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COMPARATIVE STUDY USING TECHNOLOGY VS TRADITIONAL LEARNING IN HIGH SCHOOL CONCEPTUAL PHYSICS

By

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ABSTRACT

COMPARATIVE STUDY USING TECHNOLOGY VS TRADITIONAL LEARNING IN HIGH SCHOOL CONCEPTUAL PHYSICS

By

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This study compared high school conceptual level physics students' progress on a pretest and post-test using two different teaching methods for laboratories and demonstrations in the unit on vectors and projectile motion. Using both teaching methods, the study also evaluated how students achieved based on gender. For two weeks, students in the vector or projectile motion control group were given traditional laboratories and demonstrations. The experimental group for each was given laboratories and demonstrations, using technology in the form of graphing calculators and video laserdiscs. The statistics included finding the means and standard deviations and applying the Wilks' Lambda test on the separated pretest and post-test vector and projectile motion questions. When comparing the control with the experimental group statistically, the vector experimental group performed better than the control group. On the other hand, analysis of the projectile motion part of the study revealed no statistical differences between the control and the experimental groups. In addition, when comparing gender, there was no statistically significant difference between female and male students. Moreover, there was no statistical significance between group and gender. Overall, both group and gender analysis showed improved scores from pretest to post-test. From this study, technology in the form of graphing calculators and videolaser disc had an enhanced effect on student achievement in learning only the topic of vectors. On the topic of projectile motion, the experimental and control groups did not differ significantly from pretest to post-test.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EVALUATION

Vector Statistical Graphs

Projectile Motion Statistical Graphs

APPENDIX A (Control Group Labs—Vector and Projectile Motion)

Vector Addition Lab 2

Projectile Motion Graphing Calculator Check Program for Bull's eye lab (BALLCUP) Run Sample

Projectile Motion Graphing Calculator Check Program for Softball Throw Lab (PROJMOT) Run Sample

APPENDIX B (Experimental Group Labs—Vector and Projectile Motion)

INTRODUCTION

STATEMENT OF PROBLEM AND RATIONALE FOR STUDY

Meetings in physics education and the advertisements on the pages of *The Physics Teacher*, show that the use of technology in physics education is quite evident. Many educators have touted using graphing calculators, computer simulation programs and laboratories via computer or calculator units with probes (Thornton, 1990; Taylor, 1995; Stump, 1995; Squire, 1987; Phillips, 1999; Nicol, 1997; Krieger, 1990; Flynn, 1994; Embse, 1990).

I have read how technology increases cooperative learning (Thornton, 1990), critical thinking (Krieger, 1990; Engelhardt, 1993), and motivates students through hands-on experiments (Squire, 1987; Phillips, 1999; Thornton, 1990). Can technology make students more active learners and learn at a deeper level?

This technology could be in the form of microcomputers, TV, radio, video camcorders, audio sounding, graphing calculators, MBL or CBL units (Microcomputer Based Laboratories, MBL, or Calculator Based Laboratories, CBL), and video laser discs. For my unit, technology was in the form of graphing calculators and a video laserdisc player. Because microcomputers and MBL or CBL units were not available to me, the mathematics department let me use their ten TI 83 (Texas Instrument) graphing calculators. I also used the science department's video laserdisc player. It allowed students to view parts of two physics laserdiscs: *Physics At Work* and *Cinema Classics*. During the summer of 1997, the research for this unit was done at *Michigan State University* with the intent of my unit being based on microcomputers along with MBL or

CBL units with graphing calculators. Moreover, I even had Pam Hartman at *Texas Instrument* setup a workshop in the fall at another school to gain experience using CBL units. The workshop was a success; however, the computers never showed at my school and CBL units were not available for the study. So, the ten graphing calculators and videolaser disc player had to suffice.

The unit topic was on vector and projectile motion because I wanted to learn more about them as well as learn how technology could be utilized effectively in physics education. Moreover, I chose vectors because I wanted to determine if I should expand or reduce teaching vectors based upon my research findings. In addition, with projectile motion, I wanted to learn some alternative labs and demonstrations. The topic of vector and projectile motion also requires a lot of constructing, calculating, and visualizing. I thought technology could address all three of those concerns.

