ANALYSIS OF MULTIPLE INSTRUCTIONAL TECHNIQUES ON THE UNDERSTANDING
AND RETENTION OF SELECT MECHANICS TOPICS

By

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ABSTRACT

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There are several topics that introductory physics students typically have difficulty understanding. The purpose of this thesis is to investigate if multiple instructional techniques will help students to better understand and retain the material. The three units analyzed in this study are graphing motion, projectile motion, and conservation of momentum. For each unit students were taught using new or altered instructional methods including online laboratory simulations, inquiry labs, and interactive demonstrations. Additionally, traditional instructional methods such as lecture and problem sets were retained. Effectiveness was measured through pre- and post-tests and student opinion surveys. Results suggest that incorporating multiple instructional techniques into teaching will improve student understanding and retention. Students stated that they learned well from all of the instructional methods used except the online simulations.

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Introduction

Rationale:

The subject of physics is typically considered by high school students to be difficult. This is due to many reasons. First, physics is mathematically demanding, requiring a solid understanding of Algebra 2. Second, students are challenged to think in ways that are different than what they have always done in past science classes; they are asked to combine science and math into one united subject. Third, they are continually asked to revise long held ideas about the physical world of which they have many contradictory observations. For example, most students will tell you that heavy objects fall faster than lighter ones, and unquestioningly believe this until repeatedly challenged. In addition, most students, when confronted with data different than what they believe it should be in a lab, will ignore, reject, exclude, or misinterpret, generally making only minor conceptual changes (Hynd 1995). After teaching physics at the high school level for three years, I have pinpointed three topics that students particularly have trouble understanding in relation to mechanics: projectile motion, graphing motion, and conservation of momentum. These three units could be improved by the addition of more focused laboratory experiences and other hands-on activities.

In our curriculum, the first topic taught is vectors and the second is straight line motion. Graphing motion is usually taught a day after straight line motion (displacement, velocity, and acceleration) has been presented. This topic occupies about two days of class time, and is included in the one-dimensional motion unit test. Typically, I give a short lecture, followed by a class demonstration using the motion detector. Then, students will complete a worksheet in which they plot points and graph position, velocity, and acceleration. They also complete several book problems. Often, students look at the graphs as if they are snapshots of motion, instead of viewing them as a representation of motion over time. Beichner (1996) found that in addition to a "photographic-like" representation, students become confused with the slope/height of graphs as well as the meaning of the area under graphs.

Projectile motion follows immediately after one dimensional motion. The unit involves a lecture, several demonstrations, and a lab using projectile launchers. Usually, students are quite proficient at analyzing horizontally launched projectiles. However, projectiles launched at an angle to the ground prove much more difficult to conceptualize, as does the concept of independent horizontal and vertical components. While students can repeat this fact for me, they cannot correctly answer related questions. They also struggle to solve mathematical problems in which they need to alternate between using horizontal and vertical components.

Finally, conservation of momentum typically ends up being the last unit of the trimester, following energy and circular motion. I find that the concept of transfer of momentum is difficult. Students struggle with drawing and then translating their diagrams into equations they can solve. Usually, examples of momentum are done with demonstrations, but we do not use actual velocities in solving the related problems. Students are simply asked to observe a decrease or increase in the velocity after collision.

They are also asked to solve conservation of momentum problems mathematically, and, in this particular area, students tend to get confused with positive and negative directions. There are not any labs in this unit.

My hypothesis is that using multiple instructional techniques will improve student understanding and retention of these three topics. These techniques include online simulations, labs that are more focused, and demonstrations that aptly display the concept. The traditional instruction I have used in years past such as lectures and problem sets will be retained.

Literature

There has been much research done (eg. Akpan, Beichner, Finkelstein, Lunetta) in the way of microcomputer based labs (MBL), or, simulations, in the classroom. Three characteristics of a simulation are:

1. It represents a real situation.
2. It provides user control over the problem/situation.
3. It omits certain distracting variables that are irrelevant or unimportant such as friction (Lunetta & Hofstein 1981).

Physics simulations are readily available online, but have yet to be embraced fully by teachers. The main reasons for this are: lack of prep time, quality of simulations, and the fact that teachers must change the way they teach to implement them (Foti & Ring 2008). The advantages of simulations are that they use less class time than labs and that they can even be completed and/or repeated by students at home (Choi & Gennaro 1987). Additionally, most online simulations are open source, whereas the lab supplies to perform these same experiments can be quite costly. However, students do lose the manipulative skills that they would learn executing an actual lab exercise (Hofstein & Lunetta 1982), so it is very important that simulations are not simply substituted for real lab activities. Studies have been done that indicate that simulations, when designed properly and used in the right context, can be as effective or even more effective than using real lab equipment (Finkelstein et al 2005). This study by Finkelstein showed that students who worked with physical circuit elements did worse on assessments than those who used an online simulation, even when that assessment involved building real circuits. The researchers attributed some of this disparity to the fact that simulations work to focus a student's attention on the important aspects and minimize distractions caused by equipment. An important factor to consider with simulations is whether or not the concept can be effectively shown in another way, or even more effectively shown in a lab setting or demonstration. Situations in which simulations are better alternatives are when there may be a lack of equipment available due to expense or limited resources, a history of inaccurate or contradictory results, or data collecting software/hardware reliability. It has also been found that using a simulation prior to formal instruction on a topic resulted in much higher achievement compared to formal instruction followed by simulation use (Brant, Hooper, & Sugrue 1991). Akpan also confirmed the "sim first" theory by noting that groups who performed a virtual dissection before performing an actual dissection did much better on short answer questions than groups who did the actual dissection, followed by the virtual dissection (Akpan 2001). Taking into account the results of these findings, I made every effort to assign the simulations I chose before I presented a topic in class.

The typical high school laboratory setting requires students to have a thorough knowledge of different measuring techniques. Students are asked to measure distances and times, determine masses and volumes, as well as read temperature, and then perform various calculations. 40-60% of time used during a traditional lab is in taking measurements (Hucke & Fischer 2002). While the skills involved in measurement taking are important skills to have, when the amount of time spent become excessive, one has to ask whether other aspects, such as the concept of the lab, are left behind. Measurement time can be greatly decreased by adding probe-ware into the lab, which many secondary science classrooms have if money is available. In my classroom, we do have the probes available and use them to a certain extent. Computer-based data capture and processing can be very useful. The main advantage is the ability of students to immediately analyze data, which the computer conveniently converts into a graph or chart of some sort, depending on the program used. In Hucke & Fisher's study (2002), only 5% of lab time was used for computer-specific activities such as saving and formatting graphs .

Another aspect of labs that is frequently discussed is the "cookbook" lab vs. the inquiry based lab. Cookbook labs usually have a list of steps for students to follow in order to arrive at a prescribed ending, and most students will be able to tell if they got the "right answer" or not. Fully inquiry based labs are much more open-ended. There is not one right way to do the lab, and students are left to brainstorm protocols and solutions on their own. The benefit of inquiry labs is that students learn more when doing these than when working through step-by-step directions; they also have enhanced science attitudes, reasoning skills, and better retention (Lord & Orkwisnewski 2006). However, there are some downsides to inquiry because they increase student frustration levels, they take longer to complete because students take time to come up with a feasible procedure, and there is less teacher control (Deters 2005). In addition, while inquiry labs are more likely to produce conceptual learning as compared to cookbook labs, students often find them less satisfying. Cookbook labs are definitely preferred among students, especially among the lower achieving students (Royuk & Brooks 2003). The labs I currently use are a mixture of inquiry-based and cookbook labs. To maximize the benefits of both types for this study, I used lab activity formals that take the best of both worlds: enough guidance for students to feel satisfied, but with inquiry aspects to the lab.

A classroom demonstration is typically when a teacher performs an experiment while the students observe and take notes. Usually the demonstration involves expensive equipment, limited supplies, or dangerous materials, prompting the demonstration in the first place (Milne & Oteino 2007). However, there has been some criticism of demonstrations as a teaching tool (Roth et al 1997 and Lynch & Zonchak 2002). Demonstrations are not hands-on and limit student inquiry when done in the traditional way. Sometimes they are also poorly integrated into the curriculum and therefore become more of a hindrance to learning than a help (Roth & Lucas 1997). In other words, demonstrations may bog down curriculum and do little to advance student knowledge. In order to meet the expectations that most teachers have for demonstrations, such as increasing student understanding, the demonstrations need to have specific structure to them as opposed to a "show and tell" atmosphere (Shepardson et al 1994). This specific structure includes built-in questions and discussion time, almost making it a class inquiry project as opposed to simply explaining how or why something occurs. Roth (1997) suggests some guidelines to follow:

1. Time for student discussion with their classmates in order to share and verify what they observed and understood.

2. Time for teachers to check student understanding for a correct explanation of what happened.

3. Engagement of students to talk about the demonstration.

Using these guidelines, a rich environment can be created where students can engage in many types of activities related to the demonstration.

Summary of Overarching Ideas

Graphing motion deals with three graphs: distance vs. time, velocity vs. time, and acceleration vs. time. The slope of a distance vs. time graph yields the velocity, and the slope of a velocity vs. time graph yields acceleration. Conversely, taking the area under an acceleration vs. time graph yields velocity and the area under a velocity vs. time graph yields distance. Using these guidelines, nearly any graph of motion can be analyzed to obtain a detailed description of the motion that is being represented.

Projectile motion in introductory physics deals with two dimensions only, horizontal and vertical. The central idea to remember in solving these problems is that the two components are independent of each other. It does not make any difference how large the horizontal velocity is because it does not affect the vertical velocity in any way.

However, time does link these two components together, which proves useful when solving quantitative problems of this nature. The horizontal velocity of a projectile is constant (when disregarding air resistance) because there is no acceleration. The vertical velocity of a projectile will change because of the acceleration due to gravity. Since the two components are independent of each other, solving projectile motion problems is like solving two problems: a free fall problem and a horizontal motion problem, with one variable, time, shared between the two. I have found that a major misconception among my students is that an object with a horizontal velocity will take longer to fall to the ground than an object that is simply dropped from the same height.

Momentum is the product of mass and velocity. In everyday language, momentum and inertia are used interchangeably, when in reality they are not the same thing. Inertia is an intrinsic property of an object, and is actually just the amount of mass in an object. For example, a bullet has little inertia, but a lot of momentum. The impulse-momentum theory states that the force multiplied by the change in time is equal to the change in momentum. This is the reason that we have airbags in cars: increasing the amount of time the airbag is in contact with the object decreases the force applied to the object. In a closed system, momentum is always conserved. Conservation of momentum can be applied to any closed system, commonly collisions. There are two general types of collisions: elastic and inelastic. Elastic collisions are ones in which the objects bounce off each other, and inelastic collisions are when the objects collide and stick together, moving with a common velocity.

Demographics

The research for this project was completed at Seaholm High School in Birmingham, MI. Birmingham is a suburban, middle to upper class city located in metro Detroit. The city of Birmingham website (Vision 2010) indicates that at least 38% of the over-25 population has a bachelor's degree and a further 30% of the population over age 25 has a graduate degree of some sort. The median household income is just over $100,000, and the poverty is less than 3%. According to the 2000 census, Birmingham has a population of over 19,000, 97.1% of those are white, 1.1% African American, and 2.0% Asian. (Birmingham, 2010)

The school district is made up of eight elementary schools, two middle schools, two high schools, a 3rd -8th grade school for students and parents who choose this unique program, and an alternative high school program. According to district documents (Board 2009), the graduation rate is 94.53%, and only 3.13% of students qualify for free or reduced lunch. Seaholm High School itself is made up of around 1300 students. 90.3 % are Caucasian, 3.4% are African American, 1.6 % are Asian, 1.8% are Hispanic, and 2.8% are "other". In contrast, the other high school in the district, Groves, is made up of 77% Caucasian and 19% African American. The school is on a trimester schedule, and this study was conducted the third year after implementation of the trimester schedule. Trimesters have been hard for teachers and students alike to adjust to. Both groups feel rushed completing an entire semester's worth of material in 12 weeks. As a result, most Advanced Placement classes and lower level classes are three trimesters in length, in an effort to provide more time for students to comprehend the material. There is a pronounced lack of enthusiasm for trimester from a large majority of the school population. With the addition of the new Michigan Content Expectations the same year we began trimester, our science department had to make some tough decisions in the classroom when it came to labs and projects we had done in the past. Two labs were eliminated from the first trimester physics course, and a project/competition the students loved in which they constructed projectile launchers of their own design in groups- the epitome of inquiry based learning- was cut also. These were some of the reasons that I decided to work on finding some more focused labs and simulations, which take less class time. The expectation is that these will leave room to bring back some of the things that have been cut out due to time constraints.

This study was conducted on two sections of first trimester Physics A students (mechanics). These students are either taking Algebra 2 concurrently, or have already completed it. The classes are composed of both juniors and seniors. A total of 25 out of 40 students agreed to participate in the study by returning their signed consent form. The school district also offers an honors and an advanced placement physics course, so the sections studied are composed primarily of students who are of average ability in science and math, most of whom do not plan to study any subject related to physics in college.

Implementation

The unit outline below lists in chronological order the assignments that were given during the period of this study. Additionally, appendix references are listed next to each assignment as well as the type of activity and the objectives covered. Items in italics have been developed or modified specifically for this study. For a list of objectives, see Appendix A.

Unit Outline

Unit One: Graphing Motion 9 days			
Assignment Name	**Appendix**	**Type of Activity**	**Objective(s) Addressed**
Straight Line Motion Lecture	-	Discussion	-
Problem set #1 (bookwork)	-	Homework	-
Graphing Motion Pre-test	B1	Assessment	A,B,C,D
Moving Man Simulation	C1	Simulation	A,B,C,D
Graphing Motion Lecture	C2	Discussion	A,B,C,D
Graphing Motion Demonstration	C3	Demonstration	A,B,C
Motion in a Straight Line worksheet	-	Homework	A,B,C,D
Problem set #2 (bookwork)	-	Homework	A,B,C,D
Graphing Motion worksheet	C4	Homework	A,B,C
Graphing Motion Lab	C5	Lab	A,B,C,D
Translation in Transylvania worksheet	-	Homework	A,B,C,D
Quiz #1	-	Assessment	-
Free Fall Lecture	-	Discussion	-
Problem set #3 (bookwork)	-	Homework	-
Free Fall lab	-	Lab	-
Graphing Motion Post-test	B2	Assessment	A,B,C,D

Table 1: Graphing Motion Unit Outline

Unit Two: Projectile Motion 5 days			
Assignment Name	**Appendix**	**Type of Activity**	**Objective(s) Addressed**
Projectile Motion Pre-test	B3	Assessment	E,F,G
Projectile Motion Simulation	C6	Simulation	E,F
Projectile Motion Lecture	C7	Discussion	E,F,G
Projectile Motion Demonstrations	C8	Demonstration	E,G
Problem set #4 (bookwork)	-	Homework	F,G
Projectile Problems worksheet	C9	Homework	F,G
Projectile Motion Lab	C10	Lab	E,F,G
Projectile Motion Post-test	B4	Assessment	E,F,G

Table 2: Projectile Motion Unit Outline

Unit Three: Conservation of Momentum 7 days			
Assignment Name	**Appendix**	**Type of Activity**	**Objective(s) Addressed**
Conservation of Momentum Pre-test	B5	Assessment	H,I,J,K,L
Conservation of Momentum simulation	C11	Simulation	H,J,K
Momentum and Impulse Lecture	-	Discussion	H,I,L
Problem Set #5 (bookwork)	-	Homework	H,I
Problem Set #6 (bookwork)	-	Homework	H,I
Conservation of Momentum Lecture	C12	Discussion	H,I,J,K,L
Conservation of Momentum Demonstrations	C13	Demonstration	I,J,K
Problem Set #7 (bookwork)	-	Homework	H,I,J,K
Momentum and Its Conservation worksheet	-	Homework	H,I,J,K
Conservation of Momentum Lab	C14	Lab	H,J,K
Momentum Post-test	B6	Assessment	H,I,J,K,L

Table 3: Conservation of Momentum Unit Outline

As research shows, changes to teaching such as assigning simulations before labs, presenting demonstrations that are more interactive, and using inquiry based labs will improve student understanding and comprehension. Therefore, during the period of time this study was conducted, simulation assignments were always collected before the lab was conducted. Additionally, demonstrations were adapted to conform to the research-based effective techniques and labs were altered to be more inquiry driven.

Pre-tests (Appendix B1,B3,B5) were given before any item in the unit was taught. Students were not allowed to see the pre-tests at any time after they were collected. Pre-test and posttest questions (Appendix B2,B4,B6) were closely related in order to accurately gauge student comprehension after the concepts were taught. Whenever possible, questions were identical between pre and post test. Simulations (Appendix C1,C6,C11) were assigned to students and their responses were collected before they began the actual lab in that unit.

Overview of Units

Unit One: Graphing Motion

The unit was begun by giving students the Graphing Motion Pre-test (Appendix B1) . Previous to this, the concepts of displacement, velocity, and acceleration were discussed without graphing anything. The pre-test focused on two concepts:

a. Can students look at a graph and explain what is happening to displacement, velocity, and acceleration, and vice versa?

b. Can students graph motion, given a description in words?

Over one weekend, students were also given an online simulation assignment to complete called "The Moving Man" (Appendix C1). This simulation came from the University of Colorado at Boulder website, called PhET (2010). The simulation is of a person whose motion can be controlled either by manually clicking and dragging him with the mouse, or by inputting set values. The simulation features three graphs: displacement, velocity, and acceleration situated one on top of the other as pictured in Figure 1.

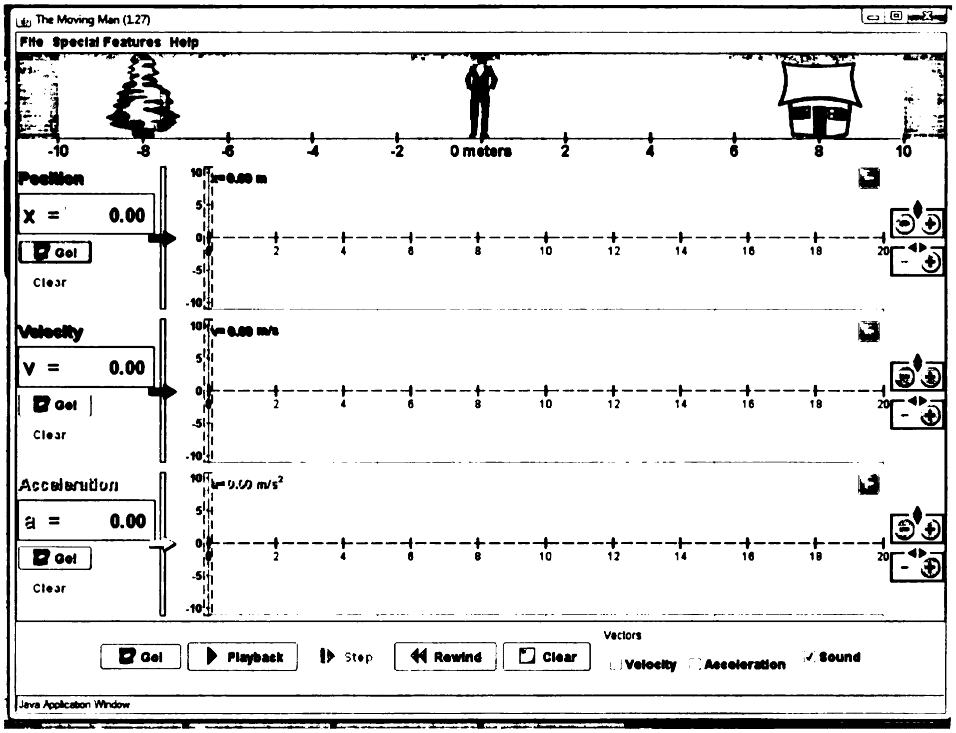


Figure 1: Moving Man Simulation (pHET 2010)

As the man moves, the graphs are made in real time. On the assignment, students replicated a series of situations, and then drew the resulting graphs. They reflected on the various situations they had drawn, to see if they could come up with an explanation of when acceleration is not equal to zero. Finally, they were given a distance graph, and asked to use it to make a velocity graph and an acceleration graph, using the simulation to check their work and understanding. This final question was very much like what they would do in the coming days in their lab, on worksheets, and then finally on their assessment.

Following the simulation, was the graphing motion lecture (Appendix C2). The lecture consisted of examples of different motions and how they would be graphed, as well as how values can be determined from the slope and area under the graphs. This was followed by the Graphing Motion Demonstration (Appendix C3). Students were asked to match their movement to the motion on the graphs. Initially students attempted this on their own. However, eventually each example was discussed thoroughly with them, and the class analyzed exactly what should be done to match the graph. In this way, the demonstration resembled a guided inquiry lab because students were given a problem (a graph to match) and were asked to figure it out with help from the instructor. Students were then given the Graphing Motion Worksheet (Appendix C4) to complete. One example was done with the class step by step, and then they completed the rest on their own.

In the next few days, students were given several other problem sets dealing with graphing motion and numerically solved straight line motion problems. Half of a class period was spent completing the Graphing Motion Lab (Appendix C5) which was specifically written to fit into one class period. Students completed the lab in groups of three or four. They turned these labs in as a group, and students were informed that everyone in the lab group was responsible for personally knowing the material.

Following these assignments, free fall problems were addressed specifically, integrating graphing into the assignments. Students completed the Free-fall Lab, and constructed graphs to fit the data. These assignments also dealt with graphing motion and helped to solidify student reasoning. The Graphing Motion Post Test (Appendix B2) closed the unit.

Unit Two: Projectile Motion

Students completed the Projectile Motion Pre-test (Appendix B3) directly after the Graphing Motion Post Test. The main objectives on the pre-test were to determine if students understood both how a projectile travels, and what changes occur in horizontal and vertical motion as the projectile moves. Students were also asked some conceptual questions to see if they knew that a horizontal velocity does not have any effect on vertical velocity. Afterward, a discussion on projectile motion took place (Appendix C7). The independence of the x and y components as well as how time links them was discussed. Finally, some quantitative problems were done on the board to serve as examples. On this initial lecture day only horizontally launched projectiles were discussed. Also, some of the Projectile Motion Demonstrations (Appendix C8) were performed.

For homework that night, the Projectile Motion Simulation was assigned (Appendix C6), once again through PhET (Figure 2).

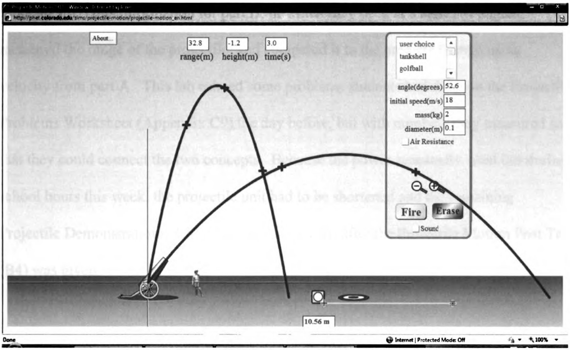


Figure 2: Projectile Motion Simulation (pHET 2010)

The projectile simulation gave a choice of several different items to fire, allowed the user to change the angle of the cannon, to change the mass, size, and speed of the object, as well as to turn air resistance on or off. Students turned air resistance off and on, and played with the simulation, using several different objects, so that they observed that it is only air resistance that keeps objects of different sizes from following the same path. They manipulated a series of variables and listed whether they hit the target or not, and made observations as to time in the air, trajectory, horizontal and vertical distances traveled. The simulation included a tape measure which can be manipulated to measure distances on the screen.

The following day a discussion was held which included velocity vector analysis and projectiles fired at angles. The Projectile Motion Lab (Appendix C10) had two parts. Part A involved firing a projectile horizontally, and then calculating the muzzle velocity.

Students used this information for part B, in which they fired at a series of angles, measured the range of the projectile, and compared it to the predicted range using velocity from part A. This lab echoed some problems students had done on the Projectile Problems Worksheet (Appendix C9) the day before, but with numbers they measured so that they could connect the two concepts. Because the power repeatedly went out during school hours this week, the projectile unit had to be shortened and the remaining Projectile Demonstrations (C8) were postponed until after the Projectile Motion Post Test (B4) was given.

