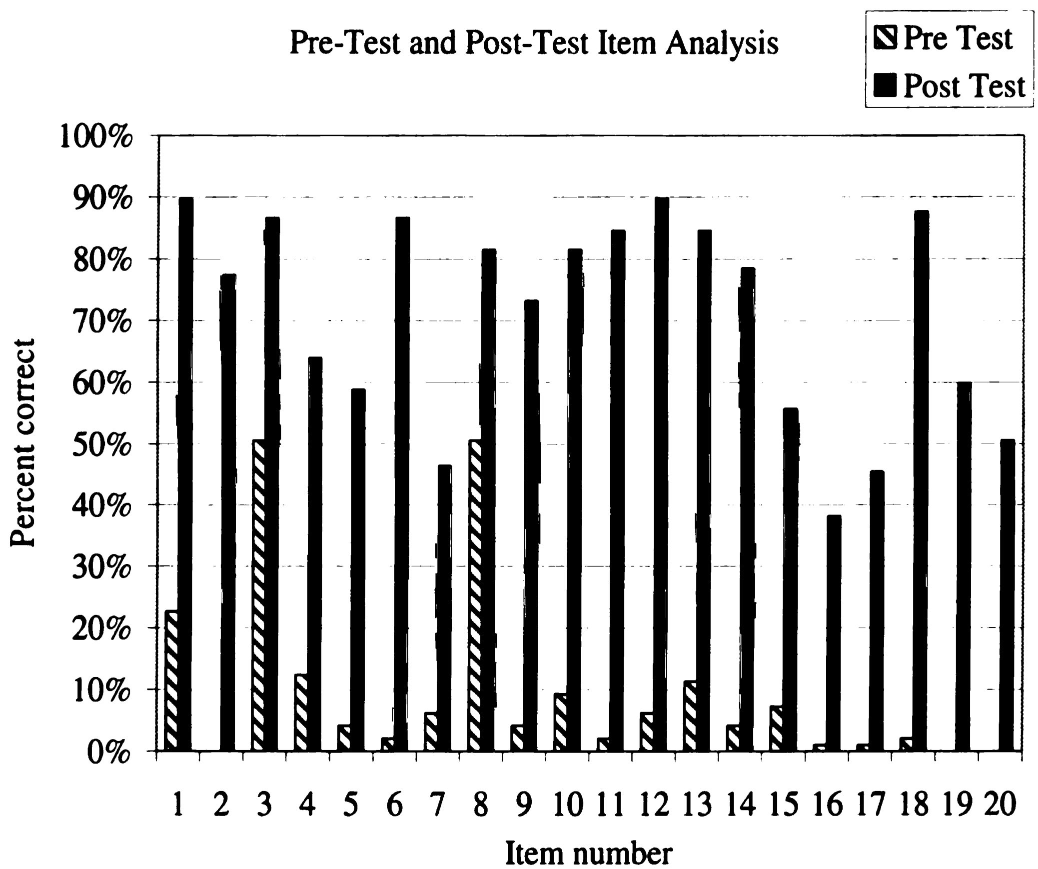


Figure 1: Pre-Test and Post-Test Item Analysis (n = 97)

Significant gains were made on all test items. Using a paired t test for analysis, the data from figure 1, $p < .0001$, suggesting that the students' comprehension of the objectives for the motion and force unit increased due to the instruction. Items 12, 13, 14, 18, 19 and 20 were LON-CAPA type calculation problems. The first three were motion calculations, and the last three were calculations dealing with forces and friction. Items 3, 4 and 7 were graphical analysis questions and the eleven remaining items were motion and force content questions.

LON-CAPA Problem Sets

Because each student was given five attempts at each calculation problem and two attempts for all multiple choice question for both problem sets, those students attempting all of the problems received full credit. Out of the 97 students, 92% successfully answered the online problems sets (Appendices C-3 and C-9). This is compared to only 76% of the students completing the hand out problems (Appendices C-2, C-4, C-5, C-6, C-7, C-10, C-11). On the pre and post-test assessments, the calculation problems that resembled the LON-CAPA problems saw an increase of from 7.2% up to 75.1%. Results are illustrated in Figure 2.

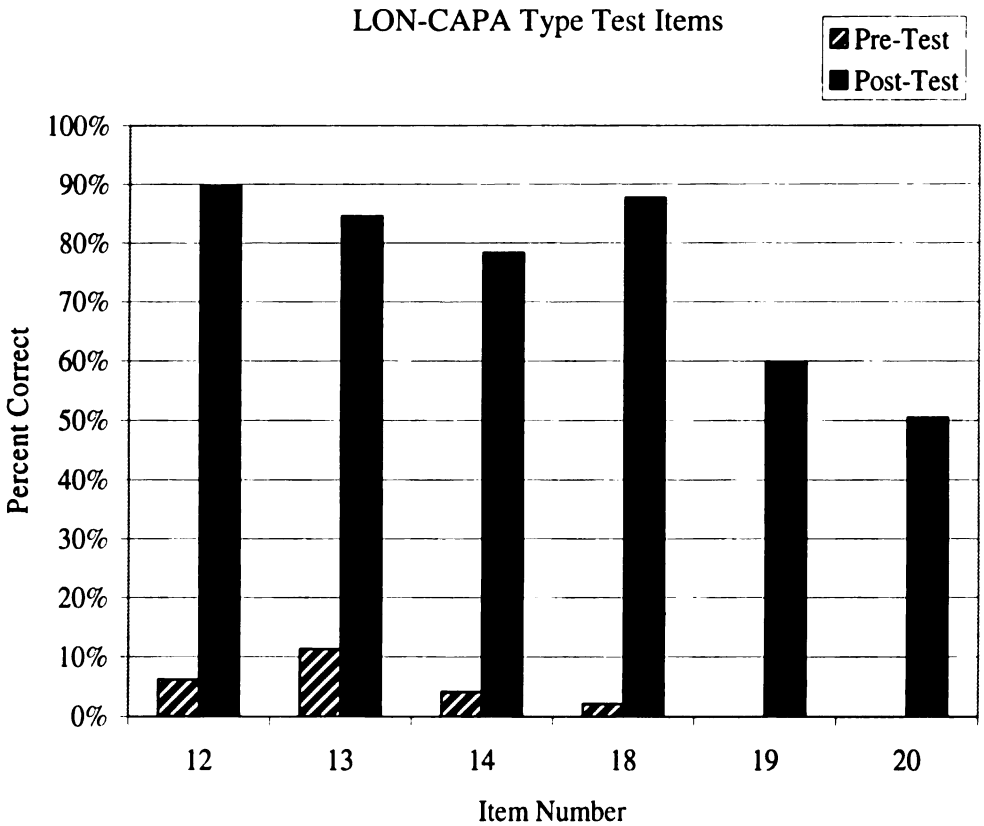


Figure 2: Pre-Test/Post-Test LON-CAPA Type Test Items (n = 97)

Again, significant gains were seen on all test items that were LON-CAPA type problems, indicating that understanding of the calculation objectives increased through instruction and use of the on-line homework system.

Graphical Analysis Problems

Problems where the students described the motion on an object from a graph showed an increase from 31.4% up to 75.3%, while problems where students had to graph the motion of an object went up from 6.2% on the pre-test up to 46.4% on the post-test (Figure 3).

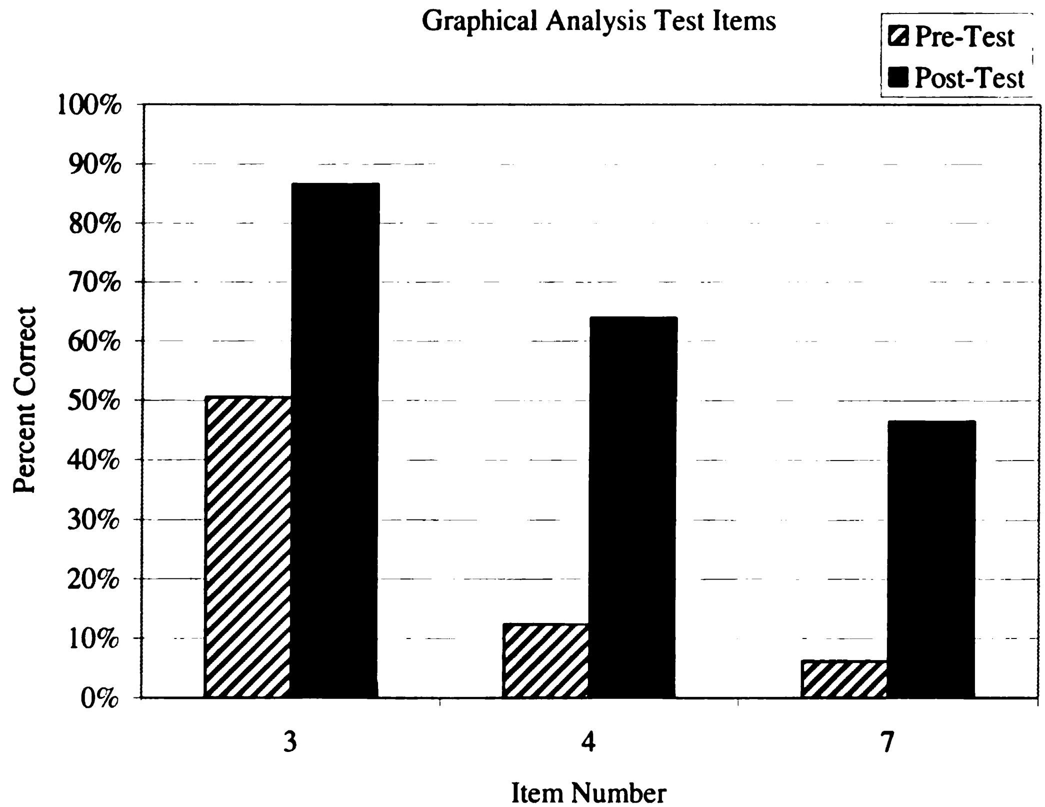


Figure 3: Graphical Analysis Test Items

Test item number three asked students to describe the motion of an object, given a graph. Item number four required students to calculate an average velocity of an object, given a graph. Test item number seven required students to create a line graph of a described motion.

Use of the Electronic Whiteboard

I selected two classes to receive instruction on a regular black board (BB) while the other three classes were instructed using the electronic whiteboard (EWB). Of the 97 students participating in this study, 40 students were in the classes receiving instruction on the black board while 57 students saw notes and examples on the electronic whiteboard. Eleven questions were selected on the pre-test and post-test that were lecture, discussion or note oriented. Of the eleven questions, the students in the classes where the electronic whiteboard was used scored an average of 4.1% higher than the students not seeing the electronic whiteboard. A paired t test of the data in figures 4 and 5 resulted in a p value greater than 0.05 (0.454), indicating there was no statistical difference in the results. Averages for ten out of the eleven questions were higher for the classes instructed on the electronic whiteboard, but those students had higher pre-test scores. Figure 4 illustrates the item analysis for the pre-test and figure 5 illustrates the item analysis for the post-test.

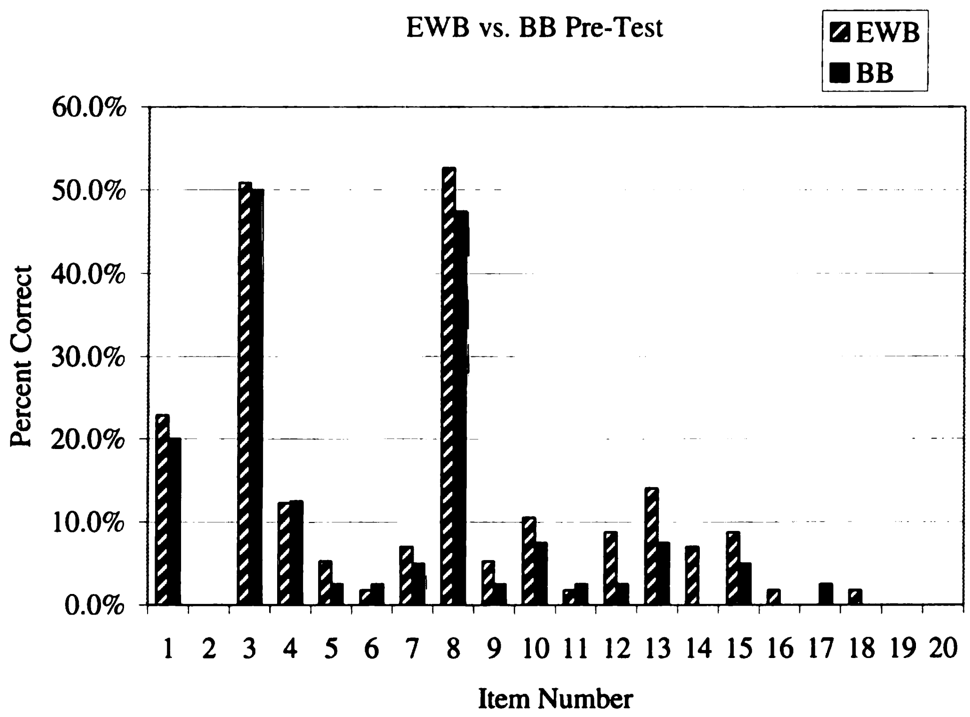


Figure 4: Pre-Test Item Analysis for Students Instructed on the Electronic White Board (EWB) n = 57 vs. Students Instructed on a Black Board (BB) n = 40

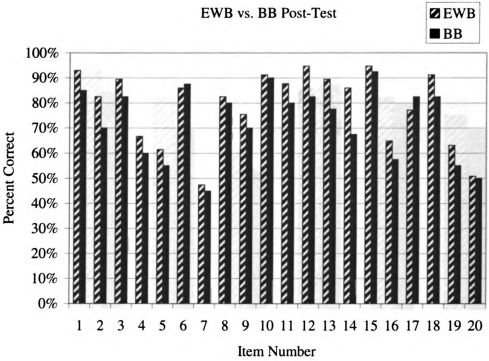


Figure 5: Post-Test Item Analysis for Students Instructed on the Electronic White Board (EWB) n = 57 vs. Students Instructed on a Black Board (BB) n = 40

Figures 4 and 5 show the validity of the Pre-Test and Post-Test. A "random" splitting of the 5 sections resulted in consistent results. Students instructed on the electronic white board and those instructed on the black board had similar scores on all test items, both prior to, and after instruction.