This work required a literature search on laboratories and demonstrations that utilized technology in learning the conceptual physics, particularly vectors and projectile motion. I also critiqued a software program called *Interactive Physics*, which had some vector and projectile motion simulations. In addition, a colleague and I, modified or developed vector and projectile motion programs on TI-81 and TI-82 graphing calculators.

Lastly, research focused on physics pedagogy topics: active learning techniques, novice vs expert, student misconceptions, and the constructivist approach in science education.

LITERATURE REVIEW

Many physics teachers want their students to be more active learners. Arnold Arons, a past president of the Association of Advancement of Physics Teachers (AAPT), probed students with questions during lectures and laboratories guided by what he referred to as "insightful inquiry" or "guiding inquiry." Another researcher, David Pinkerton used what he refers to as "Active Mental Processing (AMP) Journal" to help students become more active learners. Students were graded by the following: notes of the day, question of the day and application of the day. His TEST group that covered one semester of introductory physics at the high school level showed improved scores on a posttest compared to those taught prior to AMP. (Pinkerton, 1996). "The Mastery Process" was another approach to students becoming more active learners developed by Horace (Rog) Lucido (1992). This consisted of weekly packet evaluations, along with teacher/student interactions and the mastery conference with the student to assess their grade. I incorporated some of the elements of these active mental process techniques in my unit.

The merits of using technology, primarily using computers and graphing calculators, at the university and secondary level, had been documented in introductory physics courses. Computers, along with other forms of technology, had been used to help student motivation, problem-solving, critical thinking and develop understanding of certain physics topics. Andrea diSessa contends that computers (technology in general) will "revolutionize the way we think about thinking and the way we deal with learning," once we get beyond just getting them into the schools (1987). David Squires, believes a new way of thinking or learning could be the use of computer software that adheres to the constructivist approach. In his paper, he reviewed the traditional or "conventional" approach, where learning is done in three phases: "formal presentation of prescribed information by teacher exposition; verification of the information by closed practical work; and practice of material presented in the first two phases through written exercises." (Squires, 1987)

Moreover, he along with others (Hestenes, et al., 1992; Ibrahim and Hestenes, 1985; Larkin, et al. 1980; Mestre and Touger, 1989; Van Heuvelen, 1991), feel that there is a need to have students progress from a novice to an expert level of thinking like a physicist. The goal of Piaget's constructivist theory for science education is the same. This may be done by first assessing what is some of the naïve or novice thinking in physics. Then one would try to confront these misconceptions and try to change them. However, John Clement (1982), points out that students have a stable alternative view or misconception of many concepts. These misconceptions are "highly resistant to change…" It takes creative ways to change them. Squires (1987) seems to indicate that technology could be our saving grace or one creative way to get students to actively learn physics and help confront some misconceptions.

In 1993-94, *North Carolina State University* sent out surveys to 3000 high school teachers in the U.S., which obtained information about hardware, software and teaching styles (Beichner, 1995). It revealed that "the typical classroom had between 6 to 7 computers. Technology, in the form of computers were used an average of 1.6 times per week, and occupied 73% of the classroom time when used." Teachers thought computers allowed for more depth of coverage, allowed for new topics to be introduced, and allowed students chances for repetition. The responses were mixed as to whether time was saved in teaching topics in mechanics. Teachers helped students in graphing techniques which allowed the students to analyze their graph at a higher level (Beichner, 1995). Other studies using spreadsheet software (Krieger, 1990; Engelhardt, 1993) indicate the same benefits.

Also, Ron Thornton at *Tufts University*, adds that laboratories using computers (microcomputer based laboratories or MBL) "...allow students to take an active role in their learning and encourage them to construct physical knowledge from observation of the physical world." His study, based upon pretest and posttest observations, showed that MBL format classes improved scores when compared with college lecture style format in learning basic kinematics.

However, besides the obvious issue of cost, the need for professional development, and curricular adjustment, William J. Leonard points out that an unacceptable error can arise because the programmer did not understand the mathematics or physics involved or the calculations. For instance, having a timer collect data with a lot of significant digits doesn't mean that the results are more accurate. Students believe this to be true. Finally, students should be able to manually run the experiment and not "blindly" trust the software. We should avoid the "black box" scenario, where no one understands how the numbers were generated and/or calculated (Leonard, 1997). During the summer of 1996 Physics for Teachers course, we encountered difficulty in understanding how a photogate timer that was controlled by a software program kept time in the determining the value of "g" (g is the symbol for the acceleration due to gravity). My lab partner and I could have accepted the values, but we didn't. We tried to analyze how the software program was determining times it generated. Ultimately, my lab partner and I, along with the lab instructor, determined there was a software problem in determining the times, which affected the "g" value.