Unit Three: Conservation of Momentum

The Conservation of Momentum Pre-test (Appendix B5) primarily addressed collisions and the changes in velocity between objects of the same mass and of different masses. Students were asked to explain why increasing the time of contact between objects will decrease the force between them as long as the change in momentum remains the same, referring to the impulse-momentum theory.

The unit began with a lecture on momentum, explaining the differences between inertia and momentum, how to calculate momentum, and then the impulse-momentum theory ($Ft=m\Delta v$). Momentum Demonstrations were also included (Appendix C13).

The Conservation of Momentum Simulation (Appendix C11) was assigned for homework. It was shortened due to time constraints, so that the students chose just one elastic collision and one inelastic collision to analyze quantitatively. Students manipulated the masses and velocities of the objects and listed the final velocity of each mass, after the collision. The students were asked to calculate initial and final momentum as well as kinetic energy. The simulation allowed the user to change between elastic and inelastic collisions (Figure 3).

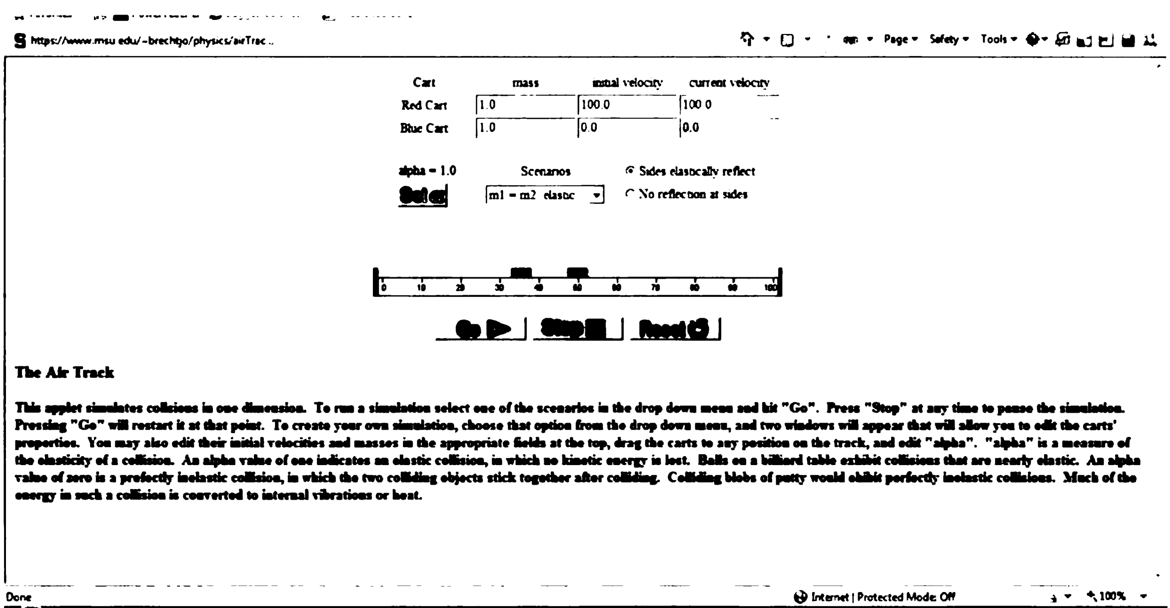


Figure 3: Conservation of Momentum Simulation (Michigan State University, 2010)

Students were introduced to conservation of momentum through the Conservation of Momentum Demonstrations (Appendix C13). They also learned which values change, and reviewed example problems in both elastic and inelastic collisions (Appendix C12). A frictionless track and collision carts were used to demonstrate the various situations. Masses and speeds of the carts were changed while students were asked to make predictions as to what would happen. Students also examined and experimented with a giant Newton's Cradle. Students worked on some problem sets dealing with conservation of momentum calculations. Finally they performed the Conservation of Momentum Lab (Appendix C14) using the collision carts. The lab was done as a class demonstration due to equipment shortages, time constraints, and difficulty in collecting the data with available equipment. Students were asked to do all the data set calculations for an elastic collision, inelastic collision, and with an unknown mass added to the cart on their own or with a partner's help. Following this demonstration, students completed book problems on conservation of momentum before the Conservation of Momentum Post Test (Appendix B6), which was given three days later.

Student Surveys

Students were surveyed as to their opinions on the various types of activities that were used. Surveys (Appendix E) were given up to two weeks after the unit had been taught and respective post tests were given. When students took the survey, they knew what their post-test scores were. The surveys asked students to rate each teaching type that was used (simulation, lab, problem set, discussion, demonstration) on a 1-5 basis, 1 indicating that the assignment did nothing to further their understanding of the topic and 5 indicating that the assignment was pivotal to their understanding. They were also asked to make comments about each assignment type.

Final Exam

The final part of this study looks at student retention of the concepts taught by asking two questions per study topic. Questions that dealt with the three topics above on the Final Exam (Appendix B7) were pinpointed. Time constraints for the final exam caused there to be only two questions per topic assessed on the final exam.

Results/Discussion

The results and discussion sections have been combined due to the large amount of data specific to each objective. In this way, the data were analyzed much more effectively. On the pre- and post-tests, questions were identical unless otherwise noted. Paired pre- and post-test questions (Appendix F) are listed in this section in terms of the number on the pre-test, followed by the number on the post-test (ex. #1/3: Pre-test #/Post-test #). Questions marked with a "P" indicate that it is a short answer or quantitative problem, and questions marked with an "MC" indicate that it is a multiple choice or true/false question. Pre-tests were comprised of 10 questions, whereas post-tests always had more questions, which is the reason why paired questions do not have matching numbers. Results were analyzed using a paired Student's T-test (n=25 unless otherwise noted) for each set of itemized pre/post-test questions. Other data in this section come from anecdotal comments by the researcher. For pre/post-test scoring rubrics, see Appendix D; for objectives, see Appendix A.

Unit One: Graphing Motion

Students indicated after taking the Graphing Motion Pre-test (Appendix B1) that they remembered seeing and drawing these motion graphs in the introductory freshmen science course, but that they didn't recall any specifics of how to draw them. During the Graphing Motion Lab (Appendix C5) in which they used graphing software, conversations overheard by the researcher were encouraging. Students actively worked together to closely match the graph to their movement, explained to each other why the line had a negative slope when it did, or talked about why there might have been a spike in the graph. On the other hand, there was a lot of confusion with the Moving Man Simulation (C1) that they had done as a homework assignment. Many students failed to use the program effectively and were frustrated. The Graphing Motion Post-test (Appendix B2) scores overall showed a better understanding of graphing motion than has been observed in years past, based on the graphs students constructed for questions 4P and 5P. Results from the paired Student's T- test for unit one show that the probability of the results, assuming the null hypothesis, is 0.004.

Objective A: Create graphs using position and time.

Objective A was taught in several ways. Students used graphing software to view how their movements looked on a graph in real time, used a computer simulation to see how different movements looked when graphed, and completed related homework questions. Three pre/post assessment questions dealt specifically with objective A. Results from these questions are shown in Figure 4.

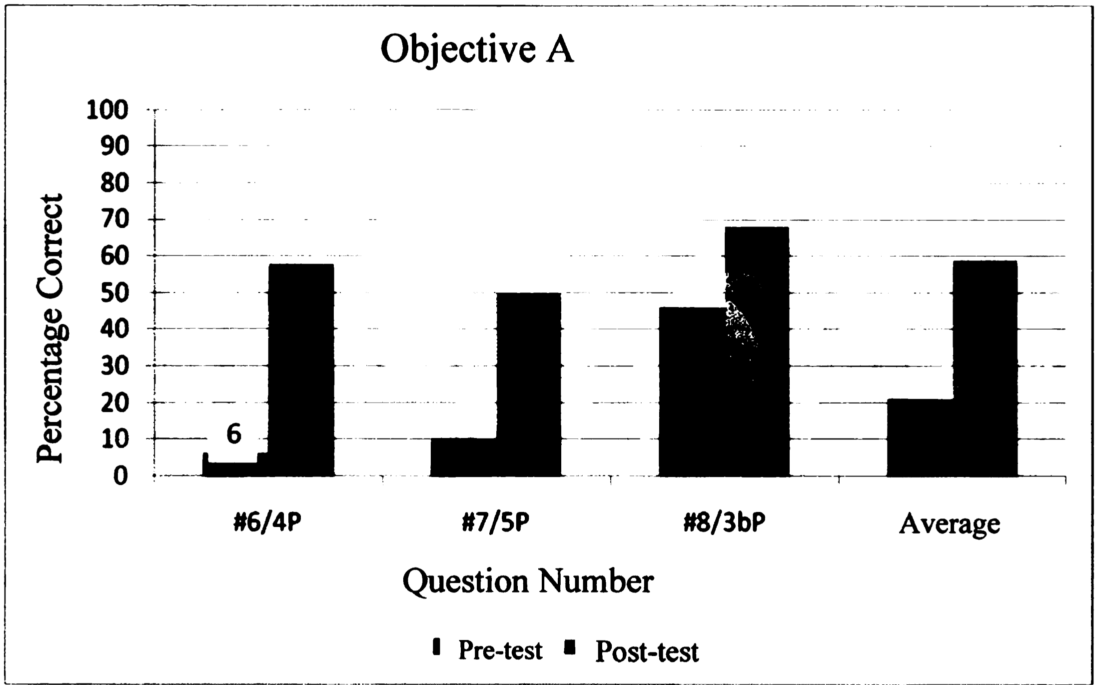


Figure 4: Graph of Objective A Pre/Post-test Results

All three paired questions were not the same between pre- and post-test. The reason for this is that post-test graphs contained additional segments, making them more difficult. These data show that while students had slightly lower scores when solving the velocity-time graph (#7/5P) as compared to the distance-time graphs (#6/4P, #8/3bP), indicating this is the more difficult problem, both of these problem types had nearly the same difference between pre and post-test. Question #6 had a difference of 52% while #7 had a difference of 40%. Question #8 asked students to read a description of motion and translate this into a velocity-time graph. This was a concept that students did fairly well on to begin with, 46% of students getting the question correct on the pre-test. On average for objective A, scores increased by 38% between the pre- and post-test. Question numbers 4P and 5P on the post-test required students to interpret a distance time and velocity time graph, respectively. Students seemed to have an easier time when beginning with a distance vs. time graph. Additionally, the questions on the post-test were extremely difficult, as compared to the pre-test. This is because the post-test graphs that students analyzed contained many different segments of line that had to be drawn correctly on the corresponding graphs. According to the rubric (Appendix D), to get the full point on the question they needed to get every single part correct, whereas to get 0.5 they needed to get more than half of the question correct. On question number 4P, the mode was 1 while the mode on number 5P was only 0.5. Anecdotally, I felt students did much better on these three questions than they have in years past.

Objectives B and C: Describe and analyze position-time and velocity-time graphs.

Objectives B and C were very similar which is why they were analyzed together. As shown in Figures 5 and 6, three pre/post assessment questions dealt specifically with objective B and two pre/post assessment questions dealt with objective C.

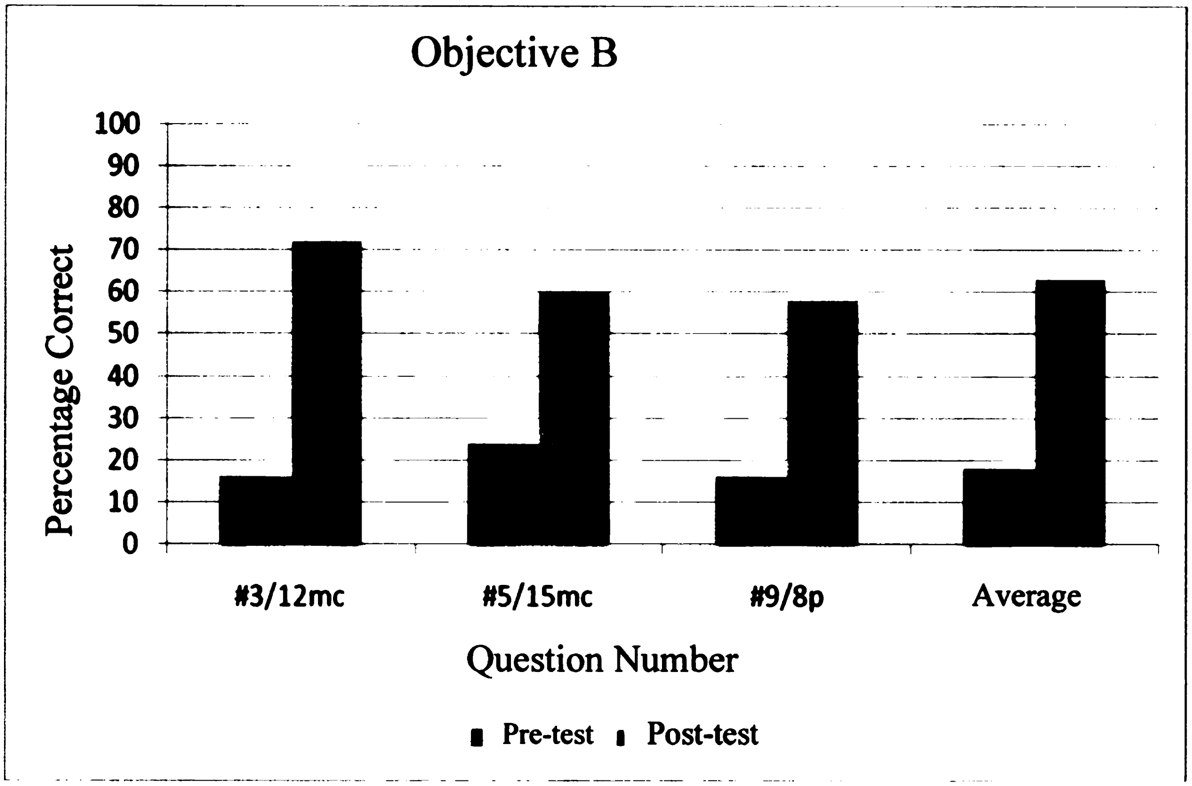


Figure 5: Graph of Objective B Pre/Post-test Results

Data show that overall student understanding improved greatly between pre- and post-tests. On average there was a 45% increase between the pre- and post-test score. The largest gain between pre- and post-test was on pre-test question #3 and post-test question #12 multiple choice. 28% of the students in the study did not get post-test question #12 mc correct. Of this 28%, not one student chose letter C, which had a negative slope. This indicates that students clearly understood the relationship between slope orientation and positive or negative acceleration. However, they did not all make the connection that acceleration translates to a line that is curved upward. Almost every student who got this question incorrect chose letter A, which shows a linear slope, indicating constant speed instead of increasing speed. Questions #5 and #9 had similar differences between pre- and post-test scores. Interestingly, #9 appeared to be a very simple question and a much higher score was anticipated. The part that caused the most trouble for students was the downward sloped section of the graph. Many students stated that the ball stood still, was "dropped", and then stood still again. I believe that if the object being graphed had been a person's movement, many more students would have gotten this correct. However, it should not matter what the object is, students should be able to interpret the graph.

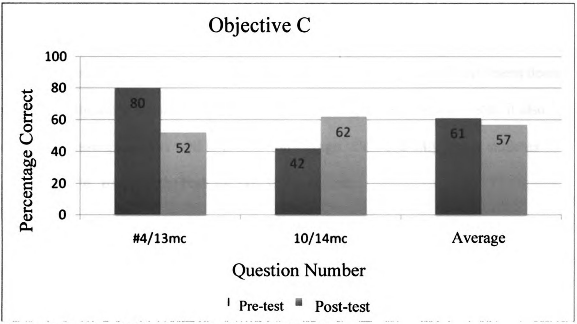


Figure 6: Graph of Objective C Pre/Post-test Results

The most puzzling result related to objective C was the decrease in score between pre- and post-test scores for question #4/13mc. Only 52% got this question correct on the post-test, and on the pre-test 80% got the question correct. The majority of the 48% who got this incorrect chose letter D, which would have been the correct answer, had this been a position time graph. I believe this demonstrates one of the greatest problems students face when dealing with graphing motion. Students have difficulty when switching between position, velocity, and acceleration graphs. Of the 80% who got this question correct on the pre-test, most stated in their explanation that "it is the only negative graph" or "because it is going in the opposite direction as the positive acceleration". It seems that after learning about graphing motion they over-analyzed the graph. Question #10/14 asked students to "choose all answers that apply." On the post-test question, 36% of students chose only one of the correct answers, and 40% of students chose both correct answers. In assigning point values as explained in Appendix D, this averaged to a score of 62%. On the pre-test question, only 8% of students got both correct, while 60% of students got one correct; according to the point values assigned, this averaged to 42% correct. The common misconception this problem deals with is that the word acceleration only means increasing speed, when in reality it also means decreasing speed as well as a direction change. Consequently, many students chose letter "e" only, on the both the pre- and post-test.

Objective D: Use area under the graph and slope to determine values from a velocity time graph.

Two questions dealt with objective D. This objective was taught and assessed primarily through lecture notes and problem sets.

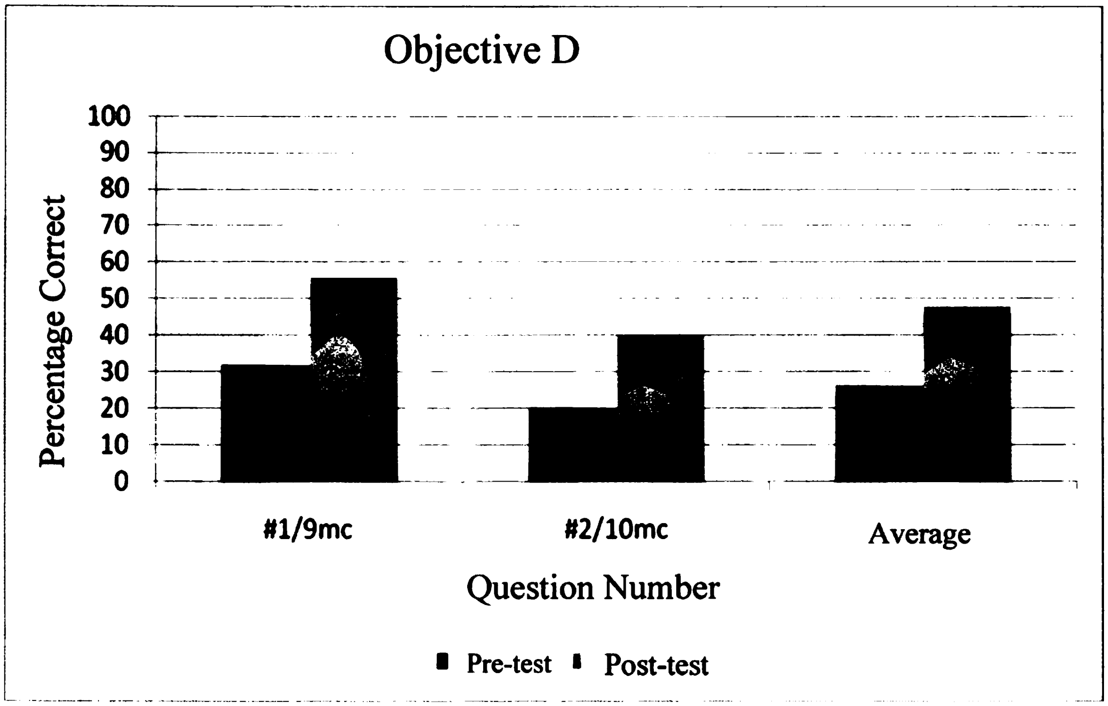


Figure 7: Graph of Objective D Pre/Post-test Results

There was an average gain of 22%. Predictably, question #1/9mc had a slightly greater gain. I attribute this to the fact that most physics students have extensive knowledge of slope, Algebra 2 being a prerequisite for physics. However, finding the area under a line graph is much less familiar to students. It is not until a calculus class that students are exposed to this idea in any depth. Looking back at all of the graphing motion objectives, it is interesting to note that this objective was the one with the lowest average post-test score. One explanation could be that this was the only objective that was assessed solely through multiple choice. This could be the reason why there was a lower overall score since students could either receive 1 point for a correct answer or 0 points for an incorrect answer. It was also taught solely by lecture and problem sets.

Unit Two: Projectile Motion

On the Projectile Motion Pre-test (Appendix B3), generally it was found that students were not knowledgeable about the mechanics of projectile motion. On the Projectile Motion Post-test (Appendix B4), students did pretty well and there were some very good answers on problem # 8, the sailboat and rock question. However, basic mathematics were a problem in that students showed an inability to separately deal with the x and y components. Results from the paired Student's T-test show that the probability of the data occurring, assuming the null hypothesis, is 0.001 (n=22).

Objective E: Identify changes in speed and direction for everyday examples of projectiles.

For objective E, questions were asked about how vertical and horizontal speed change along a projectile's trajectory as well as the path of projectile motion. These objectives were taught through many demonstrations and examples during lecture.

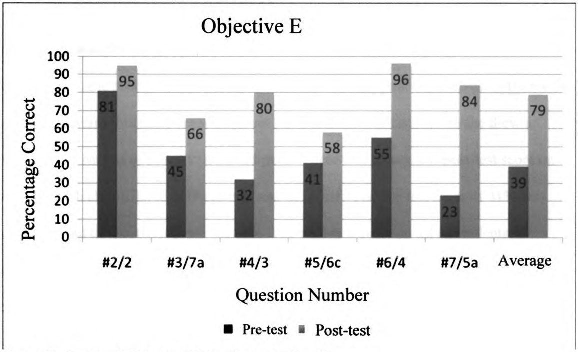


Figure 8: Graph of Objective E Pre/Post-test Results

The data show that on average there was a 40% gain between pre- and post-test score for this objective. Question #2/2 had the highest pre-test score, and students only gained 14% between assessments. This question simply asked what the path of a projectile is which most students knew when the unit began. Of the 19% who got this question incorrect on the pre-test, 12% of these students answered that projectiles do not follow a predictable path. The other 7% either guessed (as they stated in the explanation) or did not answer the question at all. On the post-test, 95% got the questions correct. The largest gain in score was 61% on question #7/5a. This question was different between pre- and post-test, but both asked students to draw or choose the correct path of a projectile that was being dropped from a moving object (plane or flying bird). On the pre-test, most students recognized that the object would not follow a straight line path (answers b or c) and instead chose a or d. However, only 30% of the class chose the correct answer. 40% of students chose letter a, the path curved backward and down.

This shows that students did not take into account that the projectile should move in the direction it was already going instead of backward, as if from the perspective of the bird or plane. On the post-test, students were asked to draw the path themselves. All drew it directed forward this time, but if a student lost points, it was because he/she drew a straight line path as opposed to a curved path. There was a very low post-test score on #5/6c, which also differed between pre- and post-test. The pre-test score of 41% was expected, but the post-test score was not. The post-test question asked students to describe the vertical velocity of a ball that is dropped. 28% of students answering this question described the ball as being thrown up and down, and therefore said velocity would first decrease, then become zero, then increase as it moved downward again. This caused these students' scores to be 0.5/1, decreasing the overall average. Other students seemed to get this question confused with the horizontal velocity vector, and instead described that. Question #3/7a also differed between pre- and post-test: on the pre-test, students only needed to draw arrows the proper size and direction, whereas on the post-test students drew this as well as quantitatively solved for their values. This is the reason that scores did not increase on this paired question as much as on other question; students were asked to get more items correct in order to receive full credit. Overall, the data show that students understand how projectiles travel. The breakdown in their thinking seems to be both in translating their thoughts into drawings or diagrams and also keeping vertical and horizontal velocities straight.

Objective F: Apply the independence of horizontal and vertical velocities to solve projectile problems.

Many students struggled with objective F for the entire unit. This was taught through the Projectile Motion Lab (Appendix C10), the Projectile Motion Simulation (Appendix C6), and many class examples and homework assignments. Since students could not be expected to have any idea how to solve numerical problems on the pre-test, conceptual questions that were related to understanding how horizontal and vertical velocities have no effect on each other were asked.