Six test items addressed motion objectives. Figure 6 illustrates how students instructed on the electronic white board performed compared to the students instructed on the black board (BB) on these selected items. Students instructed on the electronic white board scored had a higher average for 5 of the 6 items, although a paired t test on the data in figure 6 gave a p value greater than 0.05 (0.328), so the higher performance is not statistically significant.

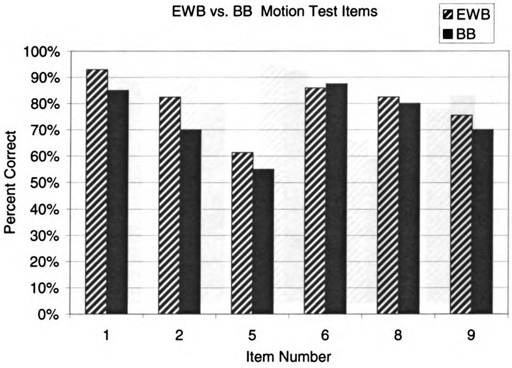


Figure 6: Performance of Students Instructed on Electronic White Board (EWB) n = 57 vs. Students Instructed on Black Board (BB) n = 40 on Motion Test Items

Figure 7 illustrates how students instructed on the electronic white board (EWB) performed compared to the students instructed on the black board (BB) on the five force related test items. Students instructed on the electronic white board again scored higher on all five selected items, but again, using a paired t test, I calculated a p value over 0.05 (0.288) showing that the difference is not statistically significant.

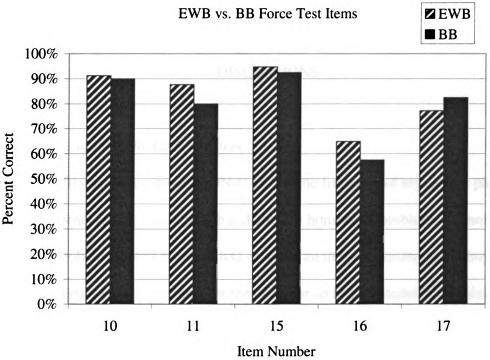


Figure 7: Performance of Students Instructed on Electronic White Board (EWB) n = 57 vs. Students Instructed on Black Board (BB) n = 40 on Force Test Items

CHAPTER IV

DISCUSSIONS

Effectiveness of the LON-CAPA System

My first experience with LON-CAPA came from one of my former physical science students asking for help with a chemistry homework problem for another teacher. I probably would not have had much of an interest pursing an online homework system had it not been for the dozen or so former students that also came in for help over the next several days. What struck me first was how these students were taking it upon themselves to get outside help. Students indicated that they came to me because this was material we had introduced the previous year and they felt comfortable coming to ask for assistance. As I was helping these students, I noticed all of the problems were similar, yet they all had different answers. I then went to the chemistry instructor and inquired about the LON-CAPA system. I was extremely impressed with the problems sets and how much time the students were putting in to solving these homework problems. I immediately wanted to put this type of application into my courses and analyze its effectiveness.

The initial set up of the online homework system does take a great deal of preparation. I took the three day LON-CAPA course at Michigan State University, June 12-14, 2006, facilitated by Felica Berryman. Another time consuming aspect is authoring LON-CAPA problems, but a new user need not author all of their own problems for there is a plethora of already authored problems available for public use on Michigan State's server known as "THEDUMP". It is wise to go through and complete any problems you plan on assigning to check for any errors.

After introducing the LON-CAPA system, I was impressed with the completion rate of the homework sets. Typical completion rates for my handed out homework sets was anywhere from 75% to 85%, but with the LON-CAPA sets, I saw completion rates rise to over 90%. I also saw an increase in students seeking extra help before and after class. Typically, with a homework set handed out in class, I would have one or two students come into my classroom after school for extra help. When both LON-CAPA problem sets were assigned in this study, I saw an average of 3 students in my classroom after school, every day, until the problem set was closed. With the traditional homework problems, students would work out the solutions and then turn them in without knowing whether they were correct or not. The LON-CAPA system gives the students instant feedback, giving them a green text box if the answer was correct, or a red text box if the answer was incorrect. I started calling this "The Power of the Green." Observing the students while they worked on their problems with the laptop cart in class, it was amusing as they'd answer their problem and then cross their fingers, saying, "Come on Green," as they waited for their answers to be submitted. Conversations with the students revealed that they liked the aspect of getting that instant feedback, but they were not happy that they could not just get an answer from a classmate since every problem was individualized and every student would have a different answer. The fact that students could not receive answers from classmates increased the amount of questions in class discussion, as well increased the amount of discussion between students. The LON-CAPA system allows students to post questions that can be answered by either myself or other students. This led to much more student-student interaction, which seemed to be extremely beneficial for all of the concerned students.

One problem that arose with the LON-CAPA system was the small margin of error allowed for students answers. I could have gone into the course parameters and widened this margin, but I wanted to stress to the students that they had to incorporate significant figures into their calculations, a concept that we had covered earlier in the school year. This problem was solved by allowing the students to have five attempts at each calculation question.

Qualitative Assessments of CBLs vs. Traditional Labs

The CBLs made data collection much more accurate and easier for students. This made it possible to complete labs in the class time provided with several trials versus the traditional lab where students usually were only able to collect one set of data. Unfortunately, having the graphs produced by the hand held palm pilots decreased the ability of the students to produce their own graphs when asked to do so on assessments. This is seen in the performance of students on the test items where they were required to produce a graph given the motion of an object. Students scored only an average of 50% on those selected test items. Test item number 4 gave students a graph and asked them to calculate the average velocity of the object over the entire time. Students scored an average of 63% on that item. Test item 7 gave the students two blank graphs, one velocity vs. time, the other distance vs. time, and asked them to draw a line on the graphs representing an object that was accelerating.

Students only scored an average of 46% on this test item. Students were able to correctly describe motion of an object given a graph, but when asked to graph a described motion, they tended to draw a line that depicted the picture of the motion instead of looking at the axes and producing an appropriate line.

Another drawback to the CBLs is that students like to "tinker" with the technology. These students have now grown up with technology all around them and have no fear of these devices. Many students had to be redirected to lab activities instead of discovering that they could take pictures with the palm pilots and "beam" them to other groups' handheld devices, or that they could text message their friends in the class and leave messages for other students in later classes.

I think a cross of the CBL and the traditional lab would have been beneficial to my students, having the data be collected with the technology, but then the graphs have be created by hand. This would have taken more time, but I feel the students would have gained a better understanding of how to produce a graph that correctly depicts the motion they observed.

Use of the Electronic Whiteboard

My district, Williamston Schools, passed a bond two years ago with money set aside for technology. As a staff, we were asked for volunteers to pilot classes with an electronic whiteboard. Since I was doing this study, I felt it would be beneficial to add this type of technology to my study. Unfortunately, there was no training that went along with it, and it took a considerable amount of time on my own to learn how to effectively use the electronic whiteboard. The results on the test items covering the content delivered during lectures or demonstration did not show a significant increase between the electronic white board vs. the black board. Average scores on questions based on the electronic whiteboard only went up 4% (figures 6 and 7). These data produced a p value of greater than 0.05, leading me to conclude that the increase was not statistically significant, but I saw an immediate increase in the participation of the students instructed on the electronic white board. The exact same lessons, with the same material presented, yielded much more student interaction when the electronic whiteboard was used. Students were much more eager to share their solutions to problems when they had the opportunity to use the electronic whiteboard.

Showing examples to the students was also much more meaningful. The use of streaming videos allowed me to show several different examples in a relatively short amount of time. Again, this takes time for preparation, but the rewards are well worth the effort.

Conclusions

The effective use of technology has a significant impact on student education. This success may not always come in the form of performance on assessments, but in the form of genuine interest. The use of technology brings an excitement factor to learning that many students do not get from a chalkboard or a textbook. Today's students are surrounded by technology every minute of the day, from their cell phones and iPods, to their video games and home computers. Bringing technology into the classroom capitalizes on how students interact with their everyday world.

With all of the technology available to teachers today, it is inexcusable for them not to attempt to better their instruction with the use of these tools. We try to impart on our students how they should become lifelong learners. We, as teachers, need to lead by example, taking the time to extend our knowledge, adapting our teaching strategies with the introduction of each new technological advance. Contrary to popular belief, you can teach old dogs new tricks. It just takes a little more time and preparation.

Future Goals

I would like to incorporate all of these technologies into other courses I currently teach at Williamston High School. It will be interesting to see how the hand held probes can be utilized in a different scientific field, Biology. I intend to set up another online course for my biology students as well as expand the use of LON-CAPA in physical science to several different units, if not the whole course. I would also like to attend more training for the use of the electronic whiteboard. I know that I am only utilizing a fraction of its capabilities. I would like to be able to produce more interactive lessons, allowing more student involvement with the use of the electronic whiteboard.

Appendices

Appendix A

Internet Survey

Sept, 4, 2006

Dear Parents/Guardians,

This year we will be using an on-line homework system called LON-CAPA. Your student will need to be able to access the internet to complete these problems. If you do not have internet access at home, access will be allowed at school, in the media center, any day before or after school. Class time will also be provided to enter answers.

Please check the appropriate box below and sign the form at the bottom. Thank you, and if you have any questions, please feel free to contact me at prestoj@wmston.k12.mi.us, or call me, 655-2142, ext. 7360.

Mr. Preston.

- ☐ Yes, we have internet access at home.
- ☐ No, we do not have internet access at home.

________________________________ ____________

Parent/Guardian Signature Date

Appendix B

Objective 1:

Motion is defined as a change in position over a time.

Objective 2:

Describe and compare the motion of an object using different frames of reference.

Objective 3:

Calculate the average speed of an object using the change of position and elapsed time.

Objective 4:

Create line graphs using measured values of position and elapsed time.

Objective 5:

Given a graph, describe and analyze the motion that a position-time graph represents.

Objective 6:

Solve problems involving average speed and constant acceleration.

Objective 7:

Given a graph, describe and analyze the motion that a velocity-time graph represents.

Objective 8:

All objects are accelerated by Earth's gravity at 9.8 m/s/s.

Objective 9:

The force of weight of any object on Earth is the product of the object's mass and the acceleration due to gravity.