What happens if your school budget does not allow for microcomputer based laboratories? The alternative is to obtain graphing calculators and connect them to sensor probes. These are referred to as calculator based laboratory (CBL) units.

These units allow students to extend the physics lab beyond the classroom's four walls. Some educators have used these units in amusement parks (Escobar, 1990; Taylor, 1994) and on playgrounds (Taylor, et al. 1995). These probes can make "...10,000 measurements per second...500 points can be stored" for five channels simultaneously. They are cheaper than the probes and unit used with a microcomputer. The programs for various labs can now be downloaded from the Texas Instrument web-site for CBLs (http://www.ti.com/calc/docs/cbl.htm). Moreover, if you have access to microcomputers, then you can link them to the CBL and analyze the data in a spreadsheet program or create reports in a word-processing program (Taylor, et al. 1995). Most articles published regarding CBLs have been anecdotal and have not been researched as extensively as Microcomputer Based Laboratories. For example, Richard Taylor points out that he used them to collect data in the playground. He did not compare it to a traditional lab. Likewise, Barbara Pecori (1998), Thomas Moses (1998), and Dan Stump (1995) just mention how they use CBLs or just the graphing calculators alone in learning topics like electricity, waves, and mechanics. None of them did a statistical comparison of teaching methods using CBLs or graphing calculators vs traditional teaching methods.

Moreover, I have not seen any studies comparing the effectiveness of using technology (i.e., graphing calculators) in conceptual level high school physics. To do a rigorous comparison, I chose teaching with technology vs traditional teaching.

What happens if you still cannot afford the graphing calculators and the CBL units with probes? Then graphing calculators alone can be utilized along with existing labs or can be used to generate labs and activities to learn physics concepts.

Many articles describe, some mentioned above, the use of graphing calculators in physics education. These calculators have been used to represent two-dimensional motion plots either using parametric equations or programming the calculator (Brueningsen and Bower, 1995; Stump, 1995; Vonder Embse, 1990). Moreover, parametric equations have been used to calculate the planetary motion around the sun and to understand circular functions in trigonometry (Cieply, 1993; Franklin and Waits, 1989). In addition, graphing calculators were central to teachers learning physics of collisions, oscillations, and two-dimensional analysis at *Michigan State University* in a summer program for teachers wanting to learn more about physics. (Stump, 1995). Finally, Dennis Phillips (1999) provided two additional examples of using only the graphing calculator in understanding blackbody radiation and Rutherford scattering without making comparisons to other teaching methods.

Unlike the articles describing Calculator Based Physics Laboratories articles, the use of only graphing calculator effectiveness has been well documented in mathematics education (Dunham, 1994; http://www.ti.com/calc/docs/research-b.htm). However, Carol Williams from *Pepperdine University*, pointed out their ineffectiveness when many students with graphing calculators failed to show work, lack the confidence to use them for multi-line problems or did not know how to use parentheses correctly, and did not know how to scale graphs (window and range). (1993)

Finally, another component of this research involved the use of a video laserdisc. Many articles report their use in elementary and middle school level classes. Mary Ellen Fitzhenry, a history teacher says, "Laserdisc technology has greatly improved my students' interest level." While Glenn Gurley, a science teacher indicates "... students listening to [video laserdisc] presentations have also become more attentive and ask relevant questions." Certainly, lots of teachers use the video laserdisc for reinforcement of lectures and/or to introduce a topic (Carole Beckwith ,http://www.pioneerusa.com/txt/teachq&a.html , 1999).

Therefore, a rigorous comparison of technology vs traditional teaching methods, which included videolaser disc technology was sorely needed at the high school level.

DEMOGRAPHICS

School Demographics

The high school population where the study took place in 1998-99 was 1,487 and had the following ethnic breakdown: 1.2% Native American; 23.9% African American; 7.1% Asian American; 16.6% Hispanic American; 51.2% European American. The gender population for the school was 51.0% males and 49.0% females. The demographics were for an urban school.