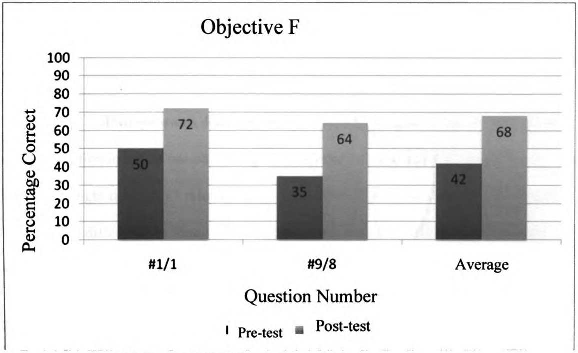


Figure 9: Graph of Objective F Pre/Post-test Results

The data show a relatively small gain on this objective. #1/1 was a true/false question so students either got 1 point or 0 points. They also had a 50/50 chance if they guessed. There was only a 22% gain on this question. Question #9/8 was probably one of the hardest questions that asked on any of the assessments. It asks students whether a rock dropped from the mast of a boat will hit the same place on a deck when the boat is stationary vs. moving. 35% of students got this question correct on the pre-test, but most of this came from partial credit. Only one student got full credit for this question. On the post-test, 100% of students received at least partial credit, and 28% of students got full credit. Students who received partial credit did not sufficiently explain why the rock would hit at the same place on the deck. Most failed to draw a picture that fully explained or backed up their reasoning. The average pre- and post-test scores are 42% and 68%, for a 26% increase.

Objective G: Understand that time is common to vertical and horizontal components of motion.

Two questions dealt specifically with objective G. Students were shown a demonstration in which one ball was given a horizontal velocity while another was dropped straight down, both released at the same time. They were able to observe that there was no difference in "hang time" between the two balls. Additionally, students were taught this concept mathematically, solving problems for practice.

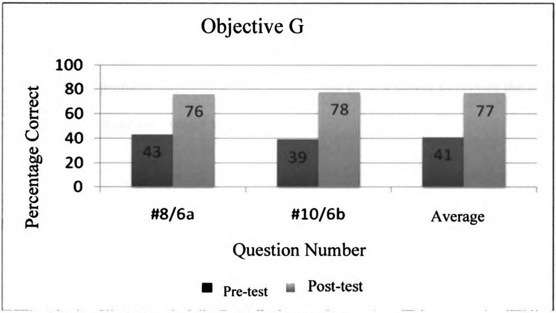


Figure 10: Graph of Objective G Pre/Post-test Results

Questions #8 and 10 are very much related. On the post-test, the two were part a and b of the same question. The pre- and post-test questions were different, but both dealt with the fact that it will take a projectile the same amount of time to fall to the ground, regardless of whether it has a horizontal velocity or not. The difference between pre- and post-test was that on the pre-test questions, students were asked to explain whether projectiles would hit the ground at the same time or not when one was given a horizontal velocity. On the post-test quantitative questions asked students to determine exactly how many seconds each object would be in the air if they were dropped at the same time. Questions showed almost identical percentages correct on both the pre- and post-tests. Overall, students had sufficient understanding of this concept. On the pre-test most students said that the object that was moving both horizontally and vertically would take longer to reach the ground than the one traveling only vertically. A typical student response to number 10 was "the bullet that is being dropped will hit the ground faster, because it doesn't have as long of a way to go before it hits the ground." On the post-test, 33% of students who got 6a and/or 6b incorrect could be attributed to mathematical errors. They had the correct equation and variables but then solved the problem incorrectly. The others seem to be a failure to choose the correct equation and to input the correct variables.

Unit Three: Conservation of Momentum

Results from the Conservation of Momentum Pre-test (Appendix B5) show that most students could equate conservation of momentum to everyday situations, such as throwing an object forward and being pushed backwards, but when it came to other examples, the results were mixed. Later in the unit, after looking over the Conservation of Momentum Simulation (Appendix C11), it was noticed that most students did very well on the calculations of momentum and kinetic energy. The problem was with the questions "Is momentum conserved?" and "Is kinetic energy conserved?". Although the majority of the students got the calculations correct, they answered these questions incorrectly. It is the researcher's belief that this is because they thought that momentum, not in the total system, but just in the individual object, should remain the same. Based on observations, students did very well with the Conservation of Momentum Lab (Appendix C14). They seemed to really understand what was going on, and the most difficult part, the unknown mass determination, went over well. Conceptually, I thought that the students did well. The biggest problems were the same ones they were warned about over and over again: unit conversions (g to kg, km/hr to m/s), paying attention to directions by making opposite directions opposite signs, and using Δp as $p_{final}-p_{initial}$ and not vice versa. Overall, the students who failed to fully understand the mathematics of conservation of momentum still seemed to have a very good grasp of the concept. It was encouraging to see that students who got many of the calculations incorrect still had very good, thorough answers for the explanation problems. Results from the Student's T-test show that the probability of this occurring, assuming the null hypothesis, is 0.000 (n=20).

Objectives H and I: Explain and calculate how time of impact and force of impact influence each other.

There was only one question on the assessments that examined objectives H and I together, which are very similar. The pre-test question asked about the concept of follow through in baseball, and why it is effective. The post-test question asked about why an egg will not break when it hits a towel as opposed to a wall. Both questions have to do with the impulse momentum theory.

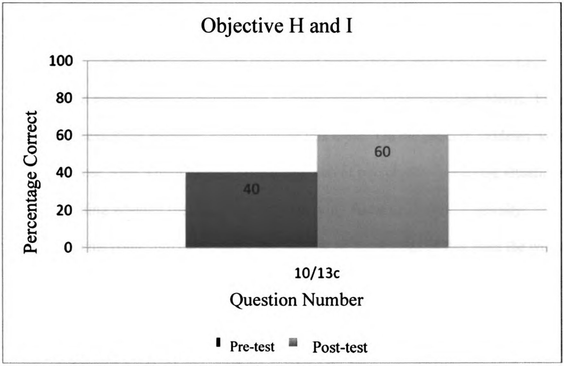


Figure 11: Graph of Objective H and I Pre/Post-test Results

On both the pre- and post-test, partial credit was assigned, as referenced in Appendix D. The scores were 40% on the pre-test and 60% post-test, with a difference of 20%. On the pre-test, several students had some idea as to why follow through was important, but couldn't explain it satisfactorily. A common answer among students was "you give the ball more energy to travel farther". While this shows that the student understands the concept at a basic level, it does not demonstrate that they understand the relationship between time of contact and change in momentum. Only 16% of students had a sufficiently correct answer to warrant full credit. The most common score on the pre-test question was 0/1. On the post-test, the most common score was 1/1 points, with 44% of students earning full credit and 32% earning half credit. The most common reason for loss of points on the post-test was students simply saying "the towel cushions the egg" which, while true, is not a "physics" explanation.

Objective J: Apply conservation of momentum to solve simple collision problems.

Objective J deals with the student being able to apply what they have learned about conservation of momentum to solve simple mathematical problems. Five questions assessed the students' knowledge on this topic. On the pre-test, students were asked to choose what would happen after a collision of two objects in varying situations, such as deciding whether the object would be moving faster or slower. Typically, physics students come into class with a fair amount of knowledge of this from the world around them. However, they do not always make the most accurate observations, so the data sometime surprise them. On the post-test, students were asked to solve problems numerically. This involved choosing the correct sign conventions, and matching the correct mass with each velocity. This objective was taught in many different ways. There were many demonstrations, a class lab on conservation of momentum where they calculated momentum of objects before and after collisions, as well as numerous individual assignments for which they had to calculate momentum.

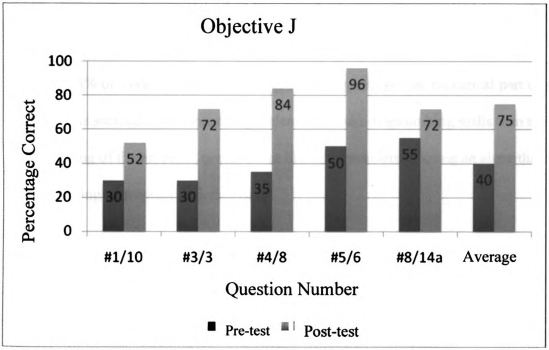


Figure 12: Graph of Objective J Pre/Post-test Results

Figure 12 shows that the greatest gain in score came on question #4/8, and the smallest gain was on question #8/14. Questions #4/8 and #5/6 differed between pre- and post because the post-test had students solve the problem quantitatively. Question #4/8 was on the change in momentum of a bowling pin and ball system. The pre-test simply asked about relative speed (faster, slower, the same) while the post-test asked students to come up with a numerical answer. Question #5/6 and #3/3 were similar in percentage differences, pre to post. The question with the lowest difference between pre and post was #8/14a. The question asked students to draw a diagram showing two snowballs of unequal masses but equal speeds colliding head on. Most students seemed to inherently understand this situation through experience with everyday interactions between objects. 44% of students on the pre-test drew a before and after picture, but the after picture showed a large snowball without any velocity vector. Whether students believed the snowball would come to rest, or just neglected this fact is not clear. On the post-test, 36% of students still made this same mistake. Another part of this same problem asked students to figure out the final speed of the combined snowballs after the collision. 56% of students who got the diagram wrong still got the numerical part of this correct. This seemed to be more of a problem with their diagramming skills than their understanding of the problem, or else more likelier, a problem of using an algorithm without having conceptual understanding.

<u>Objective K</u>: Predict how large and small masses will be affected in a collision.

Objective K was taught using the Conservation of Momentum Simulation (Appendix C11), discussion in class, Conservation of Momentum Demonstrations (Appendix C13), the Conservation of Momentum Lab (C14), as well as several problem sets.

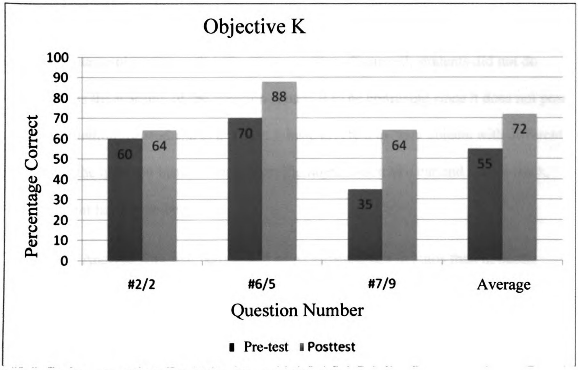


Figure 13: Graph of Objective K Pre/Post-test Results

The data related to this objective show a wide range of results among questions. Question #6/5 (Figure 13) was the only set where the pre- and post-test questions were not identical. The pre-test question asked students to predict what will happen when an object is thrown forward whereas the post-test question asks the question quantitatively. This question showed an 18% change between pre and post. The post-test score was reasonably high compared to other post-test question results in this unit. This can be attributed to the fact that many demonstrations and examples of this situation were done. Question #7/9 showed the greatest percentage improvement, from 35% to 64%. This demonstrates that a majority of students learned the difference between elastic and inelastic collisions, and also understood that if one object loses momentum in a collision, the other has to gain it. The smallest gain between pre- and post-test was for #2/2, which indicates that instruction did not have any real effect on student understanding of the concept of small and large masses in collisions. Although this question seemingly assessed the same objective as the other two questions discussed, students did not do well. Perhaps the wording of the question caused it to be confusing since it does not pose a specific situation for students to analyze; it instead refers to "two objects with different masses." If the question instead named specific objects such as a car and a semi truck, students might have done better.

Objective L: Analyze why seat belts might be more important in autos than in buses.

There was only one question that covered objective L, because this is a very specific state objective dealing with seatbelt use in buses vs. cars. This objective was covered through explanation with many class demonstrations, as well as by calculating conservation of momentum problems.

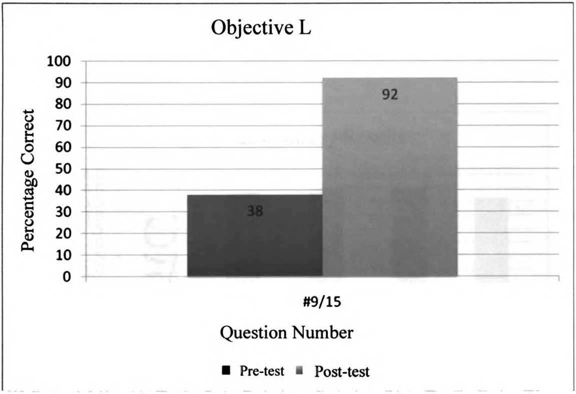


Figure 14: Graph of Objective L Pre/Post-test Results

Figure 14 shows that on the post-test, 92% of students got this question correct. Most students on the pre-test made the connection that bigger size means less effect on the people in the vehicle when hitting a smaller vehicle, but could not give a sufficient explanation as to why this happens. Some simply said, "because the car is smaller". On the post-test, students as a whole had much more complete answers and referenced conservation of momentum in their answers. One example is "because you gain more momentum in a car during a crash than you do in a bus".

Student Survey Results

The students were given a survey for each unit (Appendix E) to assess how they felt the various teaching methods and tools helped them. A five meant that they really thought the assignment helped them to learn and a one meant that they though the assignment did nothing to further their understanding. They were also asked to provide comments.

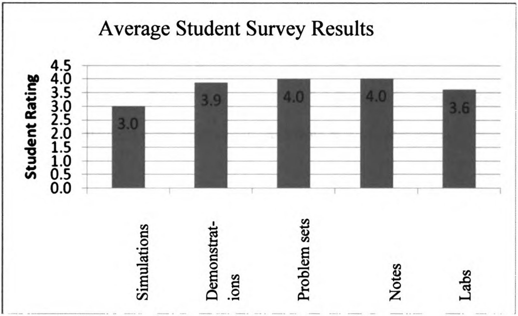


Figure 15: Graph of Student Survey Results

Overall rankings were very close to each other (Figure 15). Students ranked notes the highest at 4.0/5.0 and simulations the lowest at 3.0/5.0. It is interesting to note that they ranked the traditional school activites (notes, problem sets) the highest, and gave the lowest ranking to simulations. Most students commented that the simulations were very confusing. They had trouble following the directions and manipulating the objects. A few students said it helped them to visualize the real world situations but it seems like most were detracted by the confusion that it caused. In class, several students indicated that they did not like the lack of step-by-step instructions that they normally are given. In hindsight, it seems as though more guidance could have been given to the simulations. There were directions on how to use each simulation, but many times students do not read directions at all. Perhaps if the simulation was used as a class activity, it would be more effective. Students said that the notes and problem sets help them study the most of anything else done in class. I think they also like the familiarity of these two components. Although they complain about them quite often, it seems this is the way they believe they learn best, and are uncomfortable with other teaching activities. The highest average score that students gave was for the Conservation of Momentum Demonstrations (Appendix C13), with a score of 4.3/5.0 (Figure 15). Students said it helped them to visualize the problems and to learn from real-life scenarios.

Retention of Knowledge Over Time

Retention of knowledge over time was analyzed, by looking at final exam scores and comparing them to the students' overall post-test scores.

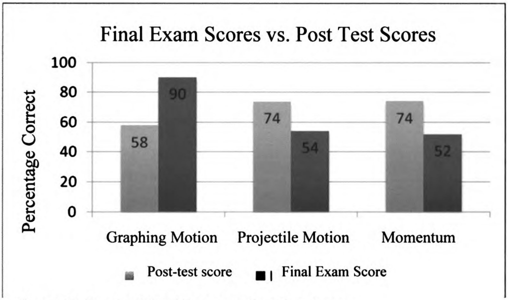


Figure 16: Graph of Final Exam vs. Post-Test Scores

One would expect students to forget what they learned as time goes by, and it is one of our goals as teachers to try to minimize that. As the data in Figure 16 show, this is the trend for *projectile motion* and *momentum*, but there is a surprising trend for *graphing motion*. In *graphing motion,* the scores actually went up between the post-test and final exam. One explanation for this is that students learned from mistakes they made on tests since they are encouraged to review all old quizzes and tests before the final exam. A more likely explanation is that these two questions were easier than some of the questions on the post-test. *Projectile motion* and *momentum* both lost around 20 percentage points in the 4-8 weeks between when the material was taught and when the final exam was administered. This trend seems fairly normal (but discouraging) based on my past experience with final exam scores. One other factor to consider is that the topics are listed here in the order they were placed on the final exam. Many students were extremely rushed by the time they reached the end of the exam and, therefore, did not believe they had the time to really attempt the momentum questions, or even the projectile motion questions.

Conclusion

Overall, the units that I taught for this study were fairly effective. Subjectively, I noticed many improvements in student understanding that came through the changes that were enacted. Simulations seemed to be the biggest down side to the changes made, although I do still plan to use them with some modifications.

Unit One: Graphing Motion

I heard some great conversations going on between students in the graphing motion section, especially in the Graphing Motion Demonstration (Appendix C3) and the Graphing Motion Lab (Appendix C5). I made the demonstration into a sort of competition as to who could get the best graph match and they were all eager to try as well as to help out the person who was trying it. The lab activity was also quite effectively carried out in the time that was allotted for it (30-40 minutes). I will continue to do this lab based on favorable student reaction (Figure 15), as well as the data supporting that it was effective (Figures 4-7). Another effective assignment was the Graphing Motion Worksheet (Appendix C4). Students needed to put together everything we had done up to that day and really think, "Does this make sense; do these graphs agree with each other?" I saw a marked improvement in student understanding of how to graph motion between this year and previous years. In previous years on the post-test, about 50% of my students would get these questions completely wrong, but this year scores were much improved, with at least half getting questions 4P and 5P 100% correct (Figure

4). Students used the worksheet as a study guide and several students came in before the test to review the worksheet and similar questions with me. On the post test, not one student got the two problems completely wrong; previously they got either the distance-time graphs or the velocity-time graphs incorrect.

The Moving Man Simulation (Appendix C1) that I assigned was by far the biggest disappointment in this unit. As research suggests, simulations should only be done if there is a lack of equipment available due to expense or limited resources, a history of inaccurate or contradictory results, or data collecting software/hardware reliability. (Brant, Hooper, & Sugrue 1991) A simulation was assigned to students because graphs made by the software tend to be "messy" since the motion detector picks up any motion at all. The simulation was used to give students nice smooth graphs to work with before they were exposed to real-life "messy," graphs. However, students were so confused by how to use the simulation that they could not get past this to learn anything. If I had provided 10 minutes at the end of class for students to log on and try out the simulation with me, then I believe it would have been much more effective. Instinctively, when given an assignment, students want to skip directions to save time, which usually hurts them in the end, as it did in this case. Also students are not used to this kind of assignment. They were not given cookbook-type directions, but instead were asked to experiment and play around with the simulation, trying to replicate graphs. As the literature shows, these types of instructions tend to frustrate students more, especially the lower level students (Royuk & Brooks 2003). I find that many times when students are asked to do something like this, especially the mid-lower level students, they will give up if they don't understand instructions within a few minutes.

Overall, the notes and problem sets were what the students felt the most comfortable learning through, since they are so familiar to them. Students ranked the notes and problem sets highest, both with 4.0/5.0 on the rating scale (Figure 15). Except for one student who said "Content difficult to master", everyone else said they really liked the problems because they "help me see different scenarios and how problems might be written on tests and quizzes." It is troubling to see that students are so focused on the grades assigned, and less that they actually master and understand the material. However, the Seaholm High School community is especially focused on grades as many students go on to prestigious colleges and universities. Perhaps if tests and quizzes were tailored a little more to ask about the discussions held, labs taught, and demonstrations, students would feel more invested in mastering the content.

Unit Two: Projectile Motion

In the projectile motion section, results were similar to those of graphing motion. The simulation once again had the lowest rating (3.2/5.0), and this time problem sets and labs were tied for the highest rank (4.3/5.0) (Figure 15). For this unit, I was able to ask a few more short answer questions related to their understanding of projectile motion that I had not asked in the past. These questions allowed me to see who understood the concepts, who did not, and if they did not, I was able to pinpoint where their understanding was insufficient.

For this unit, especially, students needed a lot of practice; so much of the notes for projectile motion consisted of problems and examples of how to solve them. Students also completed several worksheets and problem sets which we then discussed in class. Students indicated that this is how they learned best (Figure 15). According to comments, students also particularly liked the demonstrations done. Unfortunately, because of power outages and school events, the monkey demo had to be postponed until after the post test, so I could not effectively assess its influence. For the observed demonstrations, students needed to apply these concepts to new problems which not everyone could do easily. This is where the class discussion during and after a demonstration is very important. As the literature indicated, demonstrations are not very effective at all if they follow a "show-and-tell" method (e.g. Shepardson et al 1994). In order to be effective they need to be more interactive, which I attempted to do.

The Projectile Motion Simulation (Appendix C6) proved to be quite confusing, just as the Graphing Motion Simulation (Appendix C1) was. This Projectile Motion Simulation definitely needs to be rewritten because after having one group of students use it, I realize that there are some poorly worded questions. Also, when I use this next year, I will either give some time in class to get started, or demonstrate on the TV monitor how to use the program since, once again, it does not seem as though they read the directions. In the future, I think I would also omit all questions dealing with air resistance, because that is what students found the most confusing. If anything, air resistance will be left to the end of the projectile unit, and ideal cases will be dealt with first.

The Projectile Motion Lab (Appendix C10) went fairly well, except that once again the power outage proved quite detrimental as it occurred during the lab in one of my classes. We finished the lab in the dark but we were rushed and it was very hectic! I did notice that students had an easier time figuring out how to solve the different parts of the lab compared to previous years. I made a point of telling students before the lab that they had learned how to solve the problems previously, and now they were going to use a real projectile launcher to see if the calculations agree with the actual distance a projectile moves. Most groups were very efficient and understood how to carry out the lab.

Unit Three: Conservation of Momentum

In this unit, the top level students could both accurately solve conservation of momentum problems as well as explain them in writing. The middle and lower level students had trouble with either mathematically solving the problems or explaining them in writing, but rarely did they have trouble with both. This is very encouraging because it indicates that even if students struggled to solve problems in one particular way, which was expected for some students, they still understood the concepts.

The Conservation of Momentum Simulation (Appendix C11) got by far the worst rating from the students (2.6/5.0) out of all three simulations (Figure 15). This was also the most primitive simulation I used; there were not many free conservation of momentum simulations to choose from. The Conservation of Momentum Demonstrations (Appendix C13), however, were rated the highest, contrasting their midrange ranking in the other two units. Perhaps the simplicity of the demonstrations is what made them so effective, or what made students favor them so much.

The Conservation of Momentum Lab (Appendix C14) was done as a class, due to lack of time with the end of the trimester rapidly approaching. The students really liked this format, and many commented on the survey that "most labs are confusing but this one was helpful because we did it as a class". The part we did as a class was the data collection, which was quite difficult to obtain in this lab. After we got the data, students compiled them and performed calculations to determine whether momentum was conserved. I also had thrown in a twist: they had to find an unknown mass added to one of the carts using conservation of momentum. I will definitely do this lab again, and I will probably do it in the same way, as it was effective.

If students really understand what should happen in a collision, then they can double check their mathematical answers to see if they make sense. This didn't always happen on the test, but I know some students did this based on interactions with them. One aspect of student performance that was disappointing was that, despite my <u>constant</u> reminders that opposite directions indicate opposite velocity signs, students still made this mistake frequently on the post-test, resulting in scores to be lower than expected (Figures 12 and 13). In this case, I am not really sure how much more I could have done to change this. It seems to be a powerful force of habit. Perhaps using positive and negative velocity more often in earlier units could remedy this.