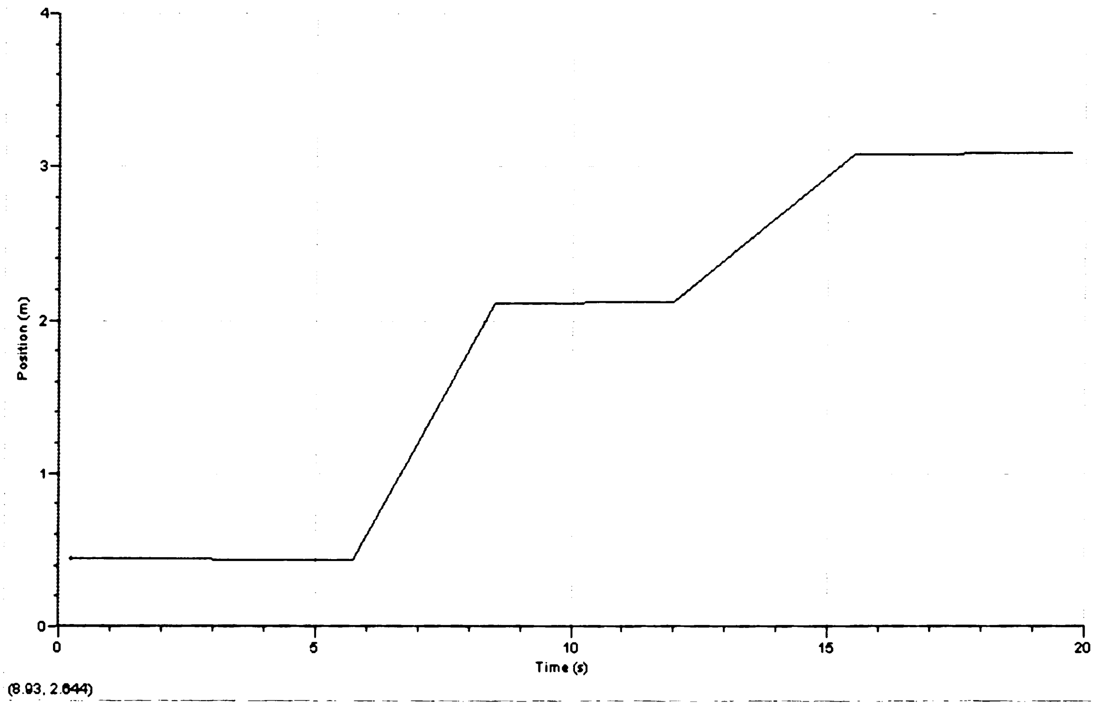
Appendix C-1

Motion and Forces Pre-test

1. Explain what it means for an object to be in motion.

2. What do we call a stationary object used to observe motion?

3. Examine the graph below and describe the motion of the object that generated it.

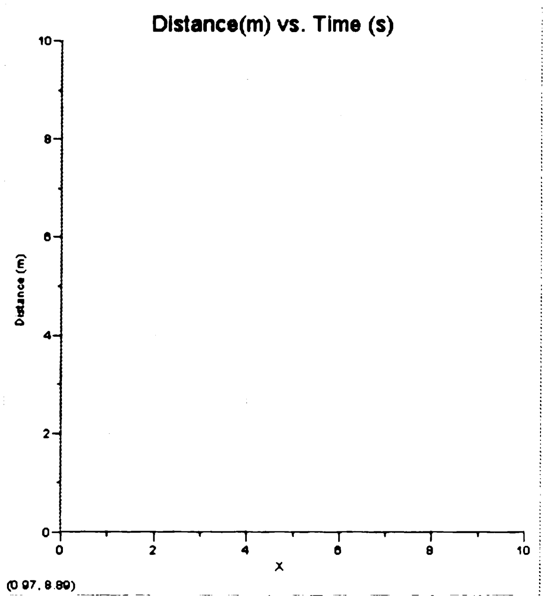


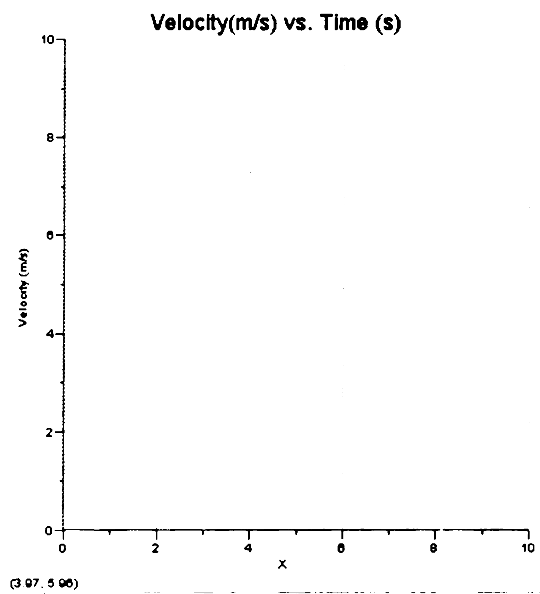
4. What is the approximate average velocity for the object in the graph above?

5. What is acceleration?

6. What are the units of acceleration?

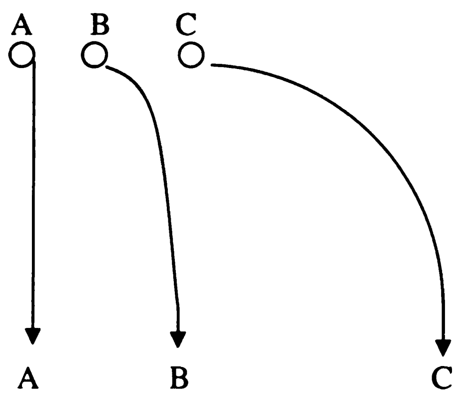
7. On the graphs below, draw a line that would show an object that is accelerating.





8. If a 5kg rock and a 50kg boulder were dropped from a height of 100m. Neglecting air resistance, which would hit the ground first? Explain.

9. Three objects of equal mass are released at the same time. One, straight down, the second at a 45 degree angle, and the third perpendicular to the ground. What order will they reach the ground? Explain.



10. What acceleration does gravity give to all objects?

11. What is the weight of any object?

12. You are taking a car to Ohio. You drive 19 miles in the first 30 minutes, 62 miles in the next hour, and 75 miles over the final two hours. What is the average velocity of your car during this trip? (Show your work.)

13. A freight train has a speed of 21.0 m/s at a given instant, and 10.6 seconds later, its speed is 27.5 m/s. What is the train's acceleration? (Show your work.)

14. A 2.4 kg rock is dropped off of the side of a building. If the rock is dropped from a height of 32 m, what will be the rocks velocity 2.7 seconds after it is dropped? (g = 9.8 m/s/s)

15. What is a force?

16. Friction is a force that opposes motion. What are the different types of friction and give an example.

17. What are the units of force and how are forces calculated?

18. What acceleration does an object, mass 90 g, undergo when a force of 45 N acts upon it? Neglect any resistance due to air. (Show all work.)

19. The coefficient of friction between a 91.4 kg box and the floor is 0.50. What force must be applied to keep the box sliding across the floor at a constant velocity? ($\mu = F_f/F_n$)

20. What is the weight of a 2.7 kg book at sea level?

Appendix C-2

Name________________________

Date________________________

Hour________________________

Speed Calculations

Solve the following problems. Show all of your work. Remember to include the correct units for each answer. 1 mile = 1609 m.

1. How far does car go if it is moving at a speed of 25 m/s for 35 sec?

2. If a train travels at a velocity of 120 miles/hr, how far will it go in 4 hours and 15 minutes?

3. If the speed of sound is 342m/s, how far away will a canyon wall be if it returns an echo to you in a time of 0.95 sec?

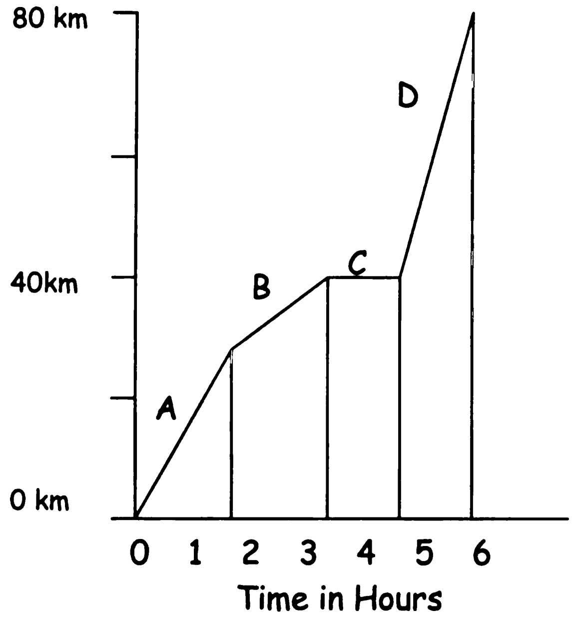
4. If the distance between Williamston and Los Angeles is 2200 miles, how long would you expect jet to take to fly the distance at a speed of 400 miles/hr?

5. The captain of a ship fixes his position at 10:00 am and estimates that the ship has a distance of 137 miles to go before it reaches the harbor. If the ship is moving at 10 miles/hr, what is the estimated time of arrival in the harbor?

6. What is the average speed (m/s) for a bus trip of 120 miles that began at 8:45 am and finished at 1:15pm?

7. Sometimes a vehicle does not travel at a steady rate and often slows down, speeds up, and stops. Ron and Julie are driving to Disney World for their annual vacation. Their distance-time graph below shows the distance covered by their vehicle over a period of 7 hours.

Explain what is going on at each of the segments labeled A, B, C, and D on the graph. If you'd like, write a short story of what is happening with this car.



8. In the graph above, what is the average speed of the vehicle?

9. How would you calculate the slope of the of the above graph?

10. Using your answer from number 8, and knowing that Disney World is 1200 miles from their starting point, how long is it going to take Ron and Julie to reach Disney World assuming they stay at the speed you calculated in number 8? Watch your units.

Appendix C-3

Due date: Sat Feb 21 17:00:00 2009

You are taking your spring break trip to Arizona to catch Mr. Preston a scorpion. You drive 11 miles in the first hour, 65 miles the next hour, and 39 miles in the final 4 hours. What is the average velocity of your car during this period of time?

[ ] miles/hour

The speed of a barrel increases from 1.5 meters per second to 9 meters per second in 5 seconds as it accelerates uniformly down a hill. What is the magnitude of the acceleration of the barrel during this 5 second interval?

A. 2.1 m/s^2

B. 1.5 m/s^2

C. 1.8 m/s^2

D. 0.30 m/s^2

A 2.5 kilogram chair is dropped from the roof of a building 40 meters tall. What is the approximate time of fall? [Neglect air resistance.]

A. 2.0 s

B. 2.9 s

C. 4.1 s

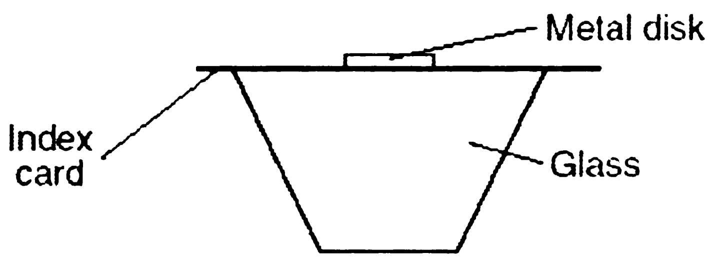
D. 8.2 s

A freight train has a speed of 27.5 m/s at a given instant and 10.6 seconds later its speed is 21.9 m/s. What is the train's acceleration? [ ]

What additional time would be necessary to bring the train to a complete stop, if it continues to slow at the rate in the previous question? [ ]

What total distance is travelled in stopping during the entire slowing phase? [ ]

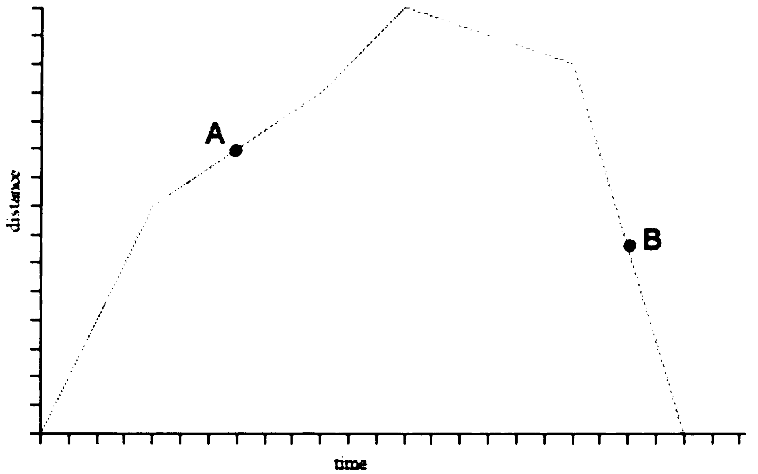
The diagram below shows a 1.0-newton metal disk resting on an index card that is balanced on top of a glass.



When the index card is quickly pulled away from the glass in a horizontal direction, the disk falls straight down into the glass. This action is a result of the disk's

A. temperature
B. inertia
C. charge
D. shape

Refer to the graph below to answer the next three questions. This distance vs. time graph represents the motion of a frog swimming in a pond. The distance increment on the graph is 2.0 meters, and the time increment on the graph is 4.0 seconds. (You may want to pencil those numbers in.) Also, each graph inflection point corresponds to tick marks on the axes.

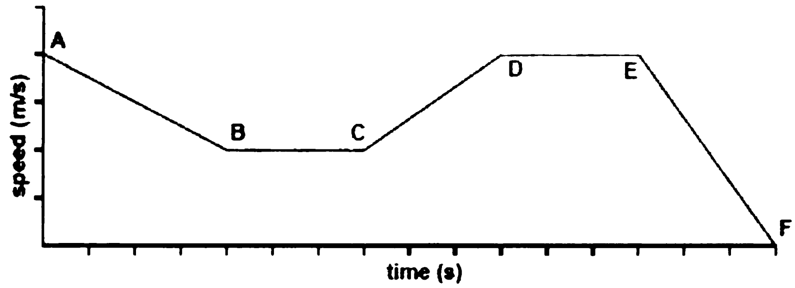


Find the velocity of the frog at point A.