Study Demographics

The study was based upon on 65 students, consisting of primarily 11th and 12th graders and two 10th graders. The following was the ethnic breakdown: 1.5% Native American; 6.1% African American; 10.8% Asian American; 12.3% Hispanic American; 69.3% European American. The study was also evaluated in part on gender, the percentages were 51% males and 49% females. The study's ethnic demographics did not reflect the school's ethnic demographics. However, the gender demographics were the same. Three classes were used for the study.

Hour	Time		Student Number
1st	7:45 a.m. to 8:50 a.m.		19 (9 females; 10 males)
3rd	10:05 a.m. to 11:00 a.m.		18 (11 females; 7 males)
5th	12:05 p.m. to 1:00 p.m.		28 (12 females; 16 males)
		Total	65 (32 females; 33 males)

IMPLEMENTATION OF UNIT

Overview

This unit was taught in the first semester towards the beginning of the second marking period, which is nine weeks. Prior to this unit on vectors and projectile motion, we discussed Newton's three laws of motion; the next unit of study would be on momentum.

The unit was four weeks long, with two weeks on vectors and two weeks on projectile motion. For the vector part of the unit, 1^{st} and 3^{rd} hour served as the control (38 students) and 5^{th} hour (27 students) was the experimental group. For the projectile motions part of the unit, 1^{st} and 3^{rd} hour served as the experimental group and 5^{th} hour served as the control. This switching was to establish a control for the unit and to allow all students to be exposed to the technology teaching methods.

Both the control and the experimental groups were asked to take notes and answer conceptual questions from the classroom text, Paul Hewitt's *Conceptual Physics*, along with question and answer problems and supplemental activity assignments. Finally, both groups were given the same pretest, posttest and concept map test. The difference between the control and experimental groups were the labs and the demonstrations. Both groups were given two labs and had three demos, but varied in format.

The control group labs for vectors pertained to understanding vector resultant and components using conventional classroom techniques. This consisted of using half and full meter sticks for one lab and using force tables for the other one (Appendix A-I and A-II). The experimental group utilized technology in the form of graphing calculator programs designed to understand vector components and resultant. (Appendix B-I and B-II)

The control group labs for projectile motion learned projectile motion by going outside and using a softball to determine projectile range, time, height, and angle. They also conducted a lab where a bearing was allowed to roll down an incline plane to land into a container, fast-food ketchup container (see Appendix A-III and A-IV). Both control labs were a hands-on approach. The experimental group used graphing calculators to understand projectile motion utilizing parametric equations for the first lab. Using graphing calculators, the second lab consisted of finding the time, range, and height of a projectile when the initial velocity and angle are known (see Appendix B-III and B-IV).

Tables 1—4 provide an overview of the four weeks on instruction for both the control and the experimental group.

TABLE 1

(Week One Lesson Plan)

Date	Topic	Experimental	Control
11-9-98 (Week 1)	Vectors/Projectile Motion	• Pretest • Started Notes	• Pretest • Started Notes
11-10-98	Vectors	• Worked on Notes from Conceptual Physics • Small groups to view videolaser disc demo (Introduce vectors and define, adding vectors) Answer questions in lab notebook	• Worked on Notes from Conceptual Physics • Vector Cut Out Activity (Introduce vectors and define, adding vectors) Write up activity in lab notebook
11-11-98	Vectors	• Worked on vector questions from Conceptual Physics • Work on videolaser disc activities	• Worked on vector questions from Conceptual Physics • Work on vector cut out activity
11-12-98	Vectors	• Go over selected assigned questions • Introduce graphing calculators. • Start Vector Lab 1 using VECTRES (program finds resultant vector when two component vectors are entered)	• Go over selected assigned questions • Start Vector Addition Lab (lab focuses on two ways to add vectors using meter and half meter sticks and scaling techniques)
11-13-98	Vectors	• Collect Notes and Questions • Finish Vector Lab 1 and collect lab notebooks	• Collect Notes and Questions • Finish Addition Lab and collect lab notebooks

TABLE 2
(Week Two Lesson Plan)