Overall

I plan to use almost all of the assignments and activities described here again. The simulations helped student understanding based on data described previously, my observations, and the literature, despite what students felt. However, on these assignments I will definitely have to make some changes based on my observations as well as comments from students. The labs I did were all very effective. For the most part students did very well on them and also rated them on average 3/5 points (Figure 15). In the past I had a few labs due to time constraints because of the additional material we are asked to teach as well as trimester adaptations, I am extremely pleased to be able to fit them in once again now that I've pared them down to the most important of concepts. Since in a traditional laboratory setting students can use 40-60% of the time taking measurements (Hucke & Fischer 2002), using probeware greatly decreases this time commitment and allows one to complete the lab in a shorter amount of time, or spend more time discussing results. The Graphing Motion Worksheet (Appendix C4) was helpful and will definitely be used again. Discussions and problem sets seem to be what students feel most comfortable with (Figure 15) so I will continue to teach with these. However, I believe that they do need to be supplemented with the labs and demonstrations in every unit, as I tried to do for these units.

In the future, with budget issues on everyone's mind, we are going to need to find cheaper alternatives to labs, which is where simulations have a role. There have already been some suggestions from higher up in our district that we cut out labs and instead substitute simulations, which I completely oppose. Simulations are great to show a concept cheaply and quickly, and eliminate messy data collection. However, as shown in my survey (Figure 15), students do not like them much or adapt to them very easily. Also, there are so many skills to be gained by actually experimenting instead of manipulating objects on a computer as the literature confirms. Unfortunately, it may become necessary in the future to switch to more simulations, in which case my research and experience will prove useful.

The demonstrations will also continue to be used and I will continue to develop my demonstration skills, and seek out new demonstrations to share with students. However, as this research showed, demonstrations need to be changed from their previously common "show and tell" form. This means that I need to make a concerted effort to engage students in discussion during and after, as well as connect the demonstrations to other everyday world events. If this is done effectively, students will be able to take what they learned in a demonstration and apply it to new events, as well as explain them effectively.

The labs that I did were a blend of inquiry and cookbook type labs. In this way, students felt like they had guidance, but they also had to solve a problem without being told the answer or exactly how to get it. I think that I accomplished this effectively, and the results obtained through student comment and the surveys were positive (Appendix G3). While students will always find labs challenging because they are asked to think outside the box, labs are a very valuable and necessary learning tool. I will continue to use them and will also examine the other labs I use to see if they can be altered to be more like the style of the labs I used in this study.

I am pleased with the results of this study. The data show that average student understanding was increased by at least 30 points in each unit (Figures 4-14). This demonstrates that the teaching methods used are effective. While students sometimes prefer learning in some ways better than others, the data show that students did understand the objectives that I had for their learning. I think that student understanding of concepts was increased as shown by the data (Figures 4-14), and also, subjectively, I saw great increases in student understanding of concepts as evidenced by questions they asked and the discussions I had with them.

Appendix A

Objectives and Expectations Covered in Units

Graphing Motion

State Expectations

A. **P2.1C** Create line graphs using measured values of position and elapsed time.

B. **P2.1D** Describe and analyze the motion that a position-time graph represents, given the graph.

C. **P2.2C** Describe and analyze the motion that a velocity-time graph represents, given the graph.

D. **P2.2e** Use the area under a velocity-time graph to calculate the distance traveled and the slope to calculate the acceleration.

Projectile Motion

State Expectations

E. **P2.1h** Identify the changes in speed and direction in everyday examples of circular (rotation and revolution), periodic, and projectile motions.

F. **P2.2g** Apply the independence of the vertical and horizontal initial velocities to solve projectile motion problems.

Other

G. Understand that time is common to both the vertical and horizontal components.

Conservation of Momentum

State Expectations

H. **P3.4f** Calculate the changes in velocity of a thrown or hit object during and after the time it is acted on by the force.

I. **P3.4g** Explain how the time of impact can affect the net force (e.g., air bags in cars, catching a ball).

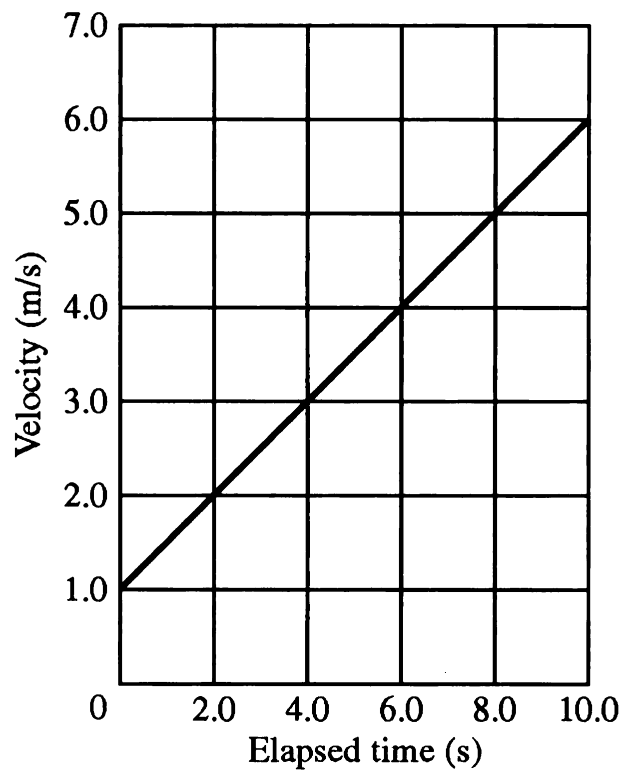
J. **P3.5a** Apply conservation of momentum to solve simple collision problems.

K. **P3.3b** Predict how the change in velocity of a small mass compares to the change in velocity of a large mass when the objects interact (e.g., collide).

L. **P3.3d** Analyze why seat belts may be more important in autos than in buses.

Appendix B1

Graphing Motion Pretest



1. What is the average acceleration of the graph shown above?
   a. $0.5\ m/s^2$
   b. $1.0\ m/s^2$
   c. $2.0\ m/s^2$
   d. $0.0\ m/s^2$

   Explain why you chose the answer you did:

   ____

   ____

   ____

   ____

2. What is the displacement for the first 4 seconds of the graph above?
    a. 16 m
    b. 8 m
    c. 4 m
    d. 12 m

    Explain why you chose the answer you did:

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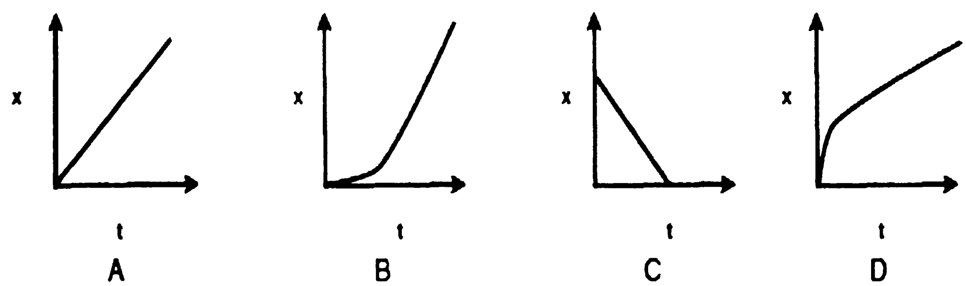
    ____

3. Which distance vs. time graph shows constant positive acceleration?



Explain why you chose the answer you did:

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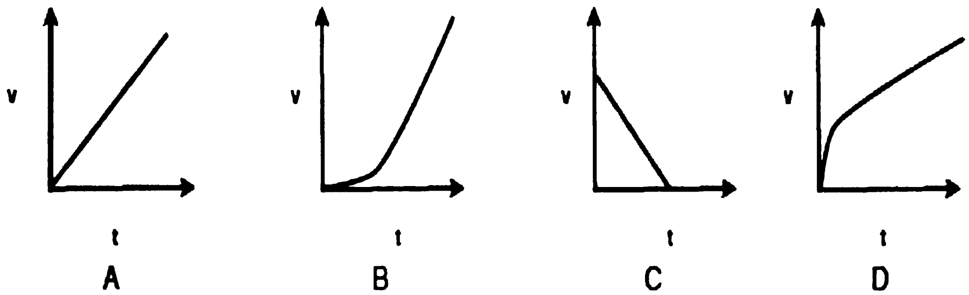
4. Which velocity vs. time graph shows constant negative acceleration?



Explain why you chose the answer you did:

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5. True or False: A position time graph must be horizontal to have an acceleration of zero.
   Explain why you chose the answer you did:

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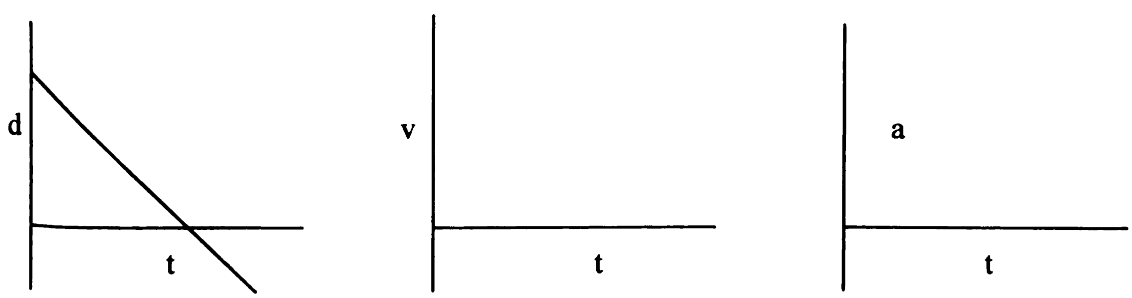
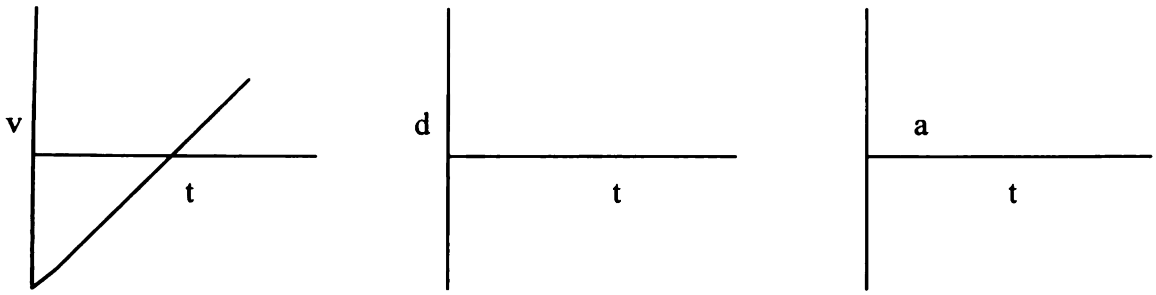
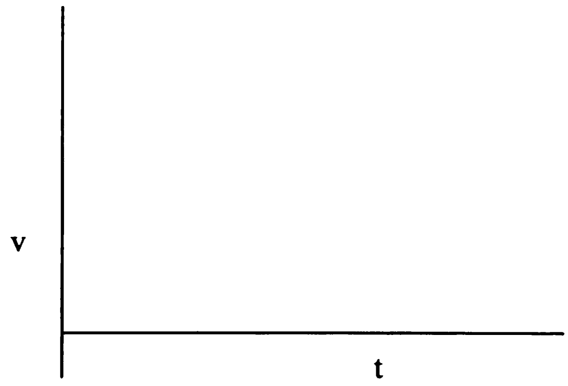
6. A car moves with the motion described by the distance vs. time graph below. Draw the same car's motion on the corresponding velocity vs. time and acceleration vs. time graphs.



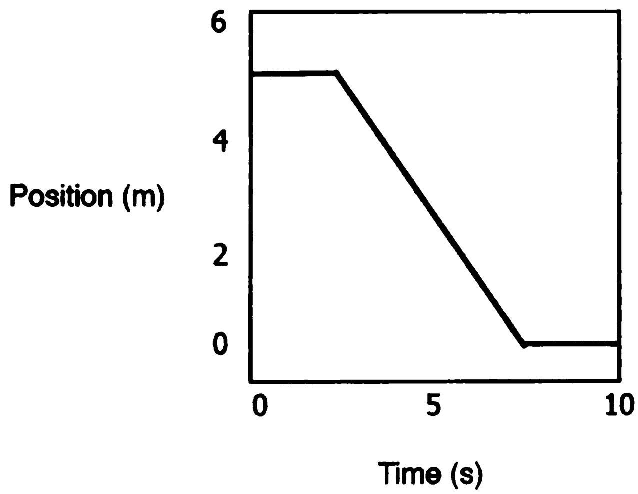
7. A car moves with the motion described by the velocity vs. time graph below. Draw the same car's motion on the corresponding distance vs. time graph and acceleration vs. time graphs.



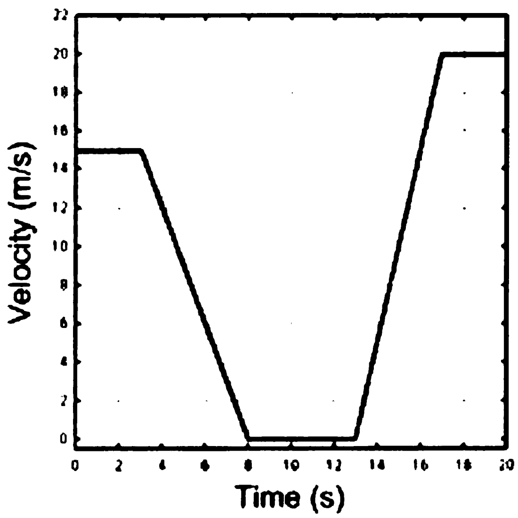
8. A car drives at a constant velocity for 2 seconds, then slows to a stop in another 2 seconds. Draw this motion into the graph below.



9. Below is a graph of a ball's motion. Describe the motion occurring.



10. A car is traveling along a road. Its velocity is recorded as a function of time and is shown in the graph below.



During which intervals is the car accelerating? Choose all the answers that apply.

a. between 0 and 3 seconds
b. for a brief instant at 3,8,13 and 17 seconds
c. between 3 and 8 seconds
d. between 8 and 13 seconds
e. between 13 and 17 seconds
f. between 17 and 20 seconds

Explain why you chose the answer you did:

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Appendix B2

TRANSLATIONAL MOTION AND KINEMATICS

Multiple Choice:

1. The acceleration of a stone thrown upward is:

   a. greater than that of a stone thrown downward
   b. the same as that of a stone thrown downward

   c. smaller than that of a stone thrown downward

   d. zero until it reaches the highest point in its motion

2. If you have a positive velocity and a negative acceleration, what will the resulting motion be?

   a. free fall towards the earth
   b. speeding up in the + x direction
   c. slowing down in the – x direction
   d. speeding up in the – x direction
   e. slowing down in the + x direction

3. A ball is thrown upward with a speed of 20 m/s. It will continue to rise for about

   a. 1 s b. 2s c. 3 s d. 4 s

4. About how long after it was thrown will the ball in the previous question reach the release point?

   a. 2 s b. 4 s c. 8 s d. 16 s

5. On a position time graph, what represents velocity?

   a. speed b. m/s c. area d. slope

6. A package is released from a hovering helicopter and it takes 9 s to reach the ground. If there were no air resistance, the package's final speed would be

a. -9m/s   b. -9.8 m/s   c. -88 m/s   d. -98 m/s

7. If you have a negative velocity and a negative acceleration, what will the resulting motion be?

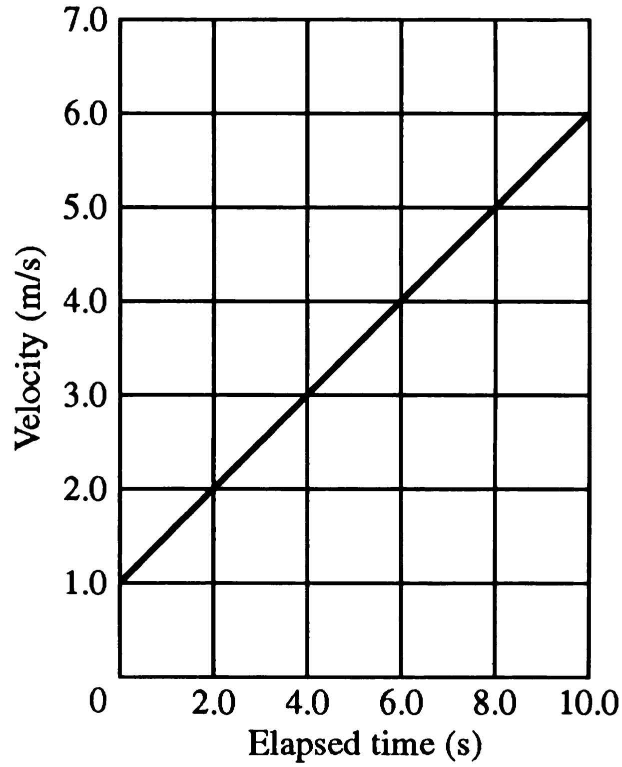
a. Slowing down in the + x direction
b. Speeding up in the + x direction
c. Slowing down in the – x direction
d. Speeding up in the – x direction

8. If a ball rolls downhill with a constant acceleration of 4 m/s^2. If it starts from rest, its speed at the end of 3 s is :

a. 3 m/s   b. 4 m/s   c. 12 m/s   d. 18 m/s

9. What is the average acceleration of the graph shown below?

a. 0.6 m/s^2 b. 0.5 m/s
c. 1.0 m/s   d. 0.5 m/s^2



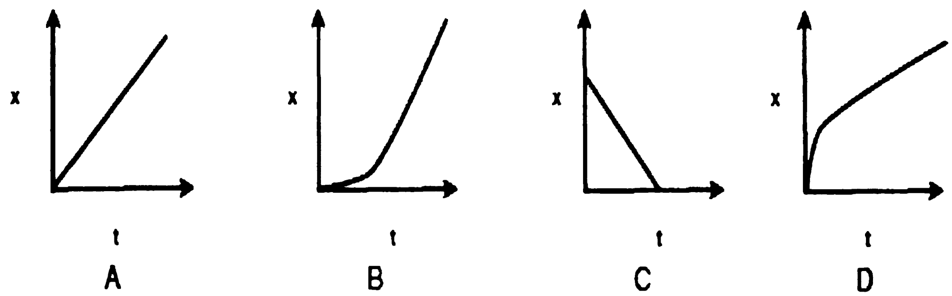
10. What is the total displacement for the first 2 seconds of the graph from #9?

a. 3.0 m
b. 2.0 m
c. 1.25 m
d. 1.5 m

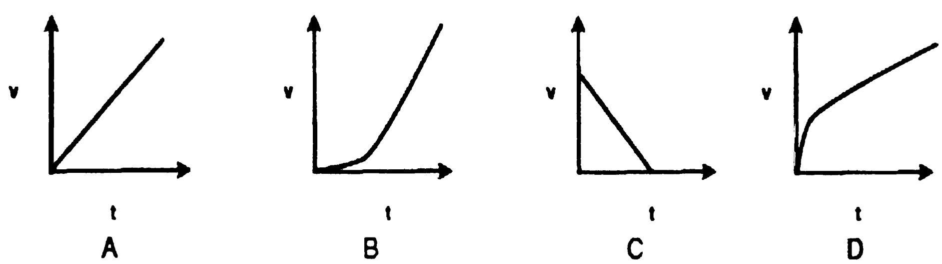
11. Velocity measures all of the following EXCEPT

a. The speed of an object
b. The total displacement of an object
c. The direction of an object's motion
d. The displacement for each time interval

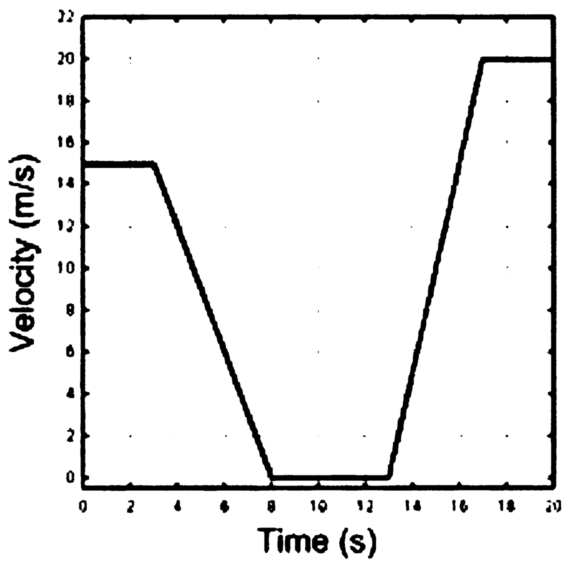
12. Which of the following ***position vs. time*** graphs shows constant positive acceleration?



13. Which of the following ***velocity vs. time*** graphs shows constant negative acceleration?



14. A car is traveling along a road. Its velocity is recorded as a function of time and is shown in the graph below.



During which intervals is the car accelerating? Choose all the answers that apply.

g. between 0 and 3 seconds
h. for a brief instant at 3,8,13 and 17 seconds
i. between 3 and 8 seconds
j. between 8 and 13 seconds
k. between 13 and 17 seconds
l. between 17 and 20 seconds

True or False

15. A position vs. time graph must be a horizontal line to have an acceleration of zero.

16. A reference point refers to an object's speed.

Problems: Show all your work for full credit!

1. A motorcycle traveling at 10 m/s accelerates at a constant rate of 3.5 m/s^2 over 96 m. What is its final velocity?

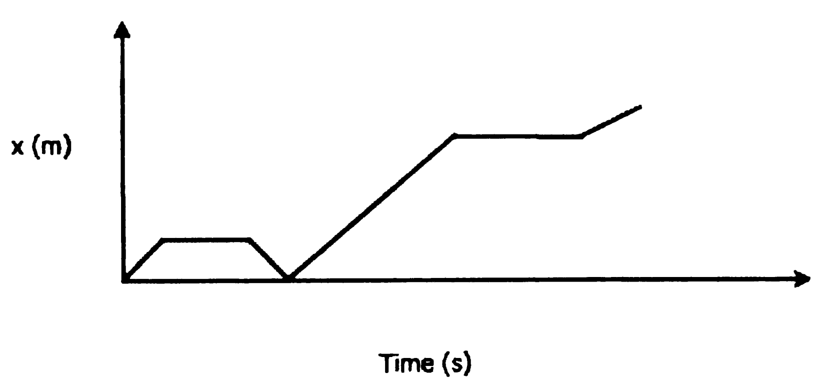
2. From the moment a 52 m/s fastball touches the catcher's mitt until it is completely stopped takes 0.021 seconds. Calculate the average acceleration of the ball being caught.

3. A racecar starts from rest and is accelerated uniformly to 41 m/s in 9.0 s.

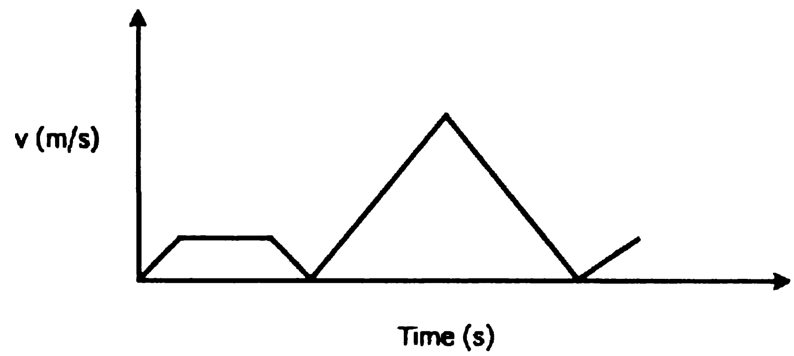
a. What is the car's displacement?

b. Draw a position vs. time graph of the car's motion.

4. Graph ***velocity vs. time & acceleration vs. time*** of the following position vs. time graph.



5. Graph ***position vs. time*** & ***acceleration vs. time*** of the following velocity vs. time graph.



6. A camera is accidentally dropped from the edge of a cliff and 13 s later hits the bottom.

   a. How fast was it going just before it hit the ground?