Calculate the frog's average velocity over the first 52 seconds.

Find the velocity of the frog at point B.

The graph below shows the speed of an object plotted versus time. Each of the increments on the speed axis is 3 m/s. Each of the increments on the time axis is 2 seconds. Again, each graph inflection point cooresponds to tick marks on the axes. Use the graph to answer the following four questions.



What is the object's acceleration during interval AB?

What is the object's acceleration during interval CD?

What is the object's average speed during interval EF?

What is the total distance travelled by the object (that is, from point A to F)?

Appendix C-4

Name____________________

Hour____________________

Speed, Velocity and Acceleration

Solve the following problems. Show all of your work.

1. Explain why you need a reference point to know if an object is moving.

2. What is the difference between an object's speed and an object's velocity?

3. A bamboo plant grows 15 cm in 6 hours. At what average speed does the plant grow? Convert your answer to m/s.

4. The distance traveled by two crawling babies is shown in the table below. Graph the information and find the slope of each line. What is the average speed of each baby?

Time (sec)	Baby Sara's Distance	Baby Scott's Distance
0	0 m	0 m
1	0.5 m	0.4 m
2	1.0 m	0.8 m
3	1.5 m	1.2 m
4	2.0 m	1.6 m
5	2.5 m	2.0 m

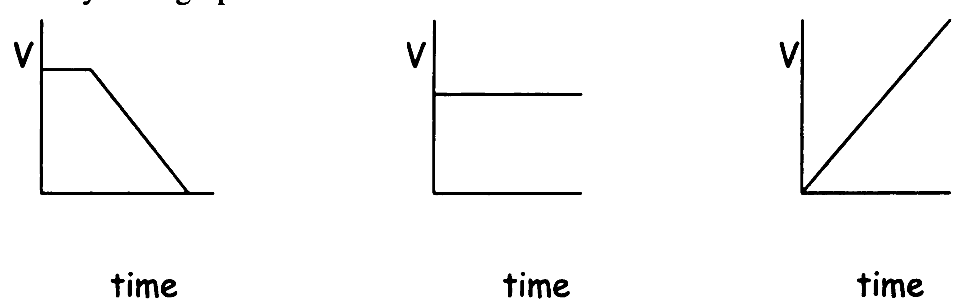
5. A roller coaster car rapidly picks up speed as it rolls down a slope. As it starts down the slope, it's speed is 4 m/s. Three seconds later, at the bottom of the slope, the speed of the car is 22 m/s. What is the car's average acceleration?

6. An eagle accelerates from 12 m/s to 24 m/s in 4 seconds. What is the eagle's average acceleration?

7. A horse trots around a large circular track, maintaining a constant speed of 5 m/s. Is the horse accelerating? Explain.

8. You are riding in a car traveling 80 km/hr. A fly trapped in the car rests on your shoulder. Describe the speed of the fly using two different frames of reference.

9. Explain 2 situations for each of the graphs below that would illustrate the velocity-time graphs.



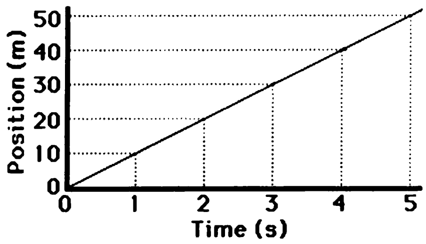
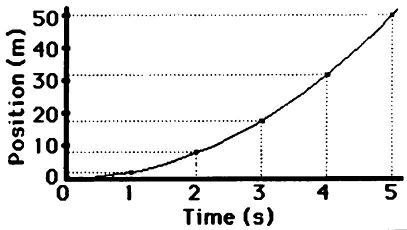
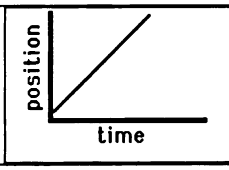
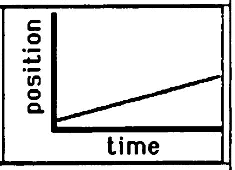
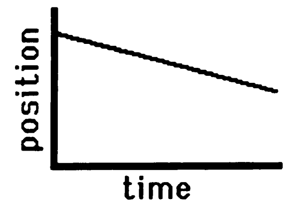
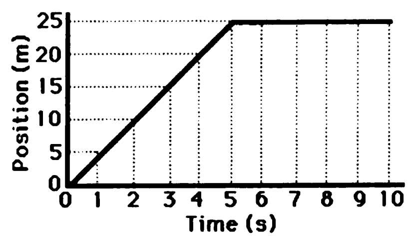
10. A passenger elevator operates at an average speed of 8 m/s. If the 60^{th} floor is 224 m above the first floor, how long does it take the elevator to go from the first floor to the 60^{th} floor? Convert your answer into minutes.

Appendix C-5

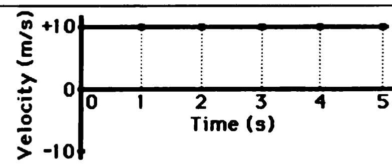
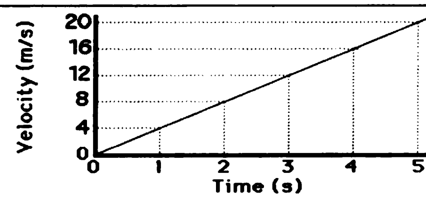
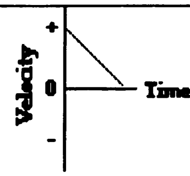
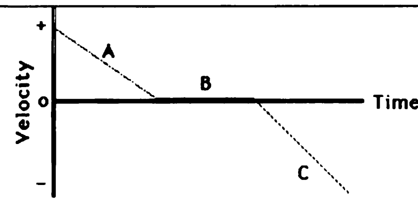
Describing Motion with Graphs.

Objective: To relate line graphs to motion and motion to line graphs.

Part I. Position vs. Time Graphs

Question/Task:	Graph:
1.a. What is the average speed of the graph to the right? 1.b. Based on the graph to the right, describe the behavior of the object.	
2. Based on the graph to the right, describe the behavior of the object.	
3. Circle the graph to the right that indicates the object that is moving the fastest.	
4. Based on the graph to the right, describe the behavior of the object.	
5. Based on the graph to the right, describe the behavior of the object.	

Part II. Velocity vs. Time Graphs

6. Based on the graph to the right, describe the behavior of the object.	
7. Based on the graph to the right, describe the behavior of the object.	
8. Based on the graph to the right, describe the behavior of the object.	
9. Based on the graph to the right, describe the behavior of the object.	

Part III. Create your own graphs!

Graph 1. On a piece of graph paper, draw and label a **distance versus time** graph of an object that behaves as follows:

a. moves forward at a constant speed 2m for 4s
b. remains still for 2s
c. moves backward at a constant speed 1m for 2s
d. remains still for 2s
e. accelerates forward 1m for 2s

Graph 2. On a piece of graph paper, draw and label a **velocity versus time** graph of an object that behaves as follows:

a. moves forward at a constant speed 2m for 4s
b. remains still for 2s
c. moves backward at a constant speed 1m for 2s
d. remains still for 2s
e. accelerates forward 1m for 2s

Important: Graphs should include labels for parts a-e, axes (time, distance, velocity), units (seconds, meters, m/s), and titles.

Appendix C-6

Name________________________

Hour______________________

What is Motion?

Solve the following problems. Show all of your work. Remember to include the correct units for each answer.

1. A student practicing for a track meet ran 440 m in 57 sec.
   a. What was her average speed?

   b. The next day she ran the same 440 m in only 54 sec. How much did her speed increase?

2. A car traveled 330 km from Lansing to Grayling in 3 hours and 20 minutes. What was the car's average velocity?

3. How fast was a plane flying if it traveled 1550 km in 120 min?

4. A student walks 15 blocks to the store.
   a. How long will it take her to reach the store if she walks 4 blocks in 3 minutes and 30 seconds?

   b. What is her average velocity?

5. The average speed of a car is 95 km/hr, how far can it travel in 40 min?

6. The speed of light is 3×10^8 m/sec. How long does it take light to reach the Earth if the sun is 93 million miles away? 1 mile = 1609m.

7. A driver starts his car moving and within 5 sec reaches a velocity of 65 km/hr as he travels west. What is his acceleration?

8. Falling objects drop with an average acceleration of 9.8 m/sec/sec. If an object falls from a tall building, how long will it take before it reaches a speed of 52m/sec?

9. A 100g ball is rolling at a rate of 5.6 m/sec. What is the momentum of the ball?

10. A marble is rolling at 115 cm/sec and a has a momentum of 12,500 g-cm/sec. What is the mass of the marble?

11. An object with a mass of 5.45 kg is fired from a canon, giving it a momentum of 1525 kg-m/sec. What is the velocity of the object?

Appendix C-7

Name____________________________

Do the following calculations. Show all work!

1. What is the velocity of a car that traveled a total of 75 km north in 1.5 hours?
2. What is the velocity of a plane that traveled 3,000 miles from New York to California in 5.0 hours?
3. John took 45 minutes to bicycle to his grandmother's house, a total of four kilometers. What was his velocity in km/hr?
4. It took 3.5 hours for a train to travel the distance between two cities at a velocity of 120 miles/hr. How many miles lie between the two cities?
5. How long would it take for a car to travel a distance of 200 km if it is traveling at a velocity of 55 km/hr?
6. A car is traveling at 100 km/hr. How many hours will it take to cover a distance of 750 km?
7. A plane traveled for about 2.5 hours at a velocity of 1200 km/hr. What distance did it travel?
8. A girl is pedaling her bicycle at a velocity of 0.10 km/min. How far will she travel in two hours?
9. An ant carries food at a speed of 1 cm/s. How long will it take the ant to carry a cookie crumb from the table to the ant hill, a distance of 50 m?

10. The water in the Buffalo River flows at an average speed of 5 km/hr. If you and a friend decide to canoe down the river a distance of 16 km, how many hours and minutes will it take?

11. Use the information in the chart below to calculate the acceleration.

Initial Velocity	Final Velocity	Time	Acceleration
0 km/hr	24 km/hr	3 s	
0 m/s	35 m/s	5 s	
20 km/hr	60 km/hr	10 s	
50 m/s	150 m/s	5 s	
25 km/hr	1200 km/hr	2 min	

12. A car accelerates from a standstill to 60 km/hr in 10.0 seconds. What is its acceleration?

13. A train is accelerating at a rate of 2.0 km/hr/s. If its initial velocity is 20 km/hr, what is its velocity after 30 seconds?

14. A car accelerates from 25 km/hr to 55 km/hr in 30 seconds. What is its acceleration?

15. A runner achieves a velocity of 11.1 m/s 9 seconds after he begins. What is his acceleration?

Appendix C-8

Motion Quiz

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question.

1. A passenger in the rear seat of a car moving at a steady speed is at rest relative to
a. the side of the road.
b. a pedestrian on the corner ahead.
c. the front seat of the car.
d. the wheels of the car.

2. A car traveled 88 km in 1 hour, 90 km in the next 2 hours, and then 76 km in 1 hour before reaching its destination. What was the car's average speed?
a. 254 km/h
b. 63.5 km/h
c. 209 km/h
d. 74.5 km/h

3. A horizontal line on a distance-time graph means the object is
a. moving at a constant speed.
b. moving faster.
c. slowing down.
d. at rest.

4. What is the speed of a bobsled whose distance-time graph indicates that it traveled 100 m in 25 s?
a. 4 m/s
b. 250 m/s
c. 0.25 mph
d. 100 m/s

5. A distance-time graph indicates that an object moves 100 m in 4 s and then remains at rest for 1 s. What is the average speed of the object?
a. 50 m/s
b. 25 m/s
c. 20 m/s
d. 100 m/s

6. The rate at which velocity changes is called
a. speed.
b. vectors.
c. acceleration.
d. motion.

7. Suppose you increase your walking speed from 1 m/s to 3 m/s in a period of 2 s. What is your acceleration?
a. 1 m/s^2
b. 2 m/s^2
c. 4 m/s^2
d. 6 m/s^2

8. An object moving at 30 m/s takes 5 s to come to a stop. What is the object's acceleration?
a. 30 m/s^2
b. -30 m/s^2
c. -6 m/s^2
d. 6 m/s^2

9. An object that is accelerating may be
a. slowing down.
b. gaining speed.
c. changing direction.
d. all of the above

10. A train approaching a crossing changes speed from 25 m/s to 10 m/s in 240 s. How can the train's acceleration be described?
a. The train's acceleration is positive.
b. The train is not accelerating.
c. The train will come to rest in 6 minutes.
d. The train's acceleration is negative.