Date	Topic	Experimental	Control
11-16-98 (Week 2)	Vectors	• Return notes and questions and lab reports • Vector Lab 2 using VECTCOMP (allows students to enter two or more vectors find the resultant vector)	• Return notes and questions and lab reports • Potatoes and Rope Demo (shows resultant and components vectors) • Addition of Force Vectors Lab
11-17-98	Vectors	• Finish Vector Lab 2 • Compare the two labs	• Finish Addition of Force Vector Lab • Compare the two labs
11-18-98	Vectors	• Q & A 1 (Problems using a protractor and a ruler to find a resultant by parallelogram and head-to-tail methods) and collect • Small groups and review videolaser disc from week 1 check answers	• Q & A 1 (Problems using a protractor and a ruler to find a resultant by parallelogram and head-to-tail methods) and collect • Review vector terminology and concepts
11-19-98	Vectors	• Pass back Q & A 1 and discuss • Concept Development 6-1 (CD 6-1 is a review of vectors)	• Same as experimental
11-20-98	Vectors	• Quiz on vectors • Worked on projectile questions from Conceptual Physics	• Quiz on vectors • Worked on projectile questions from Conceptual Physics

TABLE 3
(Week Three Lesson Plan)

Date	Topic	Experimental	Control
11-23-98 (Week 3)	Projectile Motion	• Pass back quizzes • Go over selected assigned problems • Small groups using videolaser disc demo (2-Dimensional Motion: predict which object will hit the ground first, horizontal or vertical) • Projectile Motion overview	• Pass back quizzes • Go over selected assigned problems • 2-Dimensional Motion (predict which object will hit the ground first, horizontal or vertical) • Projectile Motion overview
11-24-98	Projectile Motion	• Projectile Motion Lab 1 (Baseball Problem using parametric equations, helps students introduce what equations are involved in projectile motion, and looks at variables) • Finish 2-Demo on video laserdisc	• Projectile Motion Lab 1 (Bulls eye, helps students introduce what equations are involved for projectile motion, and looks at variables)
11-25-98	Projectile Motion	• Finish up Projectile Motion Lab 1 • Go over parts of Concept Development 6-2 (looks at objects thrown off a cliff)	• same as experimental
11-26-98	Projectile Motion	• Collect CD 6-2 • Videolaser demo (Monkey shoot, looks at when objects fall together, they hit together)	• Collect CD 6-2 • Monkey shoot demo (hand out paper to follow along)

TABLE 3 cont.

11-27-98	Projectile Motion	• Return CD 6-2 and lab reports • Videolaser demo (Snowmobile and flare to show parabolic) • Go over parts of Concept Development 6-3	• Return CD 6-2 and lab reports • Hall cart demo • Go over parts of Concept Development 6-3

TABLE 4
(Week Four Lesson Plan)

Date	Topic	Experimental	Control
11-30-98 (Week 4)	Projectile Motion	• Collect CD 6-3 • Projectile Motion Lab 2 (using graphing calculator to determine the range, time, and height when the initial velocity and angle are entered)	• Collect CD 6-3 • Projectile Motion Lab 2 (Softball toss outside to determine the angle, initial velocity, and height when range and time are measured)
12-1-98	Projectile Motion	• Return CD 6-3 • Finish up Projectile Motion Lab 2 and collect	• Same as experimental
12-2-98	Projectile Motion	• Return Projectile Motion Lab 2 • Go over parts of Q & A 2 (Problems in calculations)	• Same as experimental
12-3-98	Projectile Motion	• Go over concerns on Q & A 2 • Concept Map Review	• Go over concerns on Q & A 2 • Concept Map Review
12-4-98	Vectors/Projectile Motion	• Collect Q & A 2 and Concept Map Review • Posttest	• Collect Q & A 2 and Concept Map Review • Posttest

Below are overviews of each of the labs for both the control and experimental group, an overview of the demos for both groups, and an overview of the pre/posttest format and design.

Vector Control Lab 1

For the first control group lab, the Vector Addition Lab (Appendix A-I) had three parts. The first part was designed for students to find the resultant vector from two component vectors with either two one meter sticks; one meter and one half meter stick; or two half meter sticks. Once students constructed their resultant and components on the lab table, they then had to scale it down to draw in their lab notebook for their lab report. For direction, students were told North would be zero degree. This is what is used in experimental vector algebra.