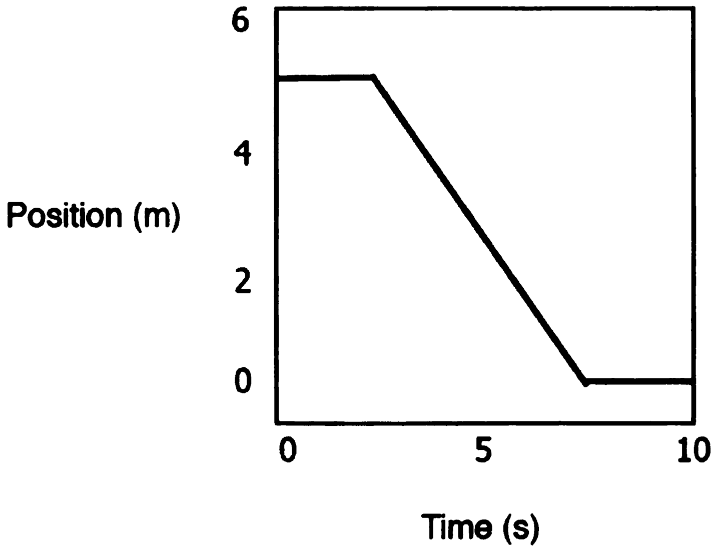
   b. How high is the cliff?

7. A rock is thrown vertically upward with a velocity of 21 m/s from the edge of a bridge 30 m above the river.

   a. What is the rock's velocity just before it hits the water?

   b. How long does the rock stay in the air?

8. Below is a graph of a ball's motion. Describe the motion occurring.



Appendix B3

Projectile Motion Pretest

1. Projectile motion consists of two components that are independent of each other. (True or False)
   Explain why you chose the answer you did:

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   ____

2. What is the path of a projectile?
   a. A wavy line
   b. A parabola
   c. A hyperbola
   d. Projectiles do not follow a predictable path.

   Explain why you chose the answer you did:

   ____

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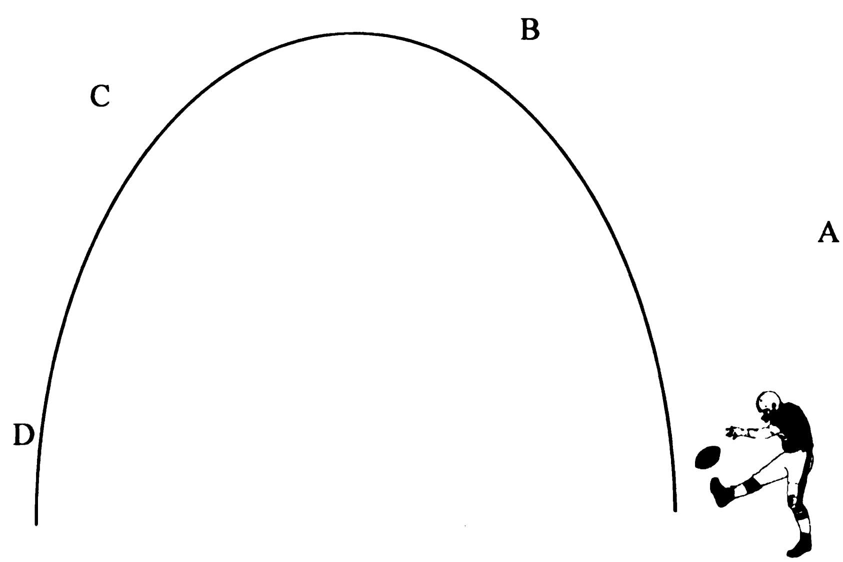
   ____

3. A football follows the trajectory as indicated below. Draw in the horizontal and vertical velocity vectors at each point indicated. Remember, vectors have two components, magnitude (length) and direction.



4. As a projectile flies through the air (disregard air resistance), what can you say of the horizontal velocity?
    a. Increases
    b. Decreases
    c. Stays the same
    d. Decreases, then increases.

    Explain why you chose the answer you did:

    ____

    ____

    ____

    ____

5. If a ball is thrown upward, and then falls to the ground (disregard air resistance), what can you say of the vertical velocity?
    a. Increases, then decreases
    b. Decreases, then increases
    c. Stays the same
    d. Decreases

    Explain why you chose the answer you did:

    ____

    ____

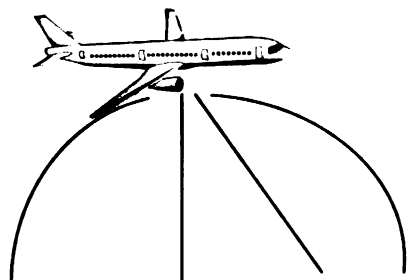
    ____

    ____

6. Which of the following cannot be considered a projectile?
    a. an airplane taking off
    b. a tennis ball lobbed over a net
    c. a frog jumping from land into the water
    d. a bullet fired from a gun

    Explain why you chose the answer you did:

7. A bowling ball accidentally falls out of an airplane as it flies horizontally from Detroit to Miami. As seen from the ground, which path would the bowling ball most closely follow? (circle one)



a. b. c. d.

Explain why you chose the answer you did:

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8. A bullet is fired horizontally from a pistol, and another bullet is dropped simultaneously from the same height. If air resistance is neglected, which bullet hits the ground first? As always, disregard air resistance. Explain your reasoning! Draw pictures if they help to explain.

9. If a rock is dropped from the top of a sailboat's mast, will it hit the deck at the same point whether the boat is at rest or in motion at a constant velocity? As always, disregard air resistance. Explain your reasoning. Draw pictures if they help to explain.

10. Does a wad of gum dropped out of the window of a moving car take longer to reach the ground than one dropped from the same height from a car at rest? As always, disregard air resistance. Explain your reasoning. Draw pictures if they help to explain.

Appendix B4

World Series of Projectile Motion

1. Projectile motion consists of two components that are dependent on each other.

   (T or F)

2. What is the path of a projectile?

   a. a wavy line
   b. a parabola
   c. a hyperbola
   d. Projectiles do not follow a predictable path.

3. As a projectile flies through the air (disregard air resistance), what can you say of the horizontal velocity?

   a. Increases
   b. Decreases
   c. Stays the same
   d. Decreases, then increases.

4. Which of the following can be considered a projectile?

   a. A child swinging on a swing at the playground.
   b. A golf ball sitting on a tee.
   c. A helium balloon.
   d. A volleyball in freefall after being hit by a player.

5. A hawk is carrying a mouse it has just caught. It accidentally drops the mouse (don't worry, the mouse is okay) from a height of 100m. The mouse lands a horizontal distance of 253m from where it was released.

   a. Draw a diagram showing the hawk's direction as well as the trajectory of the mouse as it flies through the air.
   b. How fast was the hawk moving when it dropped the mouse?

6. At baseball practice, Verlander attempts to throw two baseballs at once. He manages to throw the first, and launches it horizontally. Unfortunately at the same time he releases the first ball, the second ball falls out of his hand and straight to the ground. (Verlander is 1.95 m tall)

   a. How long does it take the first ball to hit the ground?
   b. How long does it take the second ball to hit the ground?
   c. Describe if and how the vertical velocity of the first ball changes as it moves through the air.

7. A track star in the long jump goes into the jump at 12m/s and launches herself at 20.0° above the horizontal.

a. Draw a velocity vector analysis, labeling v, v_x, and v_y at at least 3 points on the trajectory.
b. How far did she travel in the horizontal?
c. What is her hangtime?
d. Calculate her highest height.
e. Calculate her final velocity in both the x and y direction.

8. If a rock is dropped from the top of a sailboat's mast, will it hit the deck at the same point whether the boat is at rest or in motion at a constant velocity? Explain your reasoning. Draw pictures if they help to explain.

Appendix B5

Momentum Pre-test

1. Two billiard balls of equal mass, traveling at same speed but in opposite directions, collide. What happens?
   a. The balls bounce off of each other, but now they are moving at different speeds then they were before the collision.
   b. The balls bounce off of each other, and continue to travel at the same speed they were before the collision.
   c. One ball comes to rest and the other bounces off and continues at the same speed as it was previously.
   d. Both balls come to rest.

Explain why you chose the answer you did:

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2. Two objects with different masses collide and bounce back after an elastic collision. Before the collision the two objects were moving at velocities equal in magnitude but opposite in direction. After the collision,
   a. the less massive object has gained momentum.
   b. the more massive object has gained momentum.
   c. both objects had the same momentum.
   d. both objects lost momentum.

Explain why you chose the answer you did:

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3. Which of the following statements about the conservation of momentum is NOT correct?
    a. Momentum is conserved for a system of objects pushing away from each other.
    b. Momentum is not conserved for a system of objects in a head-on collision.
    c. Momentum is conserved when two or more interacting objects push away from each other.
    d. The total momentum of a system of interacting objects remains constant regardless of forces between the objects.

Explain why you chose the answer you did:

____

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4. A bowling ball moving rapidly strikes a bowling pin that is stationary. After the collision, the bowling ball continues to move in the same direction, but at a much slower speed. The bowling pin
    a. travels at the same speed as the ball was moving.
    b. travels at a slower speed than the ball was moving.
    c. travels at a faster speed than the ball was moving.
    d. does not move.

Explain why you chose the answer you did:

____

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5. Two cars collide and stick together. If car #1 was moving rapidly and car #2 was stationary, what is their combined speed after?
    a. Faster than car #1's original speed.
    b. Slower than car #1's original speed.
    c. Same as car #1's original speed.
    d. Zero

Explain why you chose the answer you did:

____

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6. You are on rollerblades, holding a medicine ball. Both you and the ball are not moving. If you throw the ball forward,
    a. you move backward
    b. you move forward
    c. you don't move at all
    d. Nonsense, why would I ever hold a medicine ball while on rollerblades.

Explain why you chose the answer you did:

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7. In an elastic collision between two objects with unequal masses,
    a. the total momentum of the system will increase.
    b. the total momentum of the system will decrease.
    c. the kinetic energy of the system will decrease.
    d. the momentum of one object will increase by the amount that the momentum of the other object decreases.

Explain why you chose the answer you did:

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8. Two snowballs, one with a mass of 0.4kg traveling east and the other with a mass of 0.75kg traveling west, collide head on and combine (stick together) to form a single snowball. The initial speed of each is 15m/s. Straight line motion. Draw a before and after picture of the collision and label.

9. Why are seatbelts more important to wear in cars than buses?

10. "Follow-through" is an important concept in when hitting a baseball with a bat. This means you should try to keep the bat in contact with the ball for as long as possible. Why is this an effective technique?

Appendix B6

"Mo-better-mentum" Last Mechanics Quiz!

1. The change in an object's momentum is equal to
    a. the product of the mass of the object and the time interval.
    b. the product of the force applied to the object and the time interval.
    c. the time interval divided by the net external force.
    d. the net external force divided by the time interval.
2. Two objects with different masses collide and bounce back after an elastic collision. Before the collision, the two objects were moving at velocities equal in magnitude by opposite in direction. After the collision,
    a. the less massive object had gained momentum.
    b. the more massive object has gained momentum.
    c. both objects had the same momentum.
    d. both objects lost momentum.
3. Which of the following statements about the conservation of momentum is NOT correct?
    a. Momentum is conserved for a system of objects pushing away from each other.
    b. Momentum is not conserved for a system of objects in a head-on collision.
    c. Momentum is conserved when two or more interacting objects push away from each other.
    d. The total momentum of a system of interacting objects remains constant regardless of forces between the objects.
4. The impulse experienced by a body is equivalent to the body's change in
    a. velocity
    c. momentum
    b. kinetic energy
    d. force
5. An astronaut with a mass of 70kg is outside a space capsule when the tether line breaks. To return to the capsule, the astronaut throws a 2kg wrench away from the capsule at a speed of 14m/s. At what speed does the astronaut move toward the capsule.
    a. 5.0m/s
    c. 3.5m/s
    b. 0.4m/s
    d. 7.0m/s
6. A bullet with a mass of 5.00×10^{-3}kg is loaded into a gun. The loaded gun has a mass of 0.52kg. The bullet is fired, causing the empty gun to recoil at a speed of 2.1m/s. What is the speed of the bullet?
    a. 48m/s
    c. 120m/s
    b. 220m/s
    d. 360m/s

7. Two objects stick together and move with the same velocity after colliding. Identify the type of collision.
   a. elastic
   b. perfectly elastic
   c. inelastic
   d. perfectly inelastic

8. A bowling ball with a mass of 7.0kg strikes a pin that has a mass of 2.0kg. The pin flies forward with a velocity of 6.0m/s, and the ball continues forward at 4.0m/s. What was the original velocity of the ball?
   a. 4.0m/s
   b. 5.7m/s
   c. 6.6m/s
   d. 3.3m/s
9. In an elastic collision between two objects with unequal masses,
   a. the total momentum of the system will increase.
   b. the total momentum of the system will decrease.
   c. the kinetic energy of the system will decrease.
   d. the momentum of one object will increase by the amount that the momentum of the other object decreases.
10. Two billiard balls of equal mass, traveling at same speed but in opposite directions, collide. What happens?
    a. The balls bounce off of each other, but now they are moving at different speeds then they were before the collision.
    b. The balls bounce off of each other, and continue to travel at the same speed they were before the collision.
    c. One ball comes to rest and the other bounces off and continues at the same speed as it was previously.
    d. Both balls come to rest.
11. What is the momentum of a 1500kg car traveling at 115km/h?
12. A ball with a mass of 0.15kg and a velocity of 5.0m/s strikes a wall and bounces straight back with a velocity of 3.0m/s. What is the change in momentum of the ball?
13. An egg has a mass of 46g and is thrown at a towel so it doesn't break. If the egg hits the towel at a speed of 20m/s and has a Δt of 0.8s,
    a. What is the average force on the egg?
    b. What is the impulse?
    c. Why does the towel keep the egg from breaking, whereas a wall might not?

14. Two snowballs, one with a mass of 0.4kg traveling east and the other with a mass of 0.75kg traveling west, collide head on and combine (stick together) to form a single snowball. The initial speed of each is 15m/s. Straight line motion.
    a. Draw a before and after picture of the collision and label.
    b. What type of collision is this?
    c. What is the new velocity?
    d. Is momentum conserved?
    e. Is total energy conserved?
    f. What type of energy is not conserved?
15. Why are seatbelts more important to wear in cars than buses?

Appendix B7

PHYSICS I A FINAL

Multiple Choice

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

_____ 1. 2 km/hr = ______ m/s

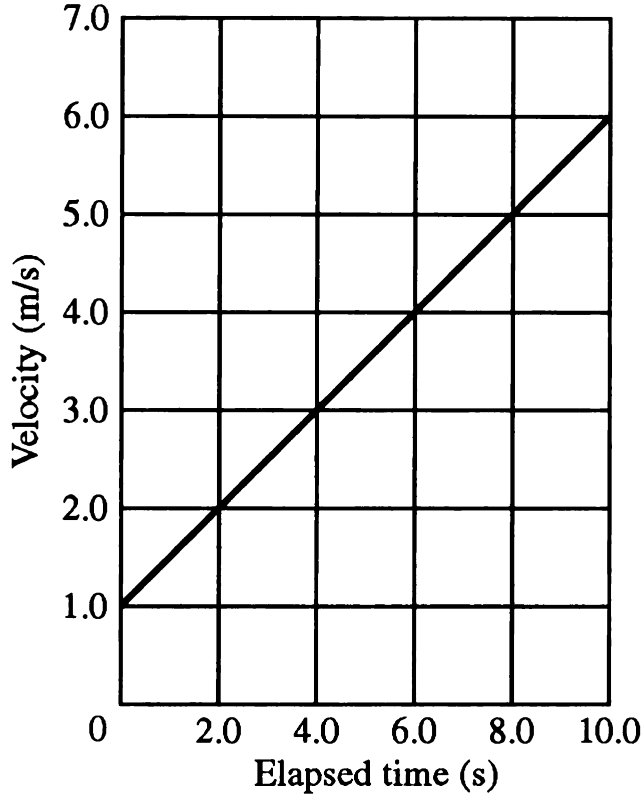
a. 0.6 m/s
c. 2 m/s
b. 0.556 m/s
d. 7.2 m/s

______ 2. Acceleration is

a. displacement.
c. velocity.
b. the rate of change of displacement.
d. the rate of change of velocity.

______ 3. When velocity is positive and acceleration is negative, what happens to the object's motion?

a. The object slows down.
c. Nothing happens to the object.
b. The object speeds up.
d. The object remains at rest.



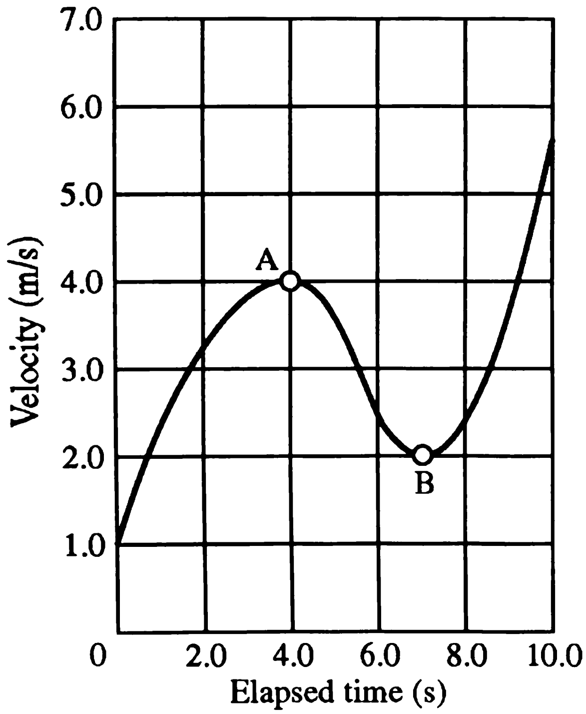
_______ 4. What does the graph above illustrate about acceleration?

a. The acceleration is constant.

b. The acceleration is zero.

c. The acceleration decreases.

d. There is not enough information to answer.



____ 5. What does the graph above illustrate about acceleration?

a. The acceleration varies.

b. The acceleration is zero.

c. The acceleration is constant.

d. The acceleration increases then becomes constant.

____ 6. A toy car is given an initial velocity of 5.0 m/s and experiences a constant acceleration of 2.0 m/s^2. What is the final velocity after 6.0 s?

a. 10.0 m/s

b. 12 m/s

c. 16 m/s

d. 17 m/s

____ 7. A curious kitten pushes a ball of yarn at rest with its nose, displacing the ball of yarn 17.5 cm in 2.00 s. What is the acceleration of the ball of yarn?

a. 11.0 cm/s^2
b. 8.75 cm/s^2
c. 14.4 cm/s^2
d. 4.38 cm/s^2

____ 8. Acceleration due to gravity is also called

a. negative velocity.
b. displacement.
c. free-fall acceleration.
d. instantaneous velocity.

____ 9. A rock is thrown straight upward with an initial velocity of 24.5 m/s where the downward acceleration due to gravity is 9.81 m/s^2. What is the rock's displacement after 1.00 s?

a. 9.81 m
b. 19.6 m
c. 24.5 m
d. 29.4 m

____ 10. A coin released at rest from the top of a tower hits the ground after falling 1.5 s. What is the speed of the coin as it hits the ground? (Disregard air resistance. g = 9.81 m/s^2.)

a. 15 m/s
b. 21 m/s
c. 31 m/s
d. 39 m/s

____ 11. A rock is thrown downward from the top of a cliff with an initial speed of 12 m/s. If the rock hits the ground after 2.0 s, what is the height of the cliff? (Disregard air resistance. $g = 9.81\ m/s^2$.)

a. 22 m

b. 24 m

c. 44 m

d. 63 m

____ 12. When there is no air resistance, objects of different masses

a. fall with equal accelerations with similar displacements.

b. fall with different accelerations with different displacements.

c. fall with equal accelerations with different displacements.

d. fall with different accelerations with similar displacements.

____ 13. Which of the following is a physical quantity that has both magnitude and direction?

a. vector

b. scalar

c. resultant

d. frame of reference

____ 14. A lightning bug flies at a velocity of 0.25 m/s due east toward another lightning bug seen off in the distance. A breeze blows on the bug at a velocity of 0.25 m/s from the west. What is the resultant velocity of the lightning bug?

a. 0.50 m/s

b. 0.00 m/s

c. 0.75 m/s

d. 0.25 m/s

____ 15. A skateboarder rolls 25.0 m down a hill that descends at an angle of 20.0□ with the horizontal. Find the horizontal and vertical components of the skateboarder's displacement.

a. 8.55 m; 23.5 m

c. 23.5 m; 73.1 m

b. 23.5 m; 8.55 m

d. 73.1 m; 26.6 m

____ 16. A stone is thrown at an angle of 30.0□ above the horizontal from the top edge of a cliff with an initial speed of 12 m/s. A stopwatch measures the stone's trajectory time from the top of the cliff to the bottom at 5.6 s. What is the height of the cliff? (Disregard air resistance. $g = 9.81\ \mathrm{m/s^2}$.)

a. 58 m

c. 120 m

b. 150 m

d. 180 m

____ 17. A model rocket flies horizontally off the edge of the cliff at a velocity of 50.0 m/s. If the canyon below is 100.0 m deep, how far from the edge of the cliff does the model rocket land?

a. 112 m

c. 337 m

b. 225 m

d. 400 m

____ 18. A firefighter 50.0 m away from a burning building directs a stream of water from a fire hose at an angle of 30.0□ above the horizontal. If the velocity of the stream is 40.0 m/s, at what height will the stream of water strike the building?

a. 9.60 m

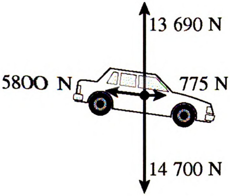
c. 18.7 m

b. 13.4 m

d. 22.4 m

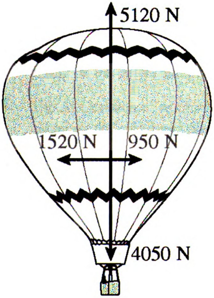
____ 19. What causes a moving object to change direction?

a. acceleration
b. velocity
c. inertia
d. force



____ 20. In the free-body diagram shown above, which of the following is the gravitational force acting on the car?

a. 5800 N
b. 775 N
c. 14 700 N
d. 13 690 N



____ 21. In the free-body diagram shown above, what is the net force and direction on the balloon?

a. 1212 N @118°

b. -570 N @118°

c. 1070 N @62°

d. 1212 N @62°

____ 22. Which of the following is the tendency of an object to maintain its state of motion?

a. acceleration

b. velocity

c. inertia

d. force

____ 23. A sled is pulled at a constant velocity across a horizontal snow surface. If a force of 8.0 □ 10^1 N is being applied to the sled rope at an angle of 53□ to the ground, what is the force of friction between the sled and the snow?

a. 48 N

b. 42 N

c. 83 N

d. 64 N

____ 24. Which statement about the acceleration of an object is correct?

a. The acceleration of an object is directly proportional to the net external force acting on the object and inversely proportional to the mass of the object.

b. The acceleration of an object is directly proportional to the net external force acting on the object and directly proportional to the mass of the object.

c. The acceleration of an object is inversely proportional to the net external force acting on the object and inversely proportional to the mass of the object.

d. The acceleration of an object is inversely proportional to the net external force acting on the object and directly proportional to the mass of the object.

____ 25. Which of the following does NOT describe a condition for a conservative force?

a. The net work is = 0
b. Internal forces = 0
c. decrease PE of the object
d. isolated system

____ 26. The statement by Newton that for every action there is an equal but opposite reaction is which of his laws of motion?

a. first
b. second
c. third
d. fourth (this is not the answer!)

____ 27. A sled weighing $1.0 \text{ X}10^2$ N is held in place on a frictionless 20.0° slope by a rope attached to a stake at the top. The rope is parallel to the slope. What is the <u>normal force</u> of the slope acting on the sled?

a. 94 N
b. 47 N
c. 37 N
d. 34 N

____ 28. A crate is carried in a pickup truck traveling horizontally at 15.0 m/s. The truck applies the brakes for a distance of 28.7 m while stopping with uniform acceleration. What is the coefficient of static friction between the crate and the truck bed if the crate does not slide?

a. 0.400
b. 0.365
c. 0.892
d. 0.656

____ 29. An Olympic skier moving at 20.0 m/s down a 30.0°slope encounters a region of wet snow and slides 145 m before coming to a halt (stopped). What is the coefficient of friction between the skis and the snow?

a. 0.540
b. 0.740
c. 0.116
d. 0.470

____ 30. A force does work on an object if a component of the force

a. is perpendicular to the displacement of the object.
b. is parallel to the displacement of the object.
c. perpendicular to the displacement of the object moves the object along a path that returns the object to its starting position.
d. parallel to the displacement of the object moves the object along a path that returns the object to its starting position.