Problems

11. During a race, a runner runs at a speed of 6 m/s. Four seconds later, she is running at a speed of 10 m/s. What is the runner's acceleration? Show your work.

12. If you ride your bike at an average speed of 2 km/h and need to travel a total distance of 20 km, how long will it take you to reach your destination? Show your work.

Essay

13. Explain how velocity is different from speed.

USING SCIENCE SKILLS

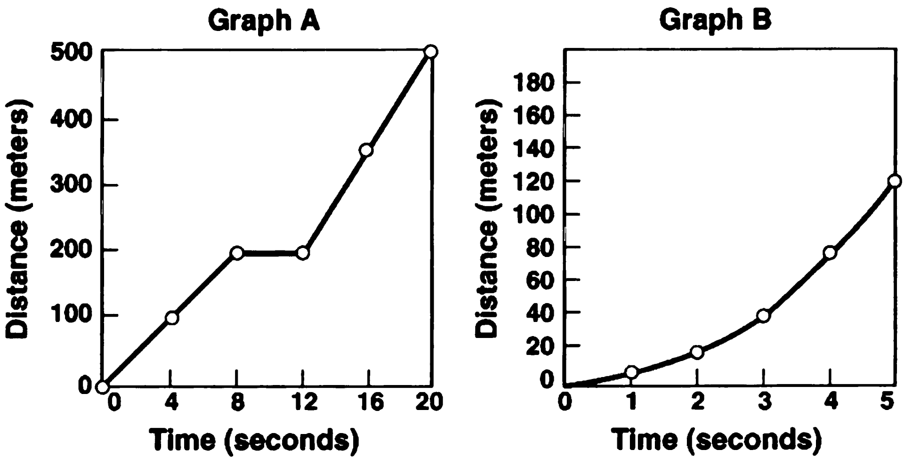


Figure 11-2

14. **Using Tables and Graphs** Which graph in Figure 11-2 shows periods of constant speed? Explain your answer.

15. **Using Models** Which graph in Figure 11-2 shows acceleration? How do you know?

16. **Calculating** Using Graph A in Figure 11-2, calculate the average speed of the object in motion from 12 s to 20 s. Explain your calculation.

Appendix C-9

Due date: Wed May 16 17:00:00 2007

Below you will find five force and mass combinations. Please list the pairs in order of increasing acceleration that is, in order from the pair that produces the lowest acceleration to the pair that will produce the greatest acceleration. (Choose 1 for the lowest through 5 for the greatest)

Choices: **1, 2, 3, 4, 5.**

A. A force of 3322.1 N acts on a mass of 76.9 kg.

B. A force of 1014.4 N acts on a mass of 191.4 kg.

C. A force of 4.7 N acts on a mass of 3.2 kg.

D. A force of 247.4 N acts on a mass of 13.3 kg.

E. A force of 215.2 N acts on a mass of 199.3 kg.

A 7650 N wrecking ball hangs from the end of a steel cable. What is its mass? [ ]

What is the wrecking ball's weight? [ ]

What is the net force acting on the wrecking ball as it hangs motionless from the end of the cable? [ ]

What is the wrecking ball's inertia? [ ]

What is the net force acting on the wrecking ball if the cable snaps? [ ]

On some strange planet you find that a 9.8 kg object falls downward 19.2 meters in 3.1 seconds. What is the magnitude of the acceleration due to gravity on this planet?

How much does the object weigh on this planet?

And, how much would this object weigh back on Earth?

A 0.20 kg birdie slams into a window with a force of 5.5 N. What is the magnitude of the birdie's acceleration?

How many "g"s is the bird in the previous question experiencing?

A physics class pushes a small wagon along a flat horizontal parking lot with a force of 99.74 N. Starting from rest the wagon travels 14.0 meters in 9.7 seconds. What is the wagon's acceleration?

What is the magnitude of the force of friction acting on the wagon in the previous question, if the loaded wagon has a mass of 149.0 kg?

A 22.5 gram arrow is shot through a 7.4 cm apple. If the arrow enters the apple at 39.7 m/s and emerges with a speed of 28.6 m/s in the same direction, what is the magnitude of the force with which the apple has resisted the arrow? (assume force is exerted only on the tip of the arrow)

You are correct. Your receipt is 159-2517

What is the magnitude of the net force needed to bring a 1760 kg car to rest from 25.0 m/s in 6.6 seconds?

You are correct. Your receipt is 159-2503

If a 4 engine jet accelerates down a runway at 9.0 m/s^2, how much acceleration would be produced if two engines failed and only 2 engines were operating?

You are correct. Your receipt is 159-3364

Suppose now that all 4 engines are operational on the jet from the previous question. What acceleration would this fully functional jet experience if it were towing 2.7 identical but inoperational jets?

You are messing around with a 0.69 kg model rocket. What is the weight of the rocket?

What is the acceleration of the rocket straight upward, if 28.3 N of thrust is applied to it in that direction?

Suppose that you hang a 0.9 kg mass on a short "massless" string that is attached to the bottom of a force scale that measures from 0 to 30 N. What is the tension on the string? (in other words, what does the scale read?)

If you pull upward on the scale so that it reads 14.72 N, what would be the acceleration of the mass?

If you allow the mass to accelerate downward at 5.7 m/s^2, what will the scale read?

At one point in a skydive, a falling 75 kg skydiver is encountering air resistance of 430 N. How much does the skydiver weigh?

What is the magnitude of the net force acting on this skydiver?

Finally, what is the magnitude of her acceleration?

Braking Car Problem A

On Williamston Rd., Jim is driving 26.8 m/s. After spotting a large deer in the road ahead, Jim brakes the car to a complete stop.

For this problem, assume that the car undergoes constant acceleration/deceleration.

Assuming that Jim 's car has a mass of 3420 pounds, compute the car's weight in Newtons.

NOTE: Remember that there are 2.205 lbs in a kilogram (Source: NIST), and acceleration due to gravity is 9.81 m/s^2.

Units are not required for this part.

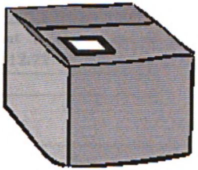
If Jim 's car takes 37.5 meters to stop, what is the acceleration of the car?

What force is required to bring the car to a halt?

How many g's did Jim experience when the car decelerated?

Force of Friction A

While you are in detention after school, your teacher tells you to slide a large, 91.4 kilogram box across the floor.



The coefficent of static friction ($\mu_{\textbf{static}}$) between the box and the floor is 0.50. Compute the force parallel to the ground ($F_{\textbf{parallel}}$)required to start accelerating the box.

A model train undergoes an acceleration of **0.509** m/s2 when a net force of **4.34** N is applied to it. **What is the mass of the train?** [ ]

What is the mass of an ice skater, if a net force of **112.72** N results in an acceleration of **2.012** m/s^2? [ ]

A **7.28-kg** shot put is thrown with a force of **452.5** N. **What is the acceleration of the shot put?** [ ]

A car has a mass of **2340.4 kg**. The car undergoes an acceleration of **4.97** m/s^2. **What is the magnitude of the accelerating force?** [ ]

A textbook is pushed across a desk with a force of **12.48** N. The acceleration of the book is **1.186** m/s^2. **What is the mass of the textbook?** [ ]

Appendix C-10

Name___________________

Force and Friction Problems.

Solve the following problems. Show all of your work. UNITS!!

1. A horizontal force of 25 N is necessary to pull a 55 N trunk across a cement sidewalk at a constant speed. What is the coefficient of sliding friction between the sidewalk and the bottom of the trunk?

2. How much force must be applied to push a 1.85 kg book across the desk at a constant speed if the coefficient of sliding friction is 0.30?

3. What force is required to accelerate a 12 kg object at 15 m/s/s?

4. What is the weight of a 48 kg box at sea level?

5. What acceleration does an object, mass 40 kg, undergo when a force of 55 N acts upon it?

6. What is the mass of a bag of cement that weights 485 N at sea level?

7. A smooth wooden block is placed on a polished table. You find that you must exert a force of 20 N to keep the 65 N block moving at a constant velocity. What is the coefficient of sliding friction for the block and the table? If a 15 N brick is placed on the block, what force will be required to keep the block and the brick moving at a constant velocity?

Appendix C-11

Name______________________

Working with Forces

Solve the following problems. Show all of your work. UNITS!!

1. What is the force on a 1 kg ball that is falling freely due to the pull of gravity? (Neglect air resistance.)

2. A man has a mass of 66 kg on the Earth. What is his weight?

3. A girl on roller skates accelerates at a rate of 2 m/s/s with a force of 100 N. What is her mass?

4. A person weighs 540 N on the Earth. What is the person's mass. What would the person weigh on the moon where the acceleration due to gravity is 1.67 N/kg?

5. An elevator has a mass of 1000 kg. What is the tension force on its cables when it is stationary?

6. What force is needed to accelerate the elevator in question 5 upward at a rate of 2 m/s/s?

7. An originally stationary car with a mass of 1500 kg reaches a velocity of 15 m/sec 5 seconds after starting. What is the car's acceleration? How much force is required to reach this acceleration?

8. An astronaut has a mass of 50 kg. How much does she weigh before liftoff?

9. When the astronaut is 6400 km above the Earth's surface, she will weigh one quarter of what she weighed on the Earth. What is the acceleration on her mass at that point in space?

10. A 7000 kg plane is launched from an aircraft carrier in 2 seconds by a force of 350,000 N. What is the plane's acceleration? What is the plane's velocity?

Appendix C-12

Motion and Forces Unit Test

Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question.

1. A passenger in the rear seat of a car moving at a steady speed is at rest relative to
   a. the side of the road.
   b. a pedestrian on the corner ahead.
   c. the front seat of the car.
   d. the wheels of the car.

2. Speed is the ratio of the distance an object moves to
   a. the amount of time needed to travel the distance.
   b. the direction the object moves.
   c. the displacement of the object.
   d. the motion of the object.

3. A car traveled 88 km in 1 hour, 90 km in the next 2 hours, and then 76 km in 1 hour before reaching its destination. What was the car's average speed?
   a. 254 km/h
   b. 63.5 km/h
   c. 209 km/h
   d. 74.5 km/h

4. The slope of a line on a distance-time graph is
   a. distance.
   b. time.
   c. speed.
   d. displacement.

5. A horizontal line on a distance-time graph means the object is
   a. moving at a constant speed.
   b. moving faster.
   c. slowing down.
   d. at rest.

6. What is the speed of a bobsled whose distance-time graph indicates that it traveled 100 m in 25 s?
   a. 4 m/s
   b. 250 m/s
   c. 0.25 mph
   d. 100 m/s

7. The rate at which velocity changes is called
   a. speed.
   b. vectors.
   c. acceleration.
   d. motion.

8. Objects in free fall near the surface of the Earth experience
   a. constant speed.
   b. constant velocity.
   c. constant acceleration.
   d. constant distance.

9. Which example describes constant acceleration due ONLY to a change in direction?
   a. increasing speed while traveling around a curve
   b. an object at rest
   c. traveling around a circular track
   d. an object in free fall

10. An object moving at 30 m/s takes 5 s to come to a stop. What is the object's acceleration?

a. 30 m/s^2
b. –30 m/s^2
c. –6 m/s^2
d. 6 m/s^2

11. The slope of a speed-time graph indicates

a. direction.
b. acceleration.
c. velocity.
d. speed.

12. An object that is accelerating may be

a. slowing down.
b. gaining speed.
c. changing direction.
d. all of the above

13. Which of the following relationships is correct?

a. 1 N = 1 kg
b. 1 N = 1 kg·m
c. 1 N = 1 kg·m/s
d. 1 N = 1 kg·m/s^2

14. When an unbalanced force acts on an object,

a. the object's motion does not change.
b. the object accelerates.
c. the weight of the object decreases.
d. the inertia of the object increases.

15. When a pair of balanced forces acts on an object, the net force that results is

a. greater in size than both forces combined.
b. greater in size than one of the forces.
c. equal in size to one of the forces.
d. equal to zero.

16. According to Newton's second law of motion, the acceleration of an object equals the net force acting on the object divided by the object's

a. mass.
b. momentum.
c. velocity.
d. weight.

17. Your weight equals your

a. mass.
b. mass divided by the net force acting on you.
c. mass times the acceleration due to gravity.
d. mass times your speed.

18. The acceleration due to gravity on the surface of Mars is about one-third the acceleration due to gravity on Earth's surface. The weight of a space probe on the surface of Mars is about

a. nine times greater than its weight on Earth's surface.
b. three times greater than its weight on Earth's surface.
c. one-third its weight on Earth's surface.
d. the same as its weight on Earth's surface.

19. The product of an object's mass and velocity is its

a. centripetal force.
b. momentum.
c. net force.
d. weight.

20. What is the momentum of a 50-kilogram ice skater gliding across the ice at a speed of 2 m/s?

a. $25\frac{kg}{m/s}$

b. 48 kg·m/s

c. 50 kg

d. 100 kg·m/s

Completion

Complete each sentence or statement.