____ 31. A hill is 100 m long and makes an angle of 12° with the horizontal. As a 50 kg jogger runs up the hill, how much work does the jogger complete against gravity?

a. 50 000 J
b. 10 000 J
c. –10 000 J
d. 0.0 J

____ 32. A construction worker pushes a wheelbarrow 5.0 m with a horizontal force of 50.0 N. How much work is done by the worker on the wheelbarrow?

a. 10 J
b. 1250 J
c. 250 J
d. 55 J

____ 33. If both the mass and the velocity of a ball are tripled, the kinetic energy of the ball is increased by a factor of

a. 6.
b. 3.
c. 9.
d. 27.

____ 34. Which of the following energy forms is associated with an object due to its position?

a. potential

b. positional

c. total

d. kinetic

____ 35. A 40.0 N crate is pulled up a 5.0 m inclined plane at a constant velocity. If the plane is inclined at an angle of 37° to the horizontal and there is a constant force of friction of 10.0 N between the crate and the surface, what is the net gain in potential energy by the crate?

a. 120 J

b. −120 J

c. 210 J

d. −210 J

____ 36. An 80.0 kg climber with a 20.0 kg pack climbs 8848 m to the top of Mount Everest. What is the climber's potential energy?

a. 6.94 □ 10^6 J

b. 4.16 □ 10^6 J

c. 2.47 □ 10^6 J

d. 1.00 □ 10^6 J

____ 37. A pole vaulter clears 6.00 m. With what velocity does the vaulter strike the mat in the landing area? (Disregard air resistance. $g = 9.81$ m/s^2.)

a. 2.70 m/s

b. 5.40 m/s

c. 10.8 m/s

d. 21.6 m/s

____ 38. True or False: Kinetic energy is conserved during an elastic collision.

a. True b. False

____ 39. A horizontal force of $2.00 \text{ X } 10^2$ N is applied to a 55.0 kg cart across a 10.0 m level surface, accelerating it 2.00 m/s^2. Using the work–kinetic energy theorem, find the force of friction that slows the motion of the cart? (Disregard air resistance. g = 9.81 m/s^2.)

a. 110 N
b. 90.0 N
c. 80.0 N
d. 70.0 N

____ 40. Which of the following is the rate at which energy is transferred?

a. potential energy
b. kinetic energy
c. mechanical energy
d. power

____ 41. What is the average power output of a weight lifter who can lift 250 kg, 2.0 m in 2.0 s?

a. 5.0×10^2 W
b. 2.5 kW
c. 4.9 kW
d. 9.8 kW

____ 42. What is the gravitational force between two trucks, each with a mass of 2.0×10^4 kg, that are 2.0 m apart? ($G = 6.673 \times 10^{-11}$ Nm^2/kg^2)

a. 5.7×10^{-2} N
b. 1.3×10^{-2} N
c. 6.7×10^{-3} N
d. 1.2×10^{-7} N

____ 43. Two small masses that are 10.0 cm apart attract each other with a force of 10.0 N. When they are 5.0 cm apart, these masses will attract each other with what force?

($G = 6.673 \times 10^{-11}$ Nm^2/kg^2)

a. 5.0 N
c. 20.0 N
b. 2.5 N
d. 40.0 N

____ 44. A mass attached to a spring vibrates back and forth. At the equilibrium position, the

a. the acceleration reaches a maximum.
c. net force reaches a maximum.
b. velocity reaches a maximum.
d. velocity reaches zero.

____ 45. If a force of 50 N stretches a spring 0.10 m, what is the spring constant?

a. 5 N/m
c. –5 N/m
b. 500 N/m
d. –500 N/m

____ 46. A 0.20 kg block rests on a frictionless level surface and is attached to a horizontal spring (k = 40 N/m). The block is initially displaced 4.0 cm from the equilibrium pt. and then released. What is the speed of the block when it passes through the equilibrium pt. ?

a. 2.1 m/s
b. 1.6 m/s
c. 1.1 m/s
d. 0.57 m/s

____ 47. A spring with a spring constant of 500 N/m is compressed 4.0 cm. What is the potential energy stored?

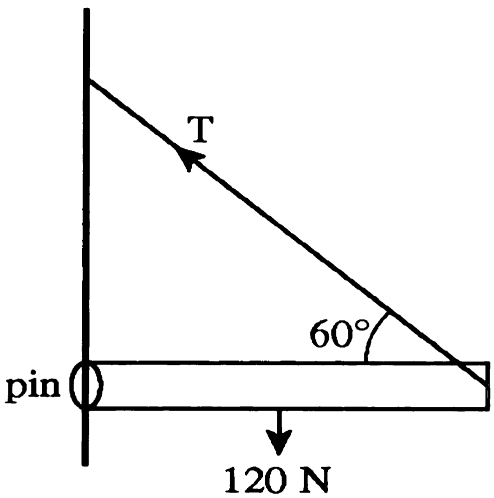
a. 8000J
c. 0.4J
b. 4000J
d. 0.8J

____ 48. A wheel has a circumference of 2.3m and rotates at 1.8 rad/sec. Find the magnitude of centripetal acceleration that a 20g object will experience on the outside of the wheel.

a. $0.233\ m/s^2$
b. $2.33\ m/s^2$
c. $11.66\ m/s^2$
d. $1.16\ m/s^2$

____ 49. The centripetal force (in Newtons) required to cause a 4.0 kg object to move at 0.06 m/s in a circle of radius 1.0m is:

a. 0.024
b. 0.014
c. 0.031
d. 0.24



50. A uniform horizontal beam with a length of 6.0 m and a weight of 120 N is attached at one end to a wall by a pin connection so that the beam can rotate. The opposite end of the beam is supported by a cable attached to the wall above the pin. The cable makes an angle of 60.0° with the beam. What is the tension in the cable needed to maintain the beam in equilibrium?

a. 35 N
b. 69 N
c. 6.0×10^1 N
d. 120 N

51. Which of the following statements is correct?

a. The farther the center of mass of an object is from the axis of rotation, the less difficult it is to rotate the object.

b. The farther the center of mass of an object is from the axis of rotation, the smaller the object's moment of inertia is.

c. The farther the center of mass of an object is from the axis of rotation, the greater the object's moment of inertia is.

d. The farther the center of mass of an object is from the axis of rotation, the greater the object's moment of inertia is, but the less difficult it is to rotate the object.

52. Centrifugal force

a. points inward toward the center of a circular path
b. points outward away from the center of the circular path
c. points along the tangent to the circle
d. isn't really a force

53. A 13g object is attached to a 0.93 m string. The object is swung in a horizontal circle, making one revolution in 1.18 sec. Find the tension force exerted by the string.

a. 1.8N c. 0.34N

b. 34N d. 18N

54. A child with a weight of 4.50×10^2 N sits on a seesaw 0.60 m from the axis of rotation. How far from the axis of rotation on the other side should a child with a weight of 6.00×10^2 N sit so the seesaw will remain balanced?

a. 0.30 m c. 0.45 m

b. 0.40 m d. 0.50 m

55. After colliding, objects are deformed and lose kinetic energy. Identify the type of collision.

a. elastic
b. perfectly inelastic
c. inelastic
d. perfectly elastic

56. A 0.4 kg mass, attached to the end of a 0.75 m string, is whirled around in a circular horizontal path. If the maximum tension that the string can withstand is 450 N, then what maximum speed can the mass have if the string is not to break?

a. 370 m/s b. 22 m/s c. 19 m/s d. 29 m/s

57. A satellite is in a circular orbit about the earth at a distance of one earth radius above the surface. What is the speed of the satellite? Mass = 5.98×10^{24} kg, radius = 6.4×10^{6} m

a. 2600 m/s b. 4800 m/s c. 5600 m/s d. 16800 m/s

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

a. zero b. 3 m/s c. 6 m/s d. 9 m/s

59. A physics student throws a 0.15 kg rubber ball down onto the floor. The ball's speed just before impact is 6.5 m/s, and just after is 3.5 m/s. If the ball is in contact with the floor for 0.025 sec., what is the magnitude of the average force applied by the floor on the ball?

a. 60 N b. 133 N c. 3.0 N d. 3.5 N

60. In order for an object to be in equilibrium:

a. all forces must equal zero

c. all forces must be static

b. the rotational and translational velocities must be constant

d. all torques must equal zero

61. A mass on a spring vibrates in simple harmonic motion at an amplitude of 8.0 cm. If the mass of the object is 0.20 kg and the spring constant is 130 N/m, what is the frequency?

a. 1.5 Hz

c. 4.0 Hz

b. 8.7 Hz

d. 1.6 Hz

62. What is the period of a 4.12 m long pendulum?

a. 2.01 s

c. 4.07 s

b. 3.11 s

d. 9.69 s

63. On the planet Xenos, an astronaut observes that a 1.00 m long pendulum has a period of 1.50 s. What is the free-fall acceleration on Xenos?

a. 4.18 m/s^2

c. 17.5 m/s^2

b. 10.2 m/s^2

d. 26.3 m/s^2

64. A water bed that is 1.5 m wide and 2.5 m long weighs 1055 N. Assuming the entire lower surface of the bed is in contact with the floor, what is the pressure the bed exerts on the floor?

a. 250 Pa

c. 270 Pa

b. 260 Pa

d. 280 Pa

65. Each tire of an automobile has an area of 0.026 m^2 in contact with the ground. The weight of the automobile is 2.6 □ 10^4 N. What is the pressure in the tires?

a. 3.1×10^6 Pa

b. 6.5×10^3 Pa

c. 2.5×10^5 Pa

d. 1.0×10^6 Pa

Appendix C1

Moving Man Simulation Homework

Procedure: Do the following activity using this website:

http://www.colorado.edu/physics/phet/simulations-base.html

Then click on "The Moving Man"

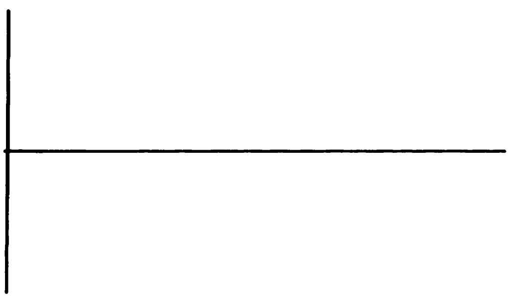
Click "Run Now"

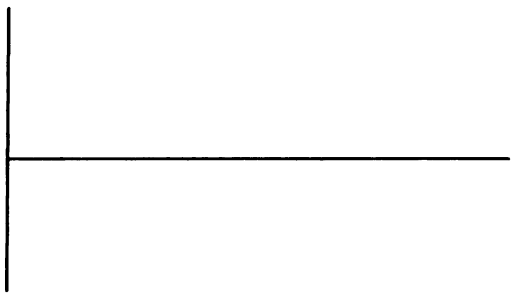
1. After "The Moving Man" is open, play with the controls a bit to get the hang of the program.

2. By changing the values of x,v, and/or a, you cause the man to move back and forth and observe what shows up on the graphs. The simulation also allows you to move the man by dragging him… however, this gives "messy" graphs so be sure to type in the values instead!

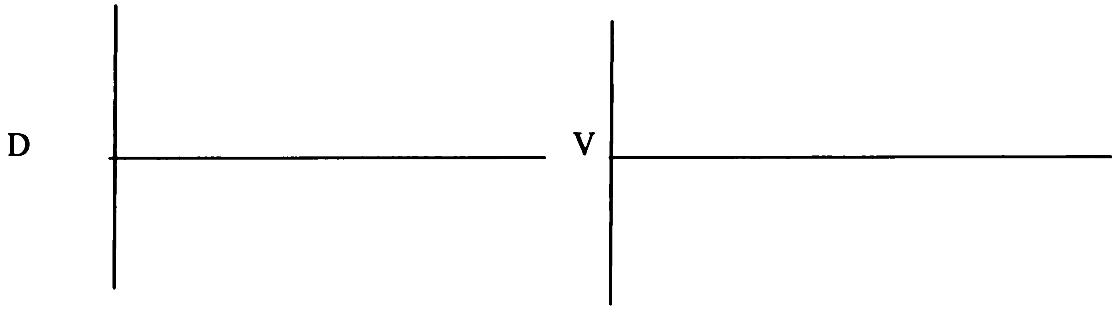
3. Using the axis provided below make sketches of d vs. t and v vs. t graphs for the actions described next to each axis. As you work through the situations, pay attention to the acceleration vs. time graph, even though you are not asked to graph it.

A man moving from 0 to 10 m at a slow steady pace.

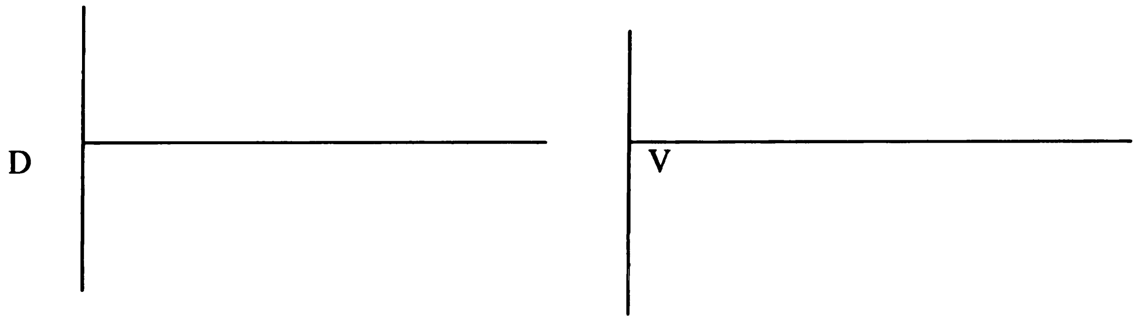
D


V


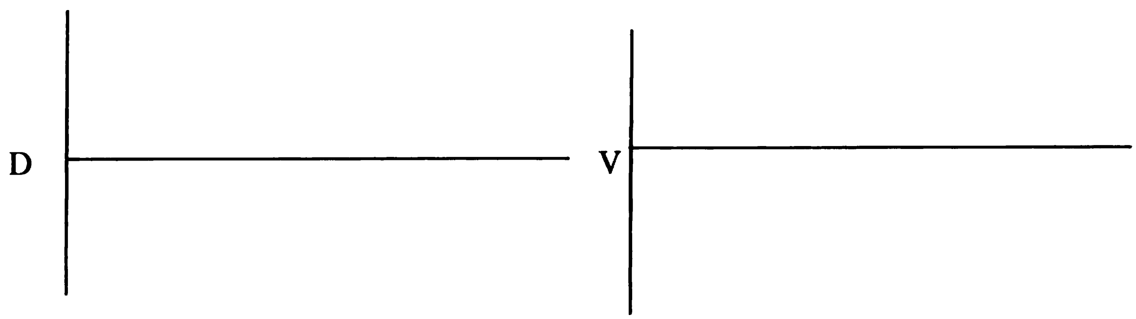
A man moving from 0 to 10m at a fast pace



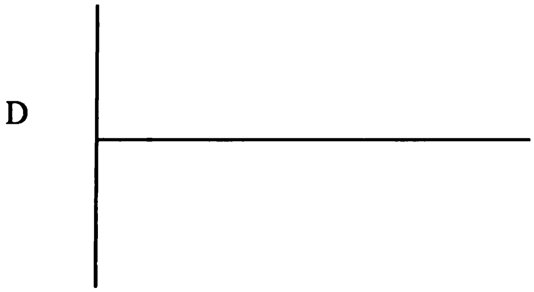
A man standing still at 4m

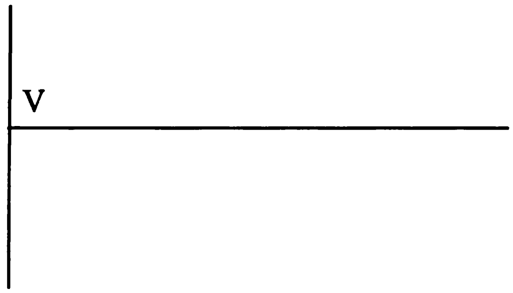


A man moving from 0 to 10m at a fast pace then moving back to 0 at a slow pace.

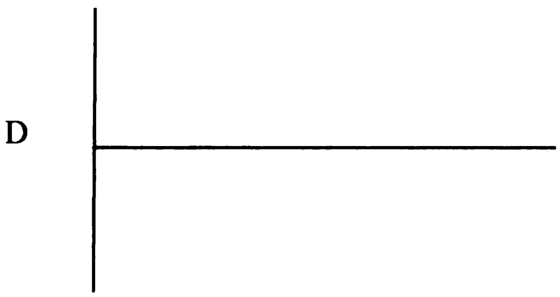


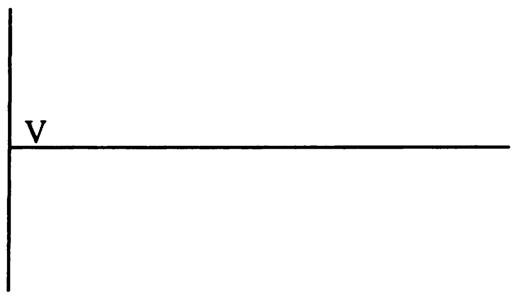
A man moving from 0 to -10m at a fast pace then moving back to 0 at a slow pace.





A man moving from 10 to 0m at a fast pace.





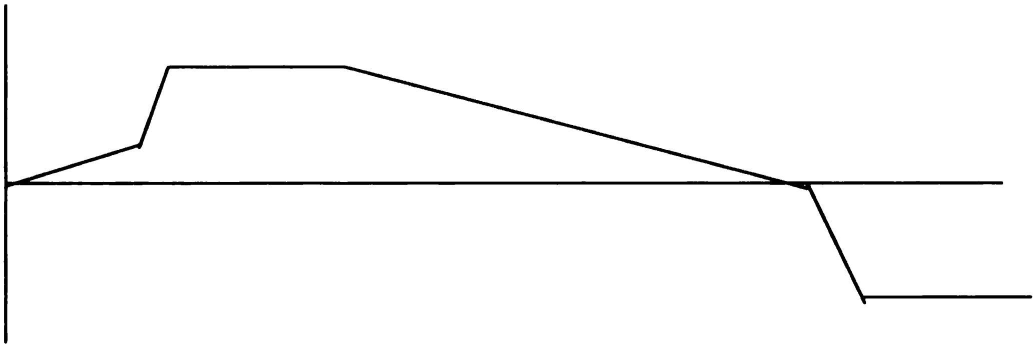
After observing the acceleration vs. time graphs for each of the above activities, what did you notice?

What kind of motion do you need to have so that the acceleration vs. time graphs is not a "flatline"?

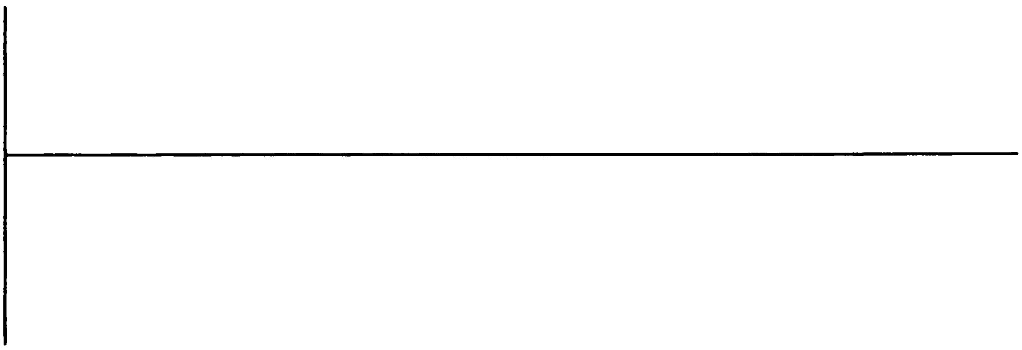
Apply what you learned:

Look at the distance vs. time graph below. Draw the corresponding velocity vs. time and acceleration vs. time graphs.