21. Speed is measured in units of ________________________.

22. A constant slope on a distance-time graph indicates ____________________ speed.

23. Because its ____________________ is always changing, an object moving in a circular path experiences a constant change in velocity.

24. A moving object does not ____________________ if its velocity remains constant.

25. Freely falling objects accelerate at 9.8 m/s^2 because the force of ____________________ acts on them.

26. The acceleration of a moving object is calculated by dividing the change in ____________________ by the time over which the change occurs.

27. The force that opposes the motion of objects that touch as they move pass each other is called ____________________.

28. When a falling object reaches terminal velocity, the net force acting on it is ____________________.

Short Answer

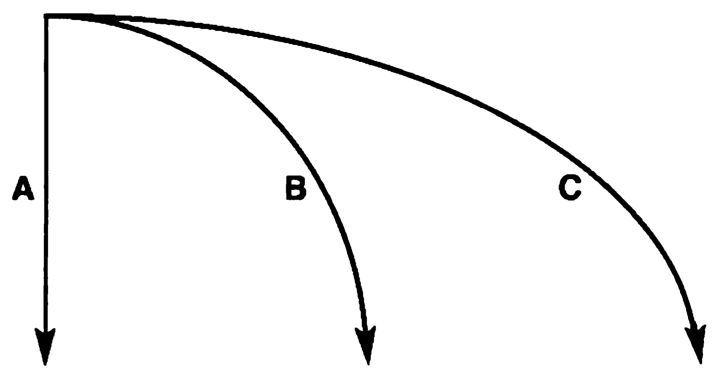


Figure 12-1

29. Figure 12-1 shows the paths followed by three balls. Each ball started moving at the same time. Ball A was dropped and balls B and C were thrown sideways. Compare the times for each ball to reach the ground.

30. How can you double the acceleration of an object if you cannot alter the object's mass?

USING SCIENCE SKILLS

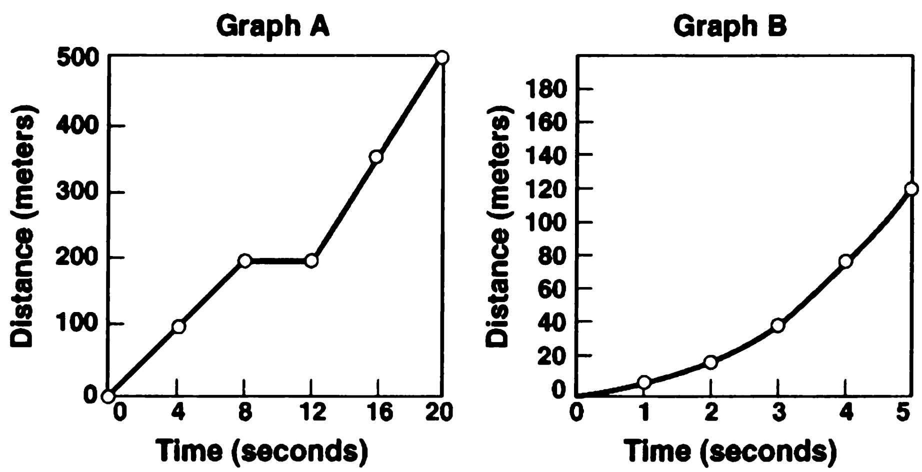


Figure 11-2

31. **Using Tables and Graphs** Which graph in Figure 11-2 shows periods of constant speed? Explain your answer.

32. **Interpreting Graphics** Look at Figure 11-2. Describe the motion of the object in Graph A.

33. **Using Models** Which graph in Figure 11-2 shows acceleration? How do you know?

34. **Calculating** Using Graph A in Figure 11-2, calculate the average speed of the object in motion from 12 s to 20 s. Explain your calculation.

Appendix D-1

Graphing Your Motion

Graphs made using a Motion Detector can be used to study motion. A Motion Detector measures the distance to the nearest object in front of it by emitting and receiving pulses of ultrasound. A calculator can use distance and time measurements to calculate velocity. In this experiment, you will use a handheld, a LabPro interface, and a Motion Detector to produce graphs of your own motion.

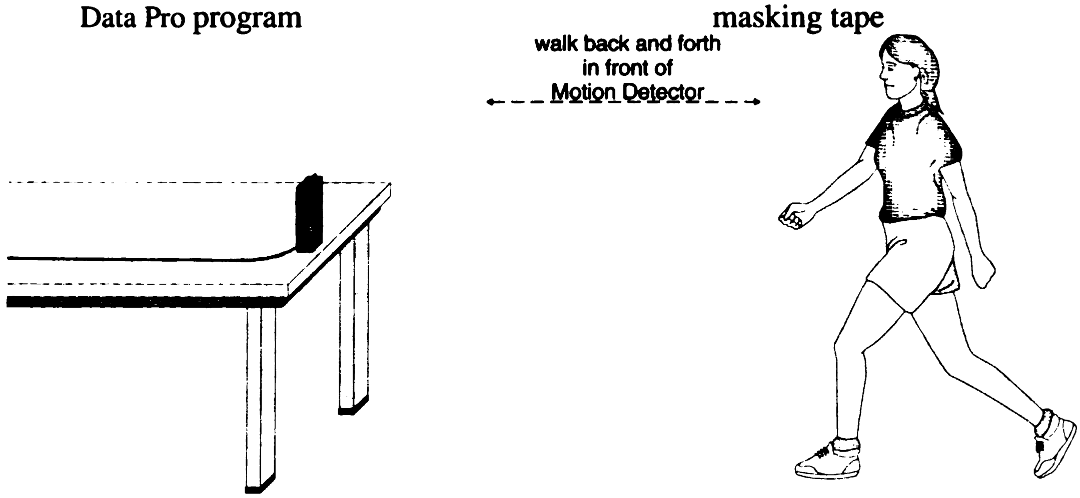
OBJECTIVES

In this experiment, you will

- Use a handheld, a LabPro interface, and a Motion Detector to measure distance and velocity.
- Use a handheld to produce graphs of your motion.
- Analyze and interpret graphs of your motion.

MATERIALS

LabPro interface
Palm handheld
Data Pro program
Vernier Motion Detector
meter stick
masking tape



PROCEDURE

Part A Distance

1. Tape a Motion Detector on a surface facing an area free of furniture and other objects. The Motion Detector should be at a height about 15 cm above your waist level.

2. Using masking tape, tape a 4 meter straight line on the floor directly in front of the Motion Detector. Mark the tape at 1 meter intervals from the Motion Detector.

3. Plug the Motion Detector into the DIG/SONIC 1 port of the LabPro interface. Connect the handheld to the LabPro using the interface cable. Firmly press in the cable ends.

4. Press the power button on the handheld to turn it on. To start Data Pro, tap the Data Pro icon on the Applications screen. Choose New from the Data Pro menu or tap (New) to reset the program.

5. Set up the handheld and interface for data collection.
   a. On the Main screen, a live distance reading should be displayed for the Motion Detector in DIG/SON 1 (in units of meters).
   b. Tap [Setup].
   c. Tap [Mode:] and choose Graph Matching.
   d. Tap [OK] to return to the Main screen.
   e. Tap [Start] on the Main screen to view a randomly generated target distance graph. You will return to this graph later in the procedure. For now, tap [Blank] to view a blank distance *vs.* time graph. The vertical axis is scaled from 0 to 3 meters, and the time axis is scaled from 0 to 10 seconds.

6. Explore data collection for a distance *vs.* time graph.
   a. Take a starting position one meter in front of the Motion Detector.
   b. Signal your partner to tap [Start].
   c. When the fast clicking begins, walk to a distance of two meters and stop.
   d. After data collection is complete, a graph of distance *vs.* time will be displayed. Discuss the results with your partners.

7. Match the first distance *vs.* time graph.
   a. Tap [New] to view a randomly generated target distance graphs for you to match.
   b. Examine the graph and plan what you will do to match it. Note: The distance tick marks represent distances 1 m apart. Data will be collected for ten seconds.
   c. Take your starting position in front of the Motion Detector.
   d. Have your partner tap [Start] to begin data collection.
   e. Move according to your plan.
   f. Examine the graph of the results.
   g. In Processing the Data (Part A), sketch a graph of your results in the space provided. **Important:** Your sketch should show *both* the first graph displayed

by the handheld *and* the graph of your motion. Then, in the space provided, describe what you had to do to match the first graph.

h. If you would like try matching the same graph again, tap [Same] to view a clean version of the same target graph. If you are ready to move on to the second graph, proceed to Step 8.

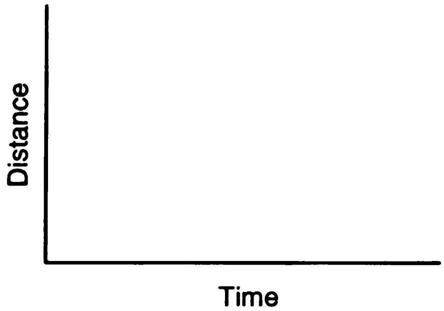
8. Repeat Step 7 for the three remaining distance *vs*. time graphs.

PROCESSING THE DATA (Part A)

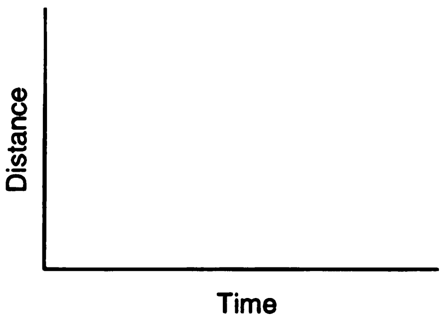
1. Describe what you had to do to match each of the graphs. Note: Your distances were different from those shown here.

Graph sketch — What I did to match my graph:

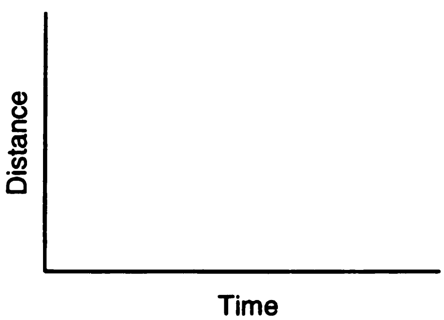
Graph 1



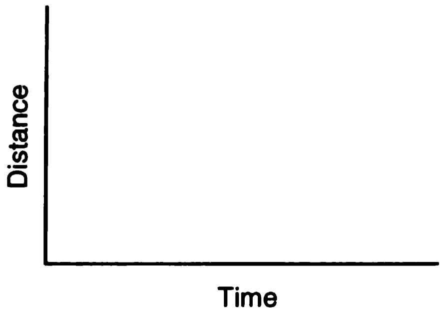
Graph 2



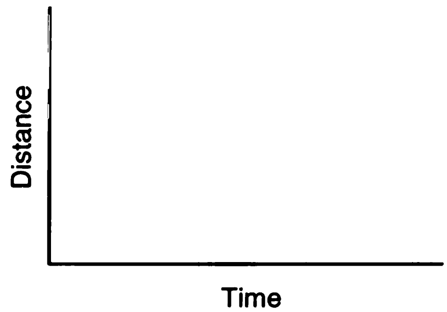
Graph 3



Graph 4



2. Sketch a distance *vs.* time graph for a car that starts slowly from a stopped position, moves down the street faster, stops at a stop sign, and then starts slowly again.



Part B Velocity

9. Tap the y-axis label and choose Velocity Match. Tap [Blank] to view a blank velocity *vs.* time graph. The vertical axis is scaled from –2.0 m/s to 2.0 m/s, and the time axis is scaled from 0 to 10 seconds.

10. Make a graph of your motion when you walk away from the detector with constant velocity. To do this, stand about 1 m from the Motion Detector and have your lab partner tap [Start]. Walk slowly away from the Motion Detector when you hear it begin to click. After data collection is complete, a graph of velocity *vs.* time will be displayed.

11. The Data Pro program can also generate random target velocity graphs for you to match. Tap [New]. A new target graph will be displayed.

12. Write down how you would walk to produce this target graph. Sketch or print a copy of the graph.

13. To test your prediction, choose a starting position and stand at that point. Have your partner tap [Start] to begin data collection. When you hear the Motion Detector begin to click, walk in such a way that the graph of your motion matches the target graph on the handheld screen. It will be more difficult to match the velocity graph than it was for the distance graph.

14. If you were not successful, tap [Same] to view a clean version of the same target graph. Have your partner tap [Start] to begin data collection when you are ready to start walking. Repeat this process until your motion closely matches the graph on the screen. Print or sketch the graph with your best attempt.

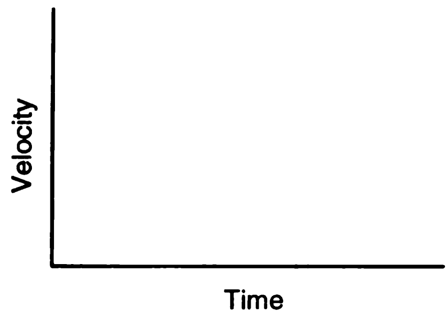
15. Tap [New]. A new target graph will be displayed. Repeat Steps 12-14 for the new graph.

PROCESSING THE DATA (PART B)

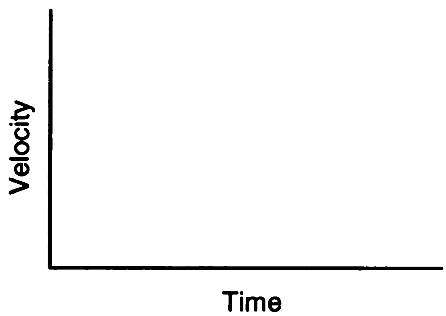
3. Describe what you had to do to match each of the graphs.

Graph sketch — What I did to match my graph:

Graph 1

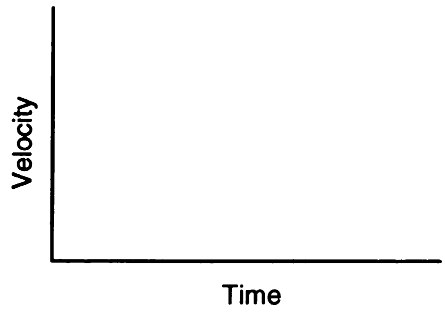


Graph 2



4. What is the definition of velocity?

5. Sketch a velocity *vs.* time graph for a person who is walking, stops for a few seconds, and then starts to run.



6. Describe the motion needed to make this graph:

   If it is a distance *vs.* time graph?

   If it is a velocity *vs.* time graph?

   You can check your answers using a Motion Detector.

Part C Acceleration

16. Tap [Done]. Once the Main screen reappears
    a. Tap [Setup].
    b. Tap [Mode:] and choose Time Graph.
    c. Tap [OK] to return to the Main screen.
17. Stand at the 1 m position, this time with your back to the Motion Detector. Have your partner tap [Start]. Pause for about one second and then walk rapidly to the 3 m mark and stop. Say "stop" when you have stopped. As you say "stop," your partner should tap [Stop].
18. Tap on the y-axis label and choose ACC(m/s^2). Sketch the graph.

PROCESSING THE DATA (PART C)

7. How does the acceleration *vs.* time graph differ from the other two graphs?

8. What is acceleration?

Appendix D-2

Acceleration

When a juggler tosses a ball straight upward, the ball slows down until it reaches the top of its path. The ball then speeds up on its way back down. A graph of its velocity *vs.* time would show these changes. Is there a mathematical pattern to the changes in velocity? What is the accompanying pattern to the distance *vs.* time graph? What would the acceleration *vs.* time graph look like?

In this experiment, you will use a Motion Detector to collect distance, velocity, and acceleration data for a ball thrown straight upward. Analysis of the graphs of this motion will answer the questions asked above.

OBJECTIVES

- Collect distance, velocity, and acceleration data as a ball travels straight up and down.
- Analyze the distance *vs.* time, velocity *vs.* time, and acceleration *vs.* time graphs.
- Determine the best-fit equations for the distance *vs.* time and velocity *vs.* time graphs.
- Determine the mean acceleration from the acceleration *vs.* time graph.

MATERIALS

LabPro interface
Palm handheld
Data Pro program
Vernier Motion Detector
volleyball or basketball

PRELIMINARY QUESTIONS

1. Think about the changes in motion a ball will undergo as it travels straight up and down. Make a sketch of your prediction for the distance *vs.* time graph. Describe in words what this graph means.

2. Make a sketch of your prediction for the velocity *vs.* time graph. Describe in words what this graph means.

3. Make a sketch of your prediction for the acceleration *vs.* time graph. Describe in words what this graph means.

PROCEDURE

1. Place the Motion Detector on a table, away from other objects.

2. Plug the Motion Detector into the DIG/SONIC 1 port of the LabPro interface. Connect the handheld to the LabPro using the interface cable. Firmly press in the cable ends.

3. Press the power button on the handheld to turn it on. To start Data Pro, tap the Data Pro icon on the Applications screen. Choose New from the Data Pro menu or tap (New) to reset the program.

4. Set up the handheld and interface for data collection.

   a. On the Main screen, a live distance reading should be displayed for the Motion Detector in DIG/SON 1 (in units of meters).
   b. Tap [Setup].
   c. On the Setup screen, tap [Settings:].
   d. Enter "0.025" as the time between samples in seconds, using the onscreen keyboard (tap "123") or using the Graffiti writing area.
   e. Enter "100" as the number of samples.
   f. Tap [OK] twice to return to the Main screen.

5. In this step, you will toss the ball straight upward above the Motion Detector and let it fall back toward the Motion Detector. This step may require some practice. Data will be collected for five seconds. Hold the ball directly above and about 0.5 m from the Motion Detector. Use two hands. Be sure to pull your hands away from the ball after it starts moving so they are not picked up by the Motion Detector. Tap [Start] to begin data collection. You will notice a clicking sound from the Motion Detector. Wait one second, then toss the ball straight upward. Be sure to move your hands out of the way after you release it. A toss of 0.5 to 1.0 m above the Motion Detector works well. You will get best results if you catch and hold the ball when it is about 0.5 m above the Motion Detector.

6. Examine the distance *vs.* time graph. Repeat Step 5 if your distance *vs.* time graph does not show an area of smoothly changing distance. Check with your teacher if you are not sure whether you need to repeat the data collection. To repeat data collection, simply tap [Start] when you are ready to toll the ball again.

DATA TABLE

Curve fit parameters:	A	B	C
Distance ($Ax^2 + Bx + C$)			
Velocity ($Ax + B$)			
Average acceleration			

ANALYSIS

1. Either print or sketch the three motion graphs. You can view a different graph (distance, velocity, or acceleration) by tapping on the vertical axis label of a displayed graph, and choosing DIG/SON 1:DIST(m), DIG/SON 1:VEL(m/s), or DIG/SON 1:ACC(m/s^2) from the menu. The graphs you have recorded are fairly complex and it is important to identify different regions of each graph. Record your answers directly on the printed or sketched graphs.

   a. Identify the region when the ball was being tossed but still in your hands:
      - Examine the velocity *vs.* time graph and identify this region. Label this on the graph.
      - Examine the acceleration *vs.* time graph and identify the same region. Label this on the graph.

   b. Identify the region where the ball is in free fall:
      - Label the region on each graph where the ball was in free fall and moving upward.
      - Label the region on each graph where the ball was in free fall and moving downward.

   c. Determine the distance, velocity, and acceleration at these specific points. Tap ▶ or any data point on a graph to read numeric values displayed to the right of the graph.
      - On the velocity *vs.* time graph, locate where the ball had its maximum velocity, after the ball was released. Mark the spot and record the value on the graph.
      - On the distance *vs.* time graph, locate the maximum height of the ball during free fall. Mark the spot and record the value on the graph.
      - What was the velocity of the ball at the top of its motion?
      - What was the acceleration of the ball at the top of its motion?

2. Display a graph of velocity *vs.* time. To do this, tap on the vertical axis label and choose DIG/SON 1:VEL(m/s). This graph should be linear in the region where the ball was in freefall. Fit a linear equation to your data in this region.

   a. Tap the Selection button, ⧉.

   b. Tap on the left boundary of the region of the velocity *vs.* time graph that is linear. An arrow (>) is displayed on this line.

   c. Tap on the right boundary of the linear section. An arrow (<) is displayed on this line.

   d. Tap the Zoom button, 🔍, to display just the freefall portion of your data.

   e. Tap [Analyze], then tap [Curve Fit].

   f. Choose Linear as the Fit Equation. Record the parameters of the curve fit in the Data Table.

   g. Tap [OK] to view the fitted curve with your data.

3. How closely does the coefficient of the x term compare to the accepted value of *g*?

4. The motion of an object in free fall is modeled by $y = v_0 t + \frac{1}{2} g t^2$, where y is the vertical position, v_0 is the initial velocity, t is time, and g is the acceleration due to gravity (9.8 m/s^2). This is a quadratic equation whose graph is a parabola.

Tap on the vertical axis label of your graph and choose DIG/SON 1:DIST(m) to view the same section of the distance *vs.* time graph. Examine this graph to see if it is a parabola in the region where the ball was in freefall. Now fit a quadratic equation to your data.

a. Tap [Curve Fit].

b. Choose Quadratic as the Fit Equation. Record the parameters of the curve fit in the Data Table.

c. Tap [OK] to view the fitted curve with your data.

5. How closely does the coefficient of the x^2 term in the curve fit compare to ½ *g*?

6. Tap on the vertical axis label of your graph and choose DIG/SON 1:ACC(m/s^2) (acceleration). The graph of acceleration *vs.* time during free fall should appear to be more or less constant. Note that because the graph is automatically scaled to fill the screen vertically, small variations may appear large. A good way to analyze the acceleration data is to find the mean (average) of these data points.

   a. Tap [Stats].

   b. Record the mean acceleration value in the Data Table.

7. How closely does the mean acceleration value compare to the values of *g* found in Steps 3 and 5?

8. List some reasons why your values for the ball's acceleration may be different from the accepted value for *g*.

EXTENSIONS

1. Determine the consistency of your acceleration values and compare your measurement of *g* to the accepted value of g. Do this by repeating the ball toss experiment five more times. Each time, fit a straight line to the free-fall portion of the velocity graph and record the slope of that line. Average your six slopes to find a final value for your measurement of *g*. Does the variation in your six measurements explain any discrepancy between your average value and the accepted value of *g*?

2. The ball used in this lab is large enough and light enough that a buoyant force and air resistance may affect the acceleration. Perform the same curve fitting and statistical analysis techniques, but this time analyze each half of the motion separately. How do the fitted curves for the upward motion compare to the downward motion? Explain any differences.

3. Perform the same lab using a beach ball or other very light, large ball. See the questions in #2 above.

4. Use a smaller, denser ball where buoyant force and air resistance will not be a factor. Compare the results to your results with the larger, less dense ball.

5. Instead of throwing a ball upward, drop a ball and have it bounce on the ground. (Position the Motion Detector above the ball.) Predict what the three graphs will look like, then analyze the resulting graphs using the same techniques as this lab.

Appendix D-3

Air Resistance

When you solve physics problems involving free fall, often you are told to ignore air resistance and to assume the acceleration is constant. In the real world, because of air resistance, objects do not fall indefinitely with constant acceleration. One way to see this is by comparing the fall of a baseball and a sheet of paper when dropped from the same height. The baseball is still accelerating when it hits the floor. Air has a much greater effect on the motion of the paper than it does on the motion of the baseball. The paper does not accelerate very long before air resistance reduces the acceleration so that it moves at an almost constant velocity. When an object is falling with a constant velocity, we describe it with the term *terminal velocity*, or v_T. The paper reaches terminal velocity very quickly, but on a short drop to the floor, the baseball does not.

Air resistance is sometimes referred to as a *drag force*. Experiments have been done with a variety of objects falling in air. These sometimes show that the drag force is proportional to the velocity and sometimes that the drag force is proportional to the square of the velocity. In either case, the direction of the drag force is opposite to the direction of motion. Mathematically, the drag force can be described using $F_{drag} = -bv$ or $F_{drag} = -cv^2$. The constants b and c are called the *drag coefficients* that depend on the size and shape of the object.

When falling, there are two forces acting on an object: the weight, mg, and air resistance, $-bv$ or $-cv^2$. At terminal velocity, the downward force is equal to the upward force, so $mg = -bv$ or $mg = -cv^2$, depending on whether the drag force follows the first or second relationship. In either case, since g and b or c are constants, the terminal velocity is affected by the mass of the object. Taking out the constants, this yields either

$$v_T \propto m \text{ or } v_T^2 \propto m$$

If we plot mass versus v_T or v_T^2, we can determine which relationship is more appropriate.

In this experiment, you will measure terminal velocity as a function of mass for falling coffee filters, and use the data to choose between the two models for the drag force. Coffee filters were chosen because they are light enough to reach terminal velocity in a short distance.

OBJECTIVES

- Observe the effect of air resistance on falling coffee filters.
- Determine how air resistance and mass affect the terminal velocity of a falling object.
- Choose between two competing force models for the air resistance on falling coffee filters.

MATERIALS

LabPro interface	Vernier Motion Detector
Palm handheld	5 basket-style coffee filters
Data Pro program	Graphical Analysis or graph paper (optional)

PRELIMINARY QUESTIONS

1. Hold a single coffee filter in your hand. Release it and watch it fall to the ground. Next, nest two filters and release them. Did two filters fall faster, slower, or at the same rate as one filter? What kind of mathematical relationship do you predict will exist between the velocity of fall and the number of filters?

2. If there were no air resistance, how would the rate of fall of a coffee filter compare to the rate of fall of a baseball?