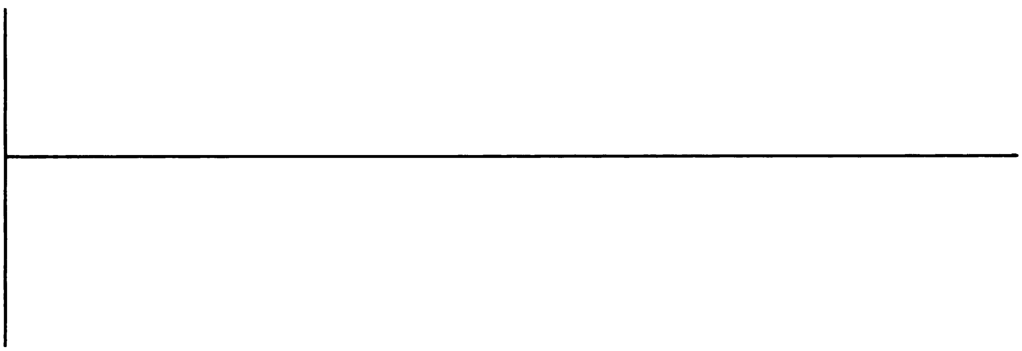
D



V

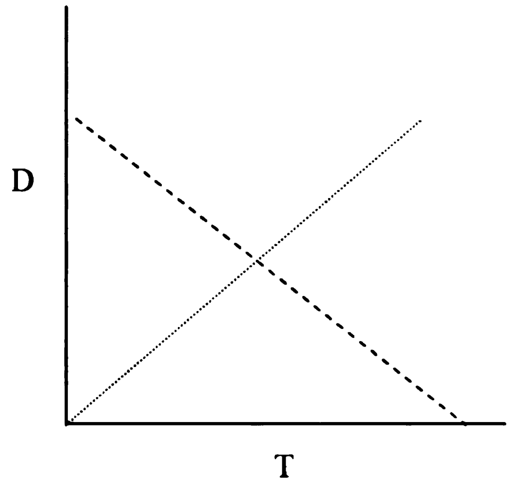


A

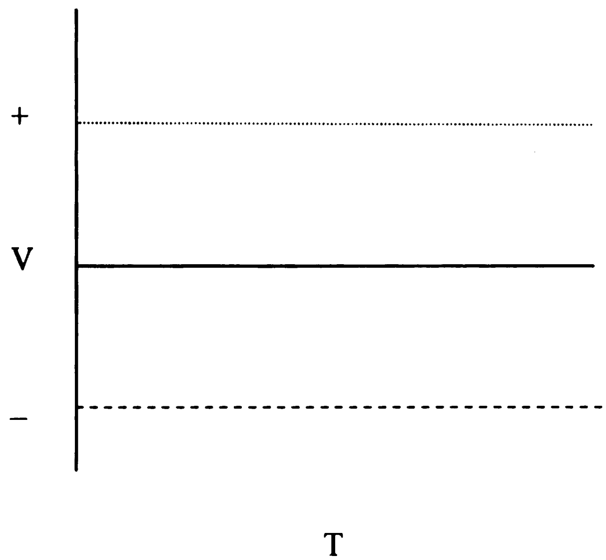


Appendix C2

Graphing Motion Notes



** translate d vs. t graph into v and a vs t graphs. Below are graphs of the same motion, but in v and a.



Both lines are at zero

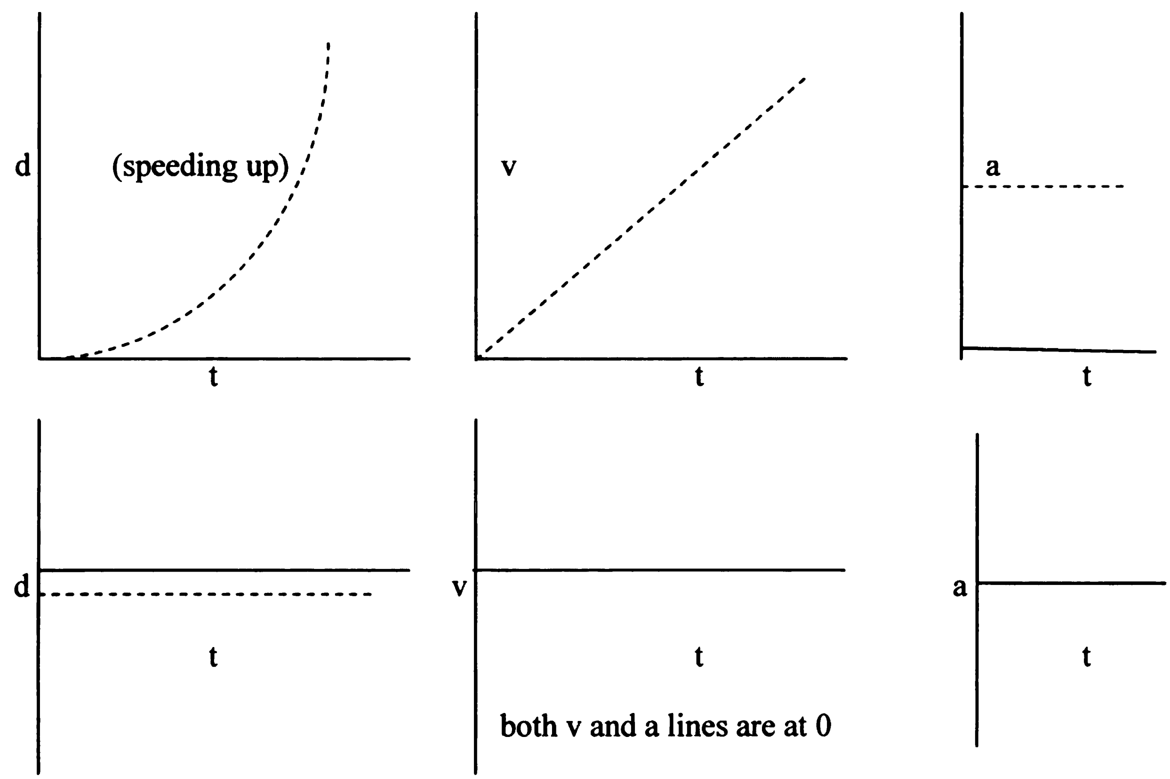
d vs. t v vs. t a vs. t

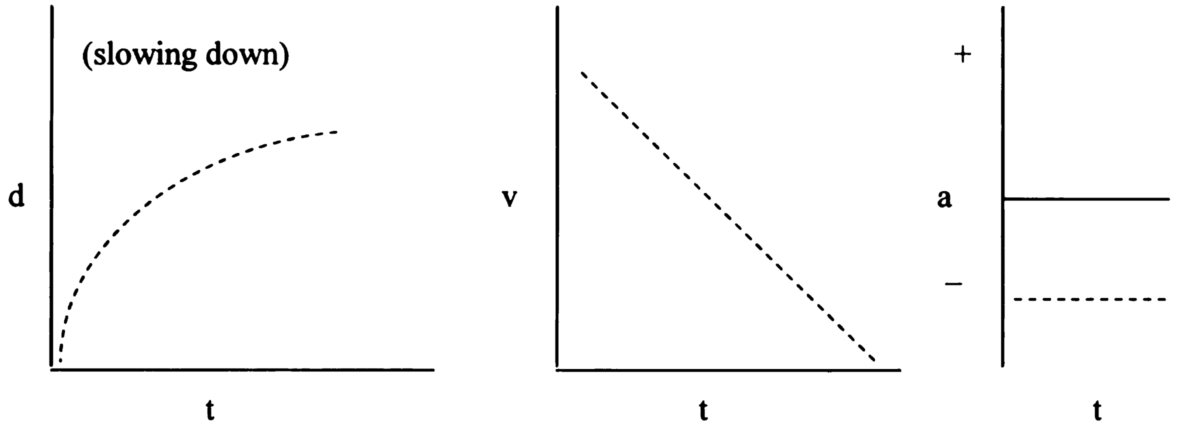
Slope

Area

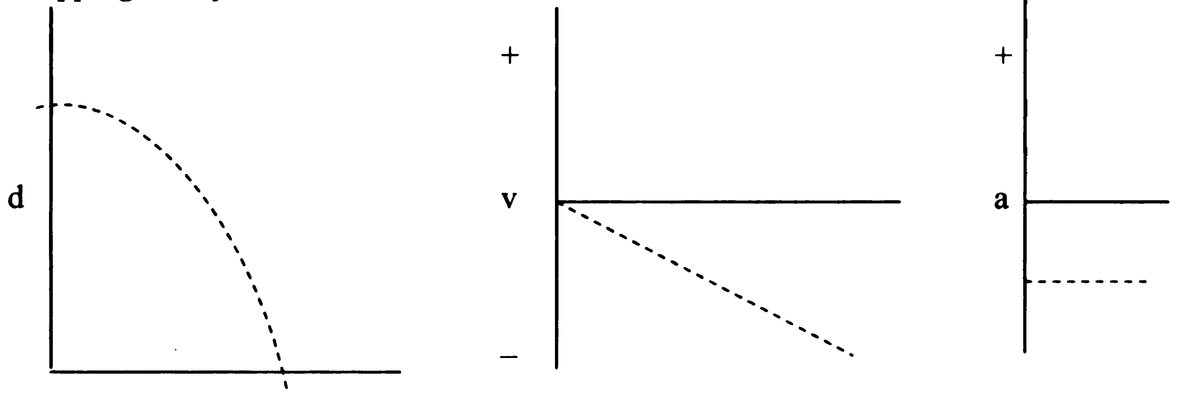
**Demonstration: Using motion detector and graphing motion program from Vernier, I show students the graphs, and call some up to move around in front of a d vs. t graph and a v vs. t graph for the class to watch. I then bring up some of the pre-made graphs, which get progressively harder. I ask students to volunteer to try to match the graphs, while the others can help them out by calling out directions.

Examples:



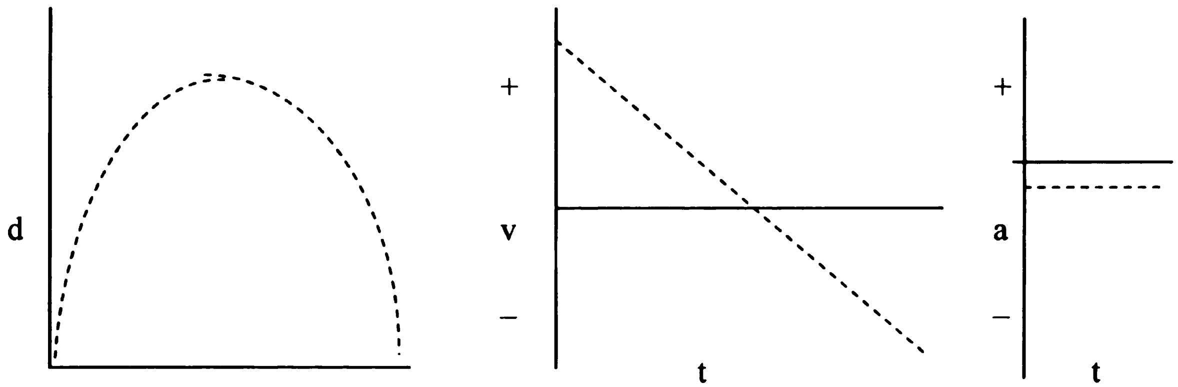


Dropping an object



this should be -9.8m/s

Throwing an object up (then falling)



Move further from the origin = graph moves up

Stop – graph straight

Move closer to origin = graph moves down

Appendix C3

Graphing Motion Demonstration

Equipment used:

Vernier software

LabPro

Motion Detector

Computer

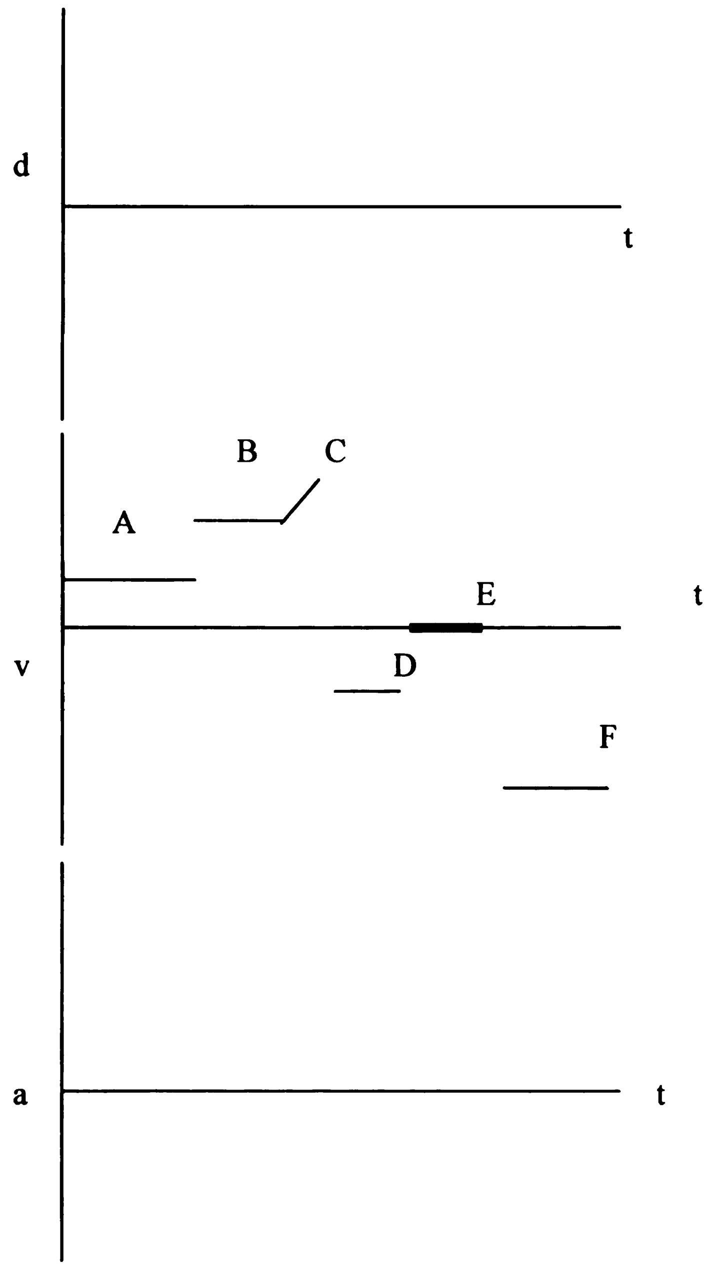
Description:

The instructor displays a graph for the class to see. The class is asked to imagine how they would need to move in order to recreate this graph. Then volunteers are asked to try to do this. Several volunteers are asked to try each of four graphs in that are premade in the Vernier software. If student volunteers struggle, the class is allowed to help the student to recreate the graph.

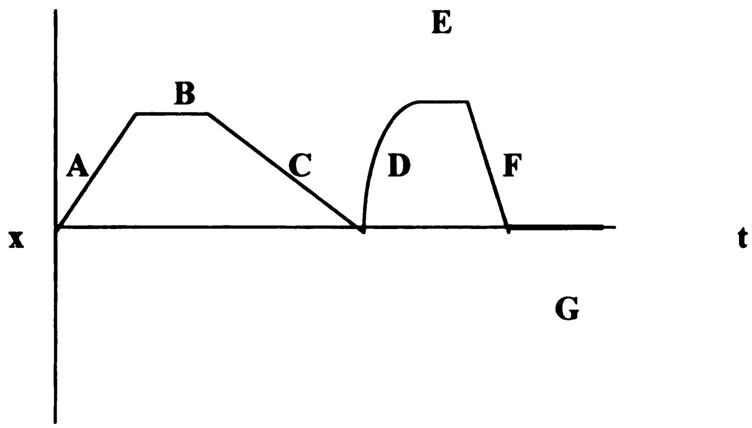
Appendix C4

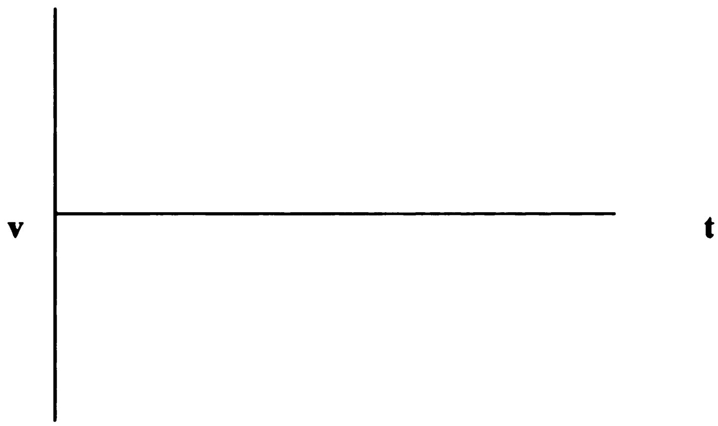
Graphing Motion Worksheet

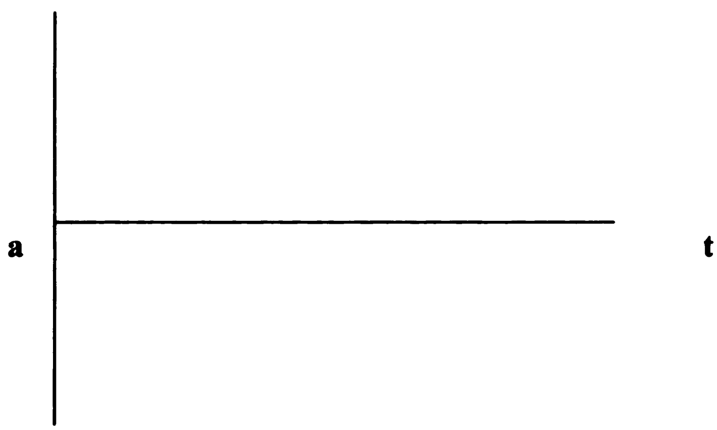
1. Describe the motion that is occurring in the v vs. t graph at each letter.
2. Fill in the corresponding x vs. t graph and a vs. t graph.
3. Confirm that your descriptions match your graphs.



1. Describe the motion that is occurring in the x vs. t graph at each letter.
2. Fill in the corresponding v vs. t graph and a vs. t graph.
3. Confirm that your descriptions match your graphs.





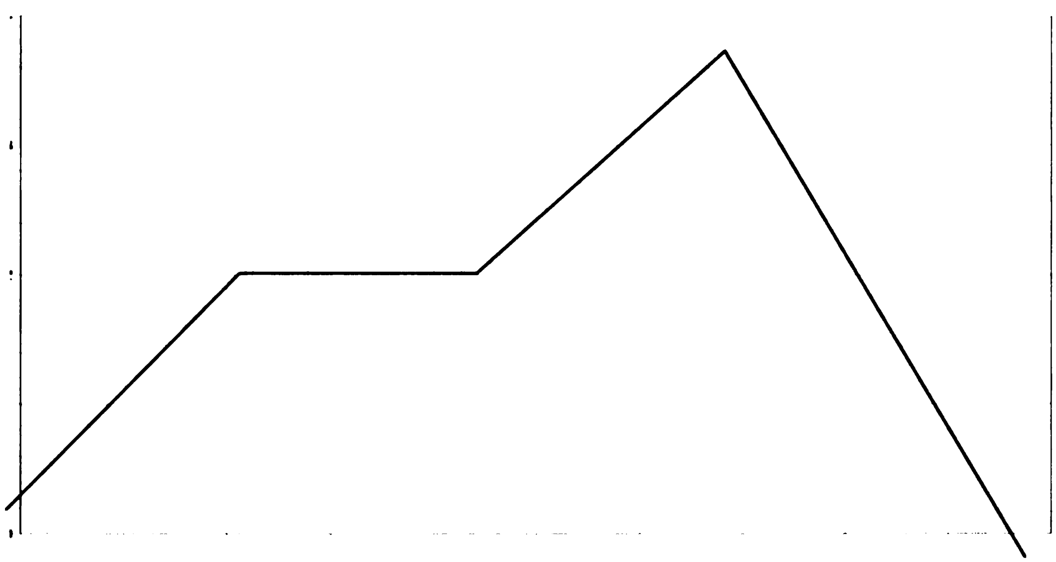


Appendix C5

Graphing Motion Lab

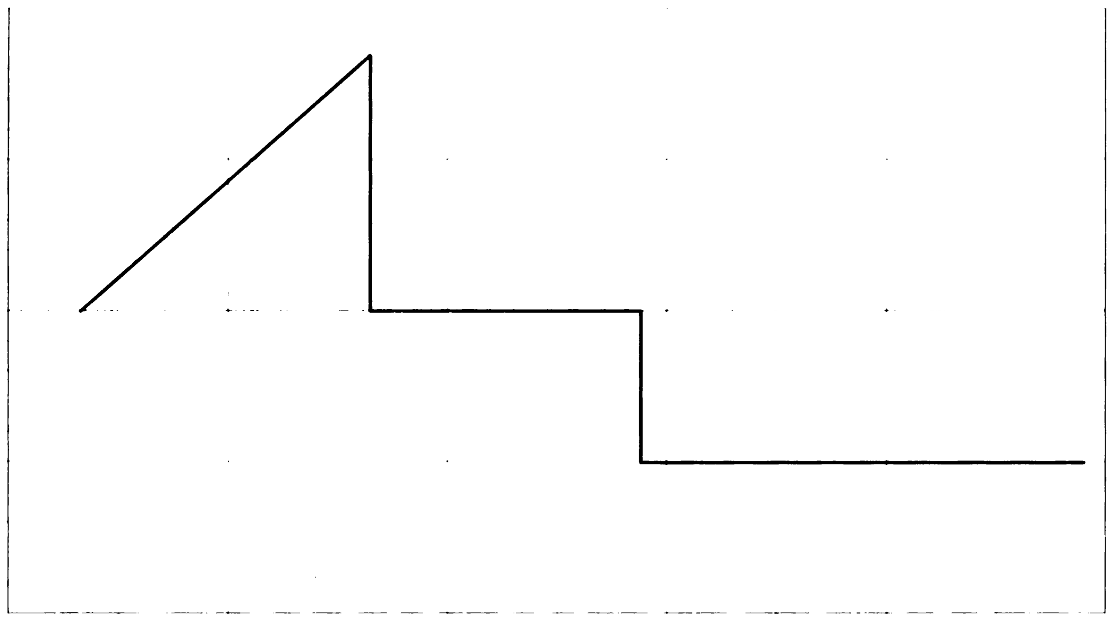
Part 1: Position vs. Time

1. Place the motion detector so that it points toward an open space at least 4 m long.
2. Open LoggerPro by clicking Start, Programs, LoggerPro. When the program opens, click File, Open, C drive, Program Files, Vernier software, LoggerPro, Experiment, Physics with Computers, Experiment 1. Open the experiment file Exp 01a Distance Graph. A position vs. time graph will appear on the screen.
3. Discuss with your group how you will reproduce the graph shown below, and then try it.
4. When you get the best graph you can, save to your H drive, and print.
5. Describe how you had to walk in order to reproduce each part of the graph. Write your description directly on the graph below.



Part 2: Velocity vs. Time

1. Switch to a velocity vs. time graph. To do this, right click on the graph and click on graph options. Under axes options, unclick the position box, and click the velocity box. Then below that, change the top to 2 and the bottom to -2. Click done.
2. Discuss with your group how you will reproduce the graph shown below, and then try it.
3. When you get the best graph you can, save to your H drive, and print.
4. Describe how you had to walk in order to reproduce each part of the graph. Write your description directly on the graph below.



Analysis:

1. What does the slope of a position vs. time graph represent?
2. What type of motion is occurring if the slope of a position vs. time graph is negative?
3. What type of motion would cause a curved line on a position vs. time graph?
4. Sketch a velocity vs. time graph and acceleration vs. time graph for the position vs. time graph in part 1.
5. What does the slope of a velocity vs. time graph represent?
6. What type of motion is occurring when the slope of a velocity vs. time graph is zero?
7. What does the area under a velocity vs. time graph represent?
8. Sketch a position vs. time graph and acceleration vs time graph for the velocity vs. time graph in part 2.

**Attach the answers to these 8 questions and your two printed graphs to this lab sheet and turn in with all group member names on it.

Appendix C6

Projectile Computer Lab

1. Go to the PHET web site

   http://phet.colorado.edu/web-pages/simulations-base.html

   Go to the Motion Page and start the Projectile Motion simulation.

2. Try using some of the different objects in the pull down menu without air resistance.

3. Now try the different objects with air resistance.

4. What do you notice about all of the projectiles when there is no air resistance?

____

____

____

5. What does air resistance do to a projectile? Why?

____

____

____

6. Why does a bowling ball go farther than a golf ball even though a golf ball has a much smaller drag coefficient?

____

____

____

7. Why does a human go so much farther than a Buick when they have the same drag coefficient?

____

____

____

8. What things are important to know in order to find out how an objects path will be changed by air resistance?

____

____

____

9. Move the target to a distance 20 meters from the cannon. With air resistance off and using the golf ball try each of the following shots. Be sure to measure and place your target along the x axis as shown.

Angle (degrees)	75°	45°	15°	89.4°	9.3°
Initial Speed (m/sec)	20 m/sec	14 m/sec	20 m/sec	98 m/sec	24.8 m/sec
Hit or Miss					

10. Which angle requires the fastest speed in order to hit the target? Why?

____

____

____

11. Which angle requires the slowest speed to hit the target? Why?

____

____

____

12. What do you notice about angles 75° and 15°?

____

____

____

13. If an X appears on the trajectory at each second how long was each shot up in the air? Which shot was in the air the longest?

____

____

____

14. How did the shots with the smallest angles go just as far as the shots that were in the air the longest?

____

____

____

15. Using the magnifying glass move the target to 490 meters. For the golf ball with no air resistance fire a shot with Angle 45° and Initial Speed 69.3 m/sec. This is Trajectory A.

Without erasing fire a shot with Angle 75° and Initial Speed of 50.7 m/sec. This is Trajectory B.

These two shapes are called parabolas. Notice the X that appears at each second—the highest point for each parabola is at 5 seconds. This is called the vertex.

Using the tape measure; measure the height of each vertex and the length of each trajectory (range).

	Trajectory A	Trajectory B
Height of Vertex (m)		
Range (m)		
Duration—seconds in air		

16. Why do the X's get closer together as you get to the top of the parabola?

____

____

____

17. What happens to the speed of the golf ball as you get closer to the top of the parabola? Does the horizontal speed change or only the vertical speed?

____

____

19. Calculate the horizontal speed of each trajectory (hint: use Trig with initial speed and angle)

	Trajectory A	Trajectory B
Horizontal Speed (m/sec)		

18. For each trajectory, what is the vertical speed at the vertex of the trajectory? Which trajectory has the highest total speed? How can you tell?

____

____

____

Appendix C7

Projectile Motion Notes

Aloud

How many components make up a vector?

1. Horizontal-straight line motion
2. Vertical-freefall

-projectile motion combines these two components

-each component is independent of the other

-so, it is like solving two problems in one: a freefall and a straight line motion problem

Are they linked by anything?

Do demo with simultaneous ball launcher. Then look at video analyzed to show that same time occurs for each.

Time links the two components!