3. Sketch your prediction of a graph of the velocity *vs.* time for one falling coffee filter.

4. When the filter reaches terminal velocity, what is the net force acting upon it?

PROCEDURE

1. Support the Motion Detector about 2 m above the floor, pointing down, as shown in Figure 1.

2. Plug the Motion Detector into the DIG/SONIC 1 port of the LabPro interface. Connect the handheld to the LabPro using the interface cable. Firmly press in the cable ends.

3. Press the power button on the handheld to turn it on. To start Data Pro, tap the Data Pro icon on the Applications screen. Choose New from the Data Pro menu or tap (New) to reset the program.

4. Place a coffee filter in the palm of your hand and hold it about 0.5 m under the Motion Detector. Do not hold the filter closer than 0.4 m.

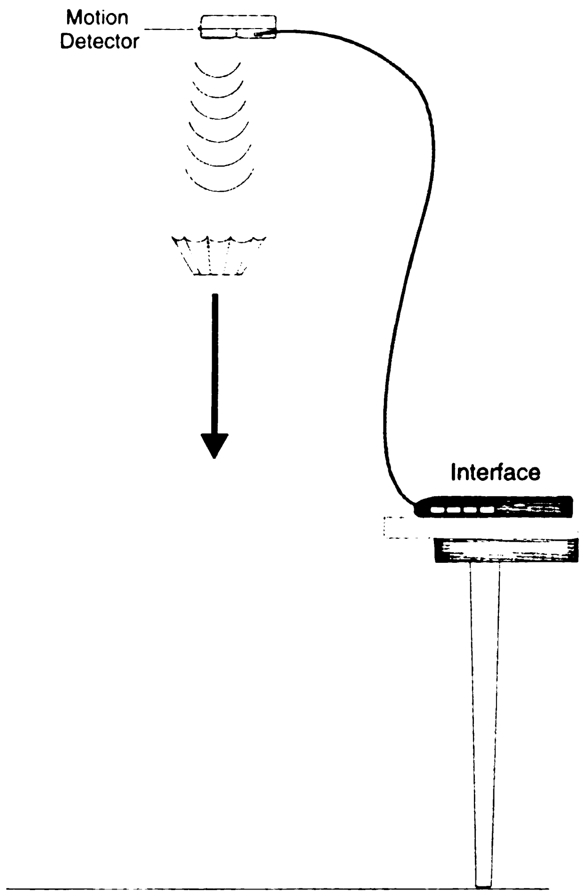


Figure 1

5. Tap [Start] to begin data collection. After the interface beeps, release the coffee filter directly below the Motion Detector so that it falls toward the floor. Move your hand out of the beam of the Motion Detector as quickly as possible so that only the motion of the filter is recorded on the graph.

6. Examine your distance graph.

   a. If the motion of the filter was too erratic to get a smooth graph, you will need to repeat the measurement. With practice, the filter will fall almost straight down with little sideways motion.

   b. To collect data again, simply tap [Start] when you are ready to release the filter. Continue to repeat this process until you get a smooth graph.

7. The velocity of the coffee filter can be determined from the slope of the distance *vs.* time graph. At the start of the graph, there should be a region of increasing slope (increasing velocity), and then the plot should become linear. Since the slope of this line is velocity, the linear portion indicates that the filter was falling with a constant or terminal velocity (v_T) during that time. To fit a line to the linear region, you first need to select that portion of your data.

   a. Tap the Selection button, [icon].

   b. Tap on the left boundary of the region of the distance *vs.* time graph that is linear. An arrow (>) is displayed on this line.

c. Tap on the right boundary of the linear section. An arrow (<) is displayed on this line.

d. Tap the Zoom button, [Zoom], to display just the freefall portion of your data.

8. Fit a straight line to the region you just selected.

a. Tap [Analyze], then tap [Curve Fit].

b. Choose Linear as the Fit Equation.

c. Record the slope in the data table (a velocity in m/s).

d. Tap [OK] to view the fitted curve with your data.

e. Tap [OK] once again to return to the Graph screen.

9. Repeat Steps 4 – 8 for two, three, four, and five coffee filters. (Optionally extend to six, seven and eight filters, but be sure to use sufficient fall distance so that a clear terminal velocity can be measured.)

DATA TABLE

Number	Terminal Velocity v_T (m/s)	(Terminal Velocity)^2 v_T^2 (m^2/s^2)
1		
2		
3		
4		
5		

ANALYSIS

1. To help choose between the two models for the drag force, plot terminal velocity v_T *vs.* number of filters (mass). On a separate graph, plot v_T^2 *vs.* number of filters. Use your handheld, Graphical Analysis, or graph paper. Scale each axis from the origin (0,0).

2. During terminal velocity the drag force is equal to the weight (*mg*) of the filter. If the drag force is proportional to velocity, then $v_T \propto m$. Or, if the drag force is proportional to the square of velocity, then $v_T^2 \propto m$. From your graphs, which proportionality is consistent with your data; that is, which graph is closer to a straight line that *goes through the origin*?

3. From the choice of proportionalities in the previous step, which of the drag force relationships ($-bv$ or $-cv^2$) appears to model the real data better? Notice that you are choosing between two different descriptions of air resistance—one or both may not correspond to what you observed.

4. How does the time of fall relate to the weight (*mg*) of the coffee filters (drag force)? If one filter falls in time, *t*, how long would it take four filters to fall, assuming the filters are always moving at terminal velocity?

Appendix D-4

Friction

Background

One of the forces you have studied is friction. Friction is a retarding force. This means it lessens the effect of other forces. Friction, therefore, causes a "loss" of useful energy in many mechanical devices. This energy, of course, is not really lost but is transferred to heat energy at the point of contact.

In this lab you will explain why the movement of one object over another produces heat and how changes in design can reduce friction. You will also learn how surface area, texture, and weight influence friction.

Materials

Spring balances (2.5 N, 10 N)
Rectangular block of wood with metal eye
8 X 11 piece of sandpaper

Procedure

1. Suspend a block of wood from the 2.5 N spring balance and obtain its weight in newtons.

Weight of block ____________

2. Place the block on the lab table with its larger surface (side A) downward.

3. Keep the spring scale level with the table and pull the block along the table. In Data Table 1 record the force indicated on the spring scale needed to start the block moving. Also record the force indicated on the spring scale once the block is sliding evenly along the lab table.

4. Repeat step 3 twice, recording your readings in Data Table 1. Calculate the average for the starting friction and the sliding friction.

5. Calculate the surface area for side A (area = length x width), and record it in the space provided.

6. Place the block on the lab table with its smaller surface (side B) downward.

7. Repeat steps 3 and 4. Record your readings in Data Table 1.

8. Calculate the area for side B and record it in the space provided

9. Repeat steps 1 through 8, sliding the surfaces of the block over a piece of sandpaper. Record your readings in Data Table 2 for side A and for side B.

10. Obtain a block of wood from another lab group, along with the data on its weight. Place the second block on top of your block so that the original A side is facing down. Record the weight of the two blocks and the sliding force required to move them both across the lab table.

Weights of two blocks _________ Average sliding force ___________

If time permits, add a third block and repeat.

Weight of three blocks _________ Average sliding force ___________

Observations

Data Table 1

Surface area of side A __________ cm^2 Surface area of side B _________ cm^2

Trial	Starting Friction (N)	Sliding Friction(N)	Trial	Starting Friction (N)	Sliding Friction(N)
1			1		
2			2		
3			3		
Average			Average		

Data Table 2

Side A Side B

Trial	Starting Friction (N)	Sliding Friction(N)	Trial	Starting Friction (N)	Sliding Friction(N)
1			1		
2			2		
3			3		
Average			Average		

How did the starting friction compare to the sliding friction?

____

Analysis and Conclusions

1. What do you think accounts for the difference between the starting friction and the sliding friction?

____

____

2. Based on your data, how does the surface area influence the sliding force of friction?

____

____

3. Based on your data, how does the texture influence the sliding force of friction?

____

____

4. How does weight influence the sliding force of friction?

____

____

Critical Thinking and Application

1. List two situations in which friction can be helpful.

____

____

2. List two ways you could reduce the friction between two or more surfaces.

____

____

References

Aarstad, T.J. (1997). The TI-92 symbolic calculator in Norwegian mathematics education. Retrieved June 26, 2006, from http://www.mathforum.org/mathed/ti92.html

Arnold, S., et. al. (1998). The use of calculator-based laboratory equipment in teaching math, chemistry, and biology. *Inquiry*, 3(1), 6.

Barclay, W.L. (1995). Graphing misconceptions and possible remedies using microcomputer-based labs.

Bell, M.A. (2002). Why use an interactive whiteboard? A baker's dozen reasons! *Teachers.net Gazette*, 3(1). Retrieved June 26, 2006, from http://teachers.net/gazette/JAN02/mabell.html

Bowen, M.G., et. al. (1999). Interpretations of graphs by university biology students and practicing scientists: Toward a social practice view of scientific representation practices. *Journal of Research in Science Teaching*, 36(9), 1020.

Brasell, H. (1987). The effect of real-time laboratory graphing on learning graphic representations of distance and velocity. *Journal of Research in Science Teaching*, 24, 385.

Brill, J.M. & Galloway, C. (2007). Perils and promises: University instructors' integration of technology in classroom-based practices. *British Journal of Educational Technology*, 38(1), 95.

Brush, T.A. (1998). Embedding cooperative learning into the design of integrated learning systems: Rationale and guidelines. *Educations Technology, Research and Development*, 46(3), 5.

Clement, J. (1989). The concept of variation and misconceptions in Cartesian graphing. *Focus on Learning Problems in Mathematics*, 11(2), 77.

Colman, R. & Colman, A. (2003). Preventing students' over-use of calculators. *The Science Teacher*, 22(7), 34.

Education World (2007). Retrieved October 20, 2007, from http://www.educationworld.com/

Eisele, J.E. (1982, Oct.). Instruction computing: Computers and cognitive learning. *Educational Technology*, 22, 33.

Goldberg, F.M., & Anderson, J.H., (1989). Student Difficulties with Graphical Representations of Negative Values of Velocity. *The Physics Teacher*, 27, 254.

Graham, T., & Smith, P. (2004). An investigation into the uses of graphics calculators with pupils in key stage two. *International Journal of Mathematical Education in Science and Technology*, 35(2), 227.

Hisim, N., (2005). Technology in the lab; Part II: Practical suggestions for using probeware in the science classroom. *The Science Teacher*, 72(7), 38.

Kashy, E., et. al. (1993). CAPA: An integrated computer assisted personalized assignment system. *American Journal of Physics*, 61(12), 1124.

Krentler, K.A. & Willis-Flurry, L.A. (2005). Does technology enhance actual student learning? The case of online discussion boards. *Journal of Education for Business*, 80(6), 316.

Kwon, O.N. (2002.) The effect of calculator-based ranger activities on students' graphing ability. *School Science and Mathematics*, 102(2), 57.

McDermott, L.C., et. al. (1987). Students' difficulties in connecting graphs and physics: Examples from kinematics. *American Journal of Physics*, 55, 503.

McKenzie, D.L., & Padilla, M.J. (1984). Effect of laboratory activity and written simulations on the acquisition of graphing skills by eighth grade students. Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, LA.

Monk, G.S. (1994). Students' understanding of function in calculus courses. *Humanistic Mathematics Network Journal*, 9, 21.

North Central Regional Educational Laboratory (2005). Critical issue: Using technology to improve student achievement. Retrieved June 1, 2008, http://www.ncrel.org/sdrs/areas/issues/methods/technlgy/te800.htm

Rother, C. (2004, October). Evaluating technology's role in the classroom: Second annual 'teachers talk tech' survey examines the long-term impact of technology on learning. *T.H.E. Journal*, 43.

Rother, C. (2005). Is technology changing how you teach? *T.H.E. Journal*,Vol. 33(3), 34.

School Matters (2007). Retrieved October 20, 2007, http://www.schoolmatters.com/schools.aspx/q/page=sp/sid=20378

Smith, A., with MirandaNet Fellows. (2000). Interactive whiteboard evaluation. Retrieved June 13, 2008, http://www.mirandanet.ac.uk/pubs/smartboard.htm

Smith, K.L. (1997). Preparing faculty for instructional technology: From education to development to creative independence. *CAUSE/EFFECT*, 20(3), 36.

Texas Instruments (1995). Texas instruments graphing calculators TI-83, TI-84, TI-89. Retrieved, June 27, 2006, from http://www.scinet.cc/articles/TI-calculators/graphing-calculators.html.

Vernier Software and Technology (2006). Beaverton, OR. Retrieved June 24, 2006, from http://www.vernier.com/

Waxman, H.C., & Huang, S.L. (1996). Classroom instruction differences by level of technology use in middle school mathematics. *Journal of Educational Computing Research*, 14, 147.

Waxman, H.C., & Huang, S.L. (1996-97). Differences by level of technology use on students' motivation, anxiety, and classroom learning environment in mathematics. *Journal of Educational Technology Systems*, 25(1), 67.