-ie. If you can find the time in the x component, it has the same value in the y component

Show video of cart moving, shooting ball upward (or do actual demo)

Written on board

I. Consists of 2 components (x,y) that act independently of each other.
   a. Assume no air resistance, remember online simulation.
   b. Parabolic shape

II. Vectors of projectiles
   **Show video made of projectile, draw diagrams below.

III. Facts to memorize
   a. x component:
      i. v_x stays the same
      ii. a=0
      iii. time is scalar
   b. y component:

i. v_y changes
ii. $a=-9.8 m/s^2$
iii. time is scalar

IV. Equations: All kinematic equations apply, but be careful!

**look at demo with beads first at horizontal, then at angle

V. Range Equation: projectile must begin and end on the same plane to use this equation!

Appendix C8

Projectile Motion Demonstrations

"Shoot the Monkey"

A Nerf gun is set up at one end of the classroom while a stuffed animal is set up on the other end, attached to the ceiling. They are hooked up so that when the trigger on the gun is pulled, the stuffed animal will automatically be dropped from the ceiling. This setup is explained to the class. Students are then asked where the instructor needs to aim in order to hit the monkey. A discussion follows on the mechanics of projectile motion and how time links the x and y coordinates. The instructor then demonstrates that only by aiming directly at the stuffed animal and firing, the projectile will hit the stuffed animal. This is because both the projectile and the stuffed animal fall towards the ground at the same rate. It does not matter that the stuffed animal is falling straight down while the projectile is moving forward and falling.

Ball Launcher

The ball launcher allows the instructor to load two metal balls into a projectile launcher at the same time. One ball is launched horizontally while the other is dropped straight downward. The launcher releases both balls at the same time. Students can observe that a horizontal velocity does not have any effect on the time it takes to reach the ground; both balls hit at exactly the same time.

Appendix C9

Projectile Problems

1. A ball falls from rest from a height of 490m.
   a. How long does it remain in the air?
   b. If the ball has a horizontal velocity of 2.00×10^2 m/s when it begins its fall, what horizontal displacement will it have?
2. An archer stands 40.0m from the target. If the arrow is shot horizontally with a velocity of 90.0m/s, how far above the bull's-eye must he aim to compensate for gravity pulling his arrow downward?
3. A bridge is 176.4m above a river. If a lead-weighted fishing line is thrown from the bridge with a horizontal velocity of 22.0m/s, how far has it moved horizontally when it hits the water?
4. A beach ball, moving with a speed of +1.27m/s, rolls off a pier and hits the water 0.75m from the end of the pier. How high above the water is the pier?
5. Carlos has a tendency to drop his bowling ball on his release. Instead of having the ball on the floor at the completion of his swing, Carlos lets go with ball 0.35m above the floor. If he throws it horizontally with a velocity of 6.3m/s, what distance does it travel before you hear a "thud"?
6. A discus is released at an angle of 45^0 and a velocity of 24.0m/s.
   a. How long does it stay in the air?
   b. What horizontal distance does it travel?
7. A shot put is released with a velocity of 12m/s and stays in the air for 2.0s.
   a. At what angle with the horizontal was it released?
   b. What horizontal distance did it travel?
8. A football is kicked at 45^0 and travels 82m before hitting the ground.
   a. What was its initial velocity?
   b. How long was it in the air?
   c. How high did it go?
9. A golf ball is hit with a velocity of 24.5m/s at 35.0^0 above the horizontal.
   a. What is the range of the ball?
   b. What is the maximum height of the ball?

Appendix C10

Projectile Motion Lab

Equipment Needed:

- Projectile launcher and plastic ball
- Plumb bob
- C clamp
- Meter stick
- Carbon paper
- White paper

Purpose:

Theory:

To predict where a ball will land on the floor when it is shot off a table at some angle above the horizontal, it is necessary to first determine the initial speed (muzzle velocity) of the ball. This can be determined by shooting the ball horizontally off the table and measuring the vertical and horizontal distances through which the ball travels. Then the initial velocity can be used to calculate where the ball will land when it is shot at an angle.

Setup:

1. Clamp the projectile launcher to a sturdy table near one end.
2. Adjust the angle of the launcher to zero degrees so the ball will be shot off horizontally.

Part A: Determining the Initial Velocity of the Ball

1. Put the ball into the launcher and cock it to the long range position. Fire one shot to locate where the ball hits the floor. At this position, tape a piece of white paper to the floor. Place a piece of carbon paper (carbon side down) on top of this paper and tape it down. When the ball hits the floor, it will leave a mark on the white paper.
2. Fire 5 shots.
3. Measure the vertical distance (Δy) from the bottom of the ball as it leaves the barrel (this position is marked on the side of the barrel) to the floor. Record this distance.
4. Use a plumb bob to find the point on the floor that is directly beneath the release point on the barrel. Measure the horizontal distance (Δx) along the floor from the release point to the dot left by the ball. Record. Continue for each remaining mark left on the paper.

5. Find the average of the 5 distances and record.
6. Using the vertical distance and the average horizontal distance, calculate the time of flight and the initial velocity of the ball. Record in a table and show calculations in the analysis section.

Part B: Predicting the Range of the Ball Shot at an Angle

1. Put the launcher on the floor and adjust the angle between 30 and 70 degrees.
2. Launch the projectile and locate where the ball hits. Place a box or some books at that location so that the ball will hit at the same level as the muzzle of the launcher.
3. Launch the projectile and measure the horizontal distance (range) as it lands on a piece of white paper and carbon paper.
4. Shoot the ball 5 times at this angle.
5. Repeat for one other angle. (You should have one angle above and one angle below 45°)

Analysis:

1. Calculate the predicted range of your projectile at the two angles, using initial velocity from part A. Be sure to include the calculations used to solve for initial velocity.
2. Calculate the % difference between your predicted value and the resulting average distance when shot at an angle.
3. Calculate the hang time for all 2 angles.
4. Choose one angle and construct a velocity vector analysis of the projectile path. For a minimum of 3 points on the path, determine and show v, v_x and v_y.
5. How would your results change if we used projectiles of the same size, but with a larger mass? Explain.

Lab Requirements:

1. *Title page*
2. *Lab sheet*
3. *Purpose*
4. *Data from part A and part B*
5. *Calculations from part A and part B*
6. *Analysis questions*
7. *3 systematic errors*
8. *#4 pg 119 in book*

Appendix C11

PHYSICS MOMENTUM LAB

AIR TRACK SIMULATION.

Go to: (https://www.msu.edu/~brechtjo/physics/airTrack/airTrack.html)

This simulation models a basic air track with two blocks.

GENERAL DIRECTIONS:

- Click **GO** to start Simulations
- **STOP** the simulation after the initial collision.
- Final velocity is "current velocity"
- Set α at '1' for ELASTIC COLLISIONS
- Set α at '0' for INELASTIC COLLISIONS
- Reset the simulation after each case.

Part I. ELASTIC COLLISIONS: QUALITATIVE ANALYSIS

DIRECTIONS: After setting the values click on **GO** and observe what happens **AFTER** the collision, then answer the questions indicating your observations regarding the **velocities** (how fast, how slow) and **direction** of each mass.

Elastic Collision Case I. $m_1 = m_2$

Set the values as: $m_1 = 1$ kg $m_2 = 1$ kg

$v_1 = 100$ m/s $v_2 = 0$ m/s

What happens to Mass 1 (RED)?

____

What happens to Mass 2 (BLUE)?

____

Elastic Collision Case II. $m_1 > m_2$

Set the values as: m1 = 2 kg m2 = 1 kg

$v_1 = 100$ m/s $v_2 = 0$ m/s

What happens to Mass 1 (RED)?

____

What happens to Mass 2 (BLUE)?

Elastic Collision Case III. $m_1 < m_2$

Set the values as: m1 = 1 kg m2 = 2 kg
$v_1 = 100$ m/s $v_2 = 0$ m/s

What happens to Mass 1 (RED)?

____

What happens to Mass 2 (BLUE)?

____

Part II. COLLISIONS: QUANTITATIVE ANALYSIS

FOR EACH CASE:

1. Find the values for the **FINAL VELOCITIES (v_{1f}** and **v_{2f})** of each block and record the values on the tables.
2. Perform your **OWN** calculations for **MOMENTUM (momentum=mass*velocity)** and **KINETIC ENERGY (KE=1/2mv^2)** showing all your work: equations and answers.

ELASTIC COLLISION I. (Set α at 1)

RED BLOCK	**BLUE BLOCK**
$m_1 = 3$ kg	**$m_2 = 2$ kg**
$v_1 = 100$ m/s	**$v_2 = 0$ m/s**
Initial momentum =	Initial momentum =
Initial KE =	Initial KE =
V_{1f} =	**V_{2f} =**
Final momentum =	Final momentum =
Final KE =	Final KE

Was momentum conserved? ______________ Was KE conserved? __________________

Remember: Conserved means total final = total initial

ELASTIC COLLISION II. (Set α at 1)

RED BLOCK	**BLUE BLOCK**
$\mathbf{m_1 = 3}$ **kg**	$\mathbf{m_2 = 2}$ **kg**
$\mathbf{v_1 = 100}$ **m/s**	$\mathbf{v_2 = -50}$ **m/s**
Initial momentum =	Initial momentum =
Initial KE =	Initial KE =
$\mathbf{V_{1f}}$ =	$\mathbf{V_{2f}}$ =
Final momentum =	Final momentum =
Final KE =	Final KE

Was momentum conserved? ____________ Was KE conserved? ________________

INELASTIC COLLISION I. (Set α at 0)

RED BLOCK	**BLUE BLOCK**
$\mathbf{m_1 = 3}$ **kg**	$\mathbf{m_2 = 2}$ **kg**
$\mathbf{v_1 = 100}$ **m/s**	$\mathbf{v_2 = 0}$ **m/s**
Initial momentum =	Initial momentum =
Initial KE =	Initial KE =
$\mathbf{V_{1f}}$ =	$\mathbf{V_{2f}}$ =
Final momentum =	Final momentum =
Final KE =	Final KE

Was momentum conserved? ____________ Was KE conserved? ________________
If not, find the loss of KE:

INELASTIC COLLISION II. (Set α at 0)

RED BLOCK	BLUE BLOCK
m_1 = 3 kg	**m_2 = 2 kg**
v_1 = 100 m/s	**v_2 = -50 m/s**
Initial momentum =	Initial momentum =
Initial KE =	Initial KE =
V_{1f} =	V_{2f} =
Final momentum =	Final momentum =
Final KE =	Final KE

Was momentum conserved? ____________ Was KE conserved? ________________
If not, find the loss of KE:

Appendix C12

Momentum Notes

Aloud:

When a baseball is hit, the speed and direction change…. Kinematics describe the motion before and after…….. force and Newton's laws describe and explain why…. Now we look at force and the duration of the collision

On board:

I. Momentum- vector quantity defined as the product of an object's mass and velocity

   $p=mv$ **direction of p is that of v units: kg*m/s

   the faster you move, the more p you have, and you are harder to stop (ex. Red Rover)

   inertia- mass only -intrinsic property of object
   momentum- mass and velocity

   ex. Pg 209 #1
   m=146kg v=17m/s
   p=(146kg)*(17m/s)=2482kgm/s right

II. Change in momentum takes force and time…ex. Semi vs Smartcar rolling down a hill… which is harder to stop?

   Impulse-momentum theory: $F\Delta t=\Delta p$ or $F\Delta t=mv_f-mv_i$

   Small force applied=larger time to stop

   $F\Delta t$=impulse

   This explains why "follow through" is so important in sports

   Ex. Airbags stop passengers in .75s, while dashboard takes .026s How do the forces compare?

   Both will give the same change in momentum so…

   $F_d\Delta t_d=F_a\Delta t_a$

$F_d(.026)=F_a(.75)$

$F_d=29F_a$ The dashboard applies a force 29 times greater that the airbag

Conservation of Momentum

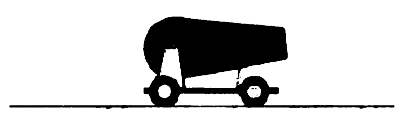
I. The total momentum present in system does not change.

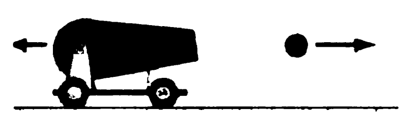
Ex. $p_{before}=p_{after}$

In order for conservation of momentum to occur, you need an isolated/closed system (no net external forces such as friction)

*we will always ignore friction in our problems

Momentum is conserved in collisions, as well as when objects push away from each other.





Total momentum of the system is 0 both before and after.... Why?

II. Collisions: total momentum remains constant in any type of collision!!

**total KE is usually not conserved because it is converted into another energy form when objects collide and deform.

a. Perfectly inelastic collisions: when two objects stick together and move with a common velocity after colliding
   **pay attention to signs indicating direction! (+ and -)
   **KE is not conserved in inelastic collisions (KE converted to sound energy)
   **objects do not keep their original shapes

b. Elastic collisions: when two objects collide and return to their original shapes with no change in total KE.
**After the collision the two objects move separately
**total momentum and KE conserved

Most real-life collisions do not fall into either of these categories- they fall somewhere in the middle

Appendix C13

Conservation of Momentum Demos

Potato and straw: Students are asked to pierce a potato with a drinking straw. If pushed slowly the straw will be crushed against the potato, but if jabbed quickly, the straw will pierce the potato. When students discover this, it leads us into a discussion about inertia and momentum.

Rollerblades and medicine ball: Standing still on rollerblades and holding a medicine ball, ask students what total momentum of system is… (zero because there is 0 velocity). Then, throw the medicine ball forward, and you move backward. As students what momentum after throwing was (still 0… conservation of momentum) why? Because there was a positive and negative velocity due to opposite directions traveled. Which moved faster, me or ball? (medicine ball, b/c less mass)

Newton's Cradle: Momentum is transferred from ball to ball. Drop different numbers of balls and see how many balls bounce off.

Dropping different sized balls: If dropping a tennis ball and basketball at same time on top of each other, what happens? Why? What if you drop them with the basketball on top and the tennis ball on the bottom… why does this happen? (Talk about different masses)

Collision carts: Use track and various carts with differing masses, for elastic and inelastic collisions. (Do very briefly, because they will do a lab involving this later)

Appendix C14

Momentum Lab

Purpose:

Data:

Mass of cart 1: ____________________kg

Mass of cart 2: ____________________kg

Elastic Collision

Initial	Final
v 1= v 2=	v 1= v 2=
p 1= p 2=	p 1= p 2=
p_{total}=	p_{total}=
KE1= KE2=	KE2= KE1=
KE_{total}=	KE_{total}=

Is momentum conserved in elastic collisions? Explain using your data.

Is kinetic energy conserved in elastic collisions? Explain using your data.

Inelastic Collision

Initial	**Final**
v 1= v 2=	v 1= v 2=
p 1= p 2=	p 1= p 2=
p_{total}=	p_{total}=
KE1= KE2=	KE2= KE1=
KE_{total}=	KE_{total}=

Is momentum conserved in inelastic collisions? Explain using your data.

Is kinetic energy conserved in inelastic collisions? Explain using your data.

Determination of unknown mass

Initial	Final
v 1= v 2=	v 1= v 2=
p 1= p 2=	p 1= p 2=
p_{total}=	p_{total}=

What is the mass of the object? Show work below.

Using the actual mass of the object, find % difference.

List 3 systematic errors.

Appendix D

Pre and post-tests were all based on a one point per question scale, with a total of 10 questions or 10 points available. Multiple choice questions were either right or wrong (1 or 0 points given) while short answer questions or questions in which students had to diagram something could be 0, 0.5, or 1 point based on the completeness and correctness of their answer.

Scoring Rubrics

Graphing Motion

Pretest Question #	Scoring Basis
1,2,3,4,5,10	Multiple choice: 1 point =correct 0 points= incorrect
6, 7	1 point: completely correct 0.5 points: at least ½ of graph correctly drawn 0 points: less than ½ of graph correctly drawn
8	1 point: completely correct (correct slope and curve to line) 0.5 points: very close to correct (either slope or curve incorrect) 0 points: both slope and curve incorrect
9	1 point: description of motion completely correct 0.5 points: general idea correct, but some words incorrect such as "forward" instead of toward or incomplete such as failing to include a direction 0 points: more than one or two mistakes in description

Table 4: Scoring Rubric for Graphing Motion Tests

Projectile Motion

Pretest Question #	Scoring Basis
1,2,4,5,6,7	Multiple choice: 1 point = correct 0 points = incorrect
3	1 point = all velocity vectors drawn in correct directions, with arrows proportionate to velocity 0.5 points = more than half of velocity vectors drawn correctly, some sizes correct 0 points = less than half of all correct or no response
8	1 point = correct answer, they will take same time 0.5 points = incorrect answer with partially correct reasoning or correct answer with partially incorrectly reasoned explanation 0 points = completely incorrect answer and reasoning or no response
9, 10	1 point = correct explanation and/or diagram 0.66 points = correctly drawn diagram and/or coherent, reasonable explanation with some inaccuracies 0.33 points = incorrect but reasoned well with supporting information 0 points = completely incorrect with no explanation to back up, no response

Table 5: Scoring Rubric for Projectile Motion Tests

Momentum

Pretest Question #	Scoring Basis
1,2,3,4,5,6,7	Multiple choice: 1 point = correct 0 points = incorrect
8	1 point = correct directions on snowballs before and after collision 0.5 points = correct either before or after collision, but not both 0 points = before and after collision incorrect or no response
9	1 point = correct explanation 0.5 points = partially correct explanation - explanation had some holes in it or reasoning gaps 0 points = incorrect answer or reasoning, or no response
10	1 point = completely correct 0.5 points = partially correct explanation – did not reference impulse-momentum theory 0 points = incorrect answer or no response

Table 6: Scoring Rubric for Conservation of Momentum Tests

Appendix E

Student End of Unit Survey: Projectile Motion

Please rate the following activities we did in class to the best of your ability. Any additional comments would be very helpful!

5= This really helped me to understand the topic!

1= This activity completely confused me, and did not help me to better understand the topic at all!

Projectile video during lecture ------------------ 1 2 3 4 5

Comments:

____

____

Projectile online simulation --------------------------- 1 2 3 4 5

Comments:

____

____

Demonstrations (Mr Potato Head, etc) --------------- 1 2 3 4 5

Comments:

____

____

Notes -- 1 2 3 4 5

Comments:

____

____

Projectile lab -- 1 2 3 4 5

Comments:

____

____

Problem sets -- 1 2 3 4 5

Comments:

____

____

Student End of Unit Survey: Graphing Motion

Please rate the following activities we did in class to the best of your ability. Any additional comments would be very helpful!

5= This really helped me to understand the topic!

1= This activity completely confused me, and did not help me to better understand the topic at all!

Moving man online simulation ---------------------- 1 2 3 4 5

Comments:

____

____

Motion sensor demonstration ------------------------- 1 2 3 4 5

Comments:

____

____

Notes --- 1 2 3 4 5

Comments:

____

____

Lab -- 1 2 3 4 5

Comments:

____

____

Problems sets (worksheets) ------------------------- 1 2 3 4 5

Comments:

____

____

Student End of Unit Survey: Conservation of Momentum

Please rate the following activities we did in class to the best of your ability. Any additional comments would be very helpful!

5= This really helped me to understand the topic!

1= This activity completely confused me, and did not help me to better understand the topic at all!

Online simulation ---------------------------------- 1 2 3 4 5

Comments:

____

____

Demonstrations (rollerblades, potato, Newton's cradle) 1 2 3 4 5

Comments:

____

____

Notes --- 1 2 3 4 5

Comments:

____

____

Assignments/Bookwork ------------------------------ 1 2 3 4 5

Comments:

____

____

Lab --- 1 2 3 4 5

Comments:

____

____

Appendix F

Corresponding pre and post test question numbers linked to objectives

Graphing Motion

Pretest	*Posttest*	*Objective covered*
#1	*#9 multiple choice*	*D*
#2	*#10 multiple choice*	*D*
#3	*#12 multiple choice*	*B*
#4	*#13 multiple choice*	*C*
#5	*#15 multiple choice*	*B*
#6	*#4 problems*	*A*
#7	*#5 problems*	*A*
#8	*#3b problems*	*A*
#9	*#8 problems*	*B*
#10	*#14 multiple choice*	*C*

Table 7: Graphing Motion Pre/Post-Test Paired Questions

Projectile Motion

Pretest	*Posttest*	*Objective covered*
#1	*#1*	*G*
#2	*#2*	*F*
#3	*#7a*	*F*
#4	*#3*	*F*
#5	*#6c*	*F*
#6	*#4*	*F*
#7	*#5a*	*F*
#8	*#6a*	*E*
#9	*#8*	*G*
#10	*#6b*	*E*

Table 8: Projectile Motion Pre/Post-Test Paired Questions

Momentum

Pretest	*Posttest*	*Objective covered*
#1	*#10*	*J*
#2	*#2*	*K*
#3	*#3*	*J*
#4	*#8*	*J*
#5	*#6*	*J*
#6	*#5*	*K*
#7	*#9*	*K*
#8	*#14a*	*J*
#9	*#15*	*L*
#10	*#13c*	*H and I*

Table 9: Conservation of Momentum Pre/Post-Test Paired Questions

Appendix G

Parental Consent and Student Assent Form
Collection of Data for Master's Thesis

Dear Parents/Guardians and Students:
I would like to take this opportunity to welcome you back to school and inform you about a project that will be a part of Physics this semester. Over the past couple years I have been working on a Master's thesis through Michigan State University's Department of Math and Science Education (DSME). The culmination of this degree consists of a research project on student learning, focusing on key areas where students typically struggle (projectile motion, graphing motion, and conservation of momentum). The unit includes assignments, laboratory experiments and activities, computer simulations, class demonstrations, and pre and post tests. These items were designed to with the intent to improve student comprehension and retention of the material covered in this course.
In order to evaluate the effectiveness of the study, normal class data will be collected from students through pre and post tests, lab questions, surveys, and select questions from daily assignments. With your permission I would like to use these data in my research thesis. The names of students will be not be used in the thesis paper, as it will only include statistics and anonymous samples of written work. Your privacy will be protected to the maximum extent allowable by law. You and your child's participation in this research study are completely voluntary.
Your child will receive no penalty in regard to their grade should you deny permission for the use of their data. Participation in this study will not increase or decrease the amount of work that is required of your child. You may request that your child's information not be included in this study at any time and your request will be honored. To insure that I do not know who has and has not volunteered to be in this study and perhaps unintentionally influence data, please return your forms to the main office. Forms will be collected by office personnel and kept locked in that location until after grades are turned in for the trimester. At that time I will access the forms and use the data only from those whose permission I have received, omitting those who have not consented.
If you are interested in having your child participate in this study, please complete the attached form and return it to me by September 11th, 2009. If you have any questions, please feel free to contact me at sf12bps@birmingham.k12.mi.us. Questions regarding the thesis project can also be directed to Dr. Merle Heidemann at heidema2@msu.edu. If you have any questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this research study, you may contact, anonymously if you wish, the Michigan State University Human Research Protection Program at 517-355-2180, FAX 517-432-4503, or e-mail irb@msu.edu, or regular mail at: 202 Olds Hall, MSU, East Lansing, MI 48824.

Sincerely,
Sara Fetsco
Physics Teacher
Seaholm High School

This consent form was approved by the Social Science/Behavioral/Education Institutional Review Board (SIRB) at Michigan State University. Approved 09/01/09 – valid through 08/31/10. This version supersedes all previous versions. IRB# 09-687.

Please fill out the following consent information:

I voluntarily agree to have ____ participate in this study. (print student name)

Please check all that apply:

Data:

__________ I give Ms Fetsco permission to use data generated from my child's work in this class for her thesis project. All data from my child shall remain confidential.

__________ I do not wish to have my child's work used in this thesis project. I acknowledge that my child's work will be graded in the same manner regardless of their participation.

Photography:

__________ I give Ms Fetsco permission to use pictures of my child during her work on this thesis project. My child will not be identified in these mediums.

__________ I do not wish to have my child's picture used at any time during this thesis project.

Signatures:

____ ________________________

(Parent/Guardian Signature) (Date)

I voluntarily agree to participate in this thesis project.

____ ________________________

(Student Signature) (Date)

*****Important*****

Return this form to the main office.

This consent form was approved by the Social Science/Behavioral/Education Institutional Review Board (SIRB) at Michigan State University. Approved 09/01/09 – valid through 08/31/10. This version supersedes all previous versions. IRB# 09-687.

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