The second part of the lab was the reverse, where a resultant vector, either one-meter stick or one half-meter stick, was placed at some angle. Then the component vectors were determined by using the parallelogram method described in the textbook. I gave a short discussion on scale factor: what is it, and why is it used. Most students that had chemistry or understood their algebra had no problems with scale factors, since they were just ratios.

The third part consisted of creating zigzag patterns, where one-meter and two half-meter sticks were used, and finding their sum. This could be done either by head-to-tail or geometric and analytic method. Most students had no difficulty with the head-to-tail or geometric method of just measuring out the resultant or sum of the vectors. However, I had to work out a problem on the board for the analytical method (adding all the x-components and y-components and using the Pythagorean theorem was difficult at the conceptual level physics) for solving the resultant vectors when more than two vectors are involved.

Question number 5 from the lab, explaining errors, was left blank by some even though we went over it prior to turning in lab notebooks. All students were done collecting data the first day, but some students needed the next day for help on calculations and answering questions. Overall, I thought the lab went well.

Vector Control Lab 2

Another control lab was the Equilibrium Lab, which was based upon the Addition of Force Vectors Lab from the laboratory book for *Merrill Physics* (see Appendix A-II for copy of lab and teacher's notes). We used method 1, which involved using force tables and spring scales. I had students make sure the ring was centered. This lab utilized some old force tables that used chain links that measured in grams. I had students convert the grams to dynes. We should have converted to Newton's, but didn't. Some of the scales were not at zero and had to be adjusted.

The direct measurement part of the lab did not take long. For the angle, 0° was north or top of the round table. They were told to measure to the nearest degree.

Some students had difficulty with the calculations, because they were unfamiliar with cosine and sine. All of them have seen the Pythagorean Theorem that allows them to find the resultant force. Some students were amazed at how close their calculations were to their measurement of forces.

Projectile Motion Control Lab 1

This lab is a classic. Most introductory physics lab manuals include this or some variation of it. April Fowler had her class use dart guns taped to tables to hit a target on a wall (1996). Another physics teacher created his own ball launcher made of 2 x 4 lumber and three 12-inch rulers that was clamped onto a rolling cart (Beach, 1996).

For this lab, I modified the "Bulls Eye Laboratory" by Robinson (1992) (see Appendix A-III) using "hotwheel" tracks and PSSC 2-Dimensional apparatus that had a ruler attached to a metal ramp. The 2-D apparatus was clamped down and attached to the hotwheel track. Students took three timings, instead of one. They were instructed on using a plum bob to make sure the target was straight under. The majority of the students hit the mark the first time. After the lab, we talked about what would be some of the variables involved, i.e., height of ramp, height of table, distance of roll on table, etc. Students found this lab fun and exciting, especially those that hit the mark the first time.

To check a student's calculations, Brian Drobert, a *Michigan State University* intern, and I developed a program using the graphing calculator. Students were not given access to this program from either the control or experimental group. Appendix A-III has an example of student data and result of this program. This program was really nice for checking lab results. In the future, I probably will use the graphing calculator to show students what happens if we change certain data values or variables (i.e., changing "g" value, horizontal distance, ramp height, fall distance, and times).

Projectile Motion Control Lab 2

Appendix A-IV has a copy of the lab as well as teacher's notes. This was a fun lab for everyone. As Brancazio puts it, "one surefire way to make physics come alive in the classroom is to illustrate physical principles with examples from sports." (1985) After reading an article on *People demos* in *The Physics Teacher* that involved students participation inside and outside, I decided this lab would involve students going outside for a softball toss (1983). A worksheet from *Merrill Physics* (1995) was modified for class use. Both female and male students volunteered to throw a softball out on a football field for the lab. I had students timing total time in the air, students spotted and recorded the range. Then I had one student throw at different angles, where the time and range as well as angle were recorded. Once the data was obtained outside, we went into classroom to analyze them. Sample calculations were gone over in front of the class with an overhead. The only problem with this lab was the part of having one student throw at predetermined angles, which were not easy to control as revealed when we did the calculations.

Brian and I wrote a program to check student calculations (see Appendix A-IV for a sample run). In future labs, I will use this program to show students how the data was calculated and what the results would be if the variables or data changed.

Vector Experimental Lab 1

For this lab, students had to find the resultant vector from two component vectors by using a protractor and a graphing calculator program (see Appendix B-I for a sample run). Then students were asked to compare the accuracy of their diagrams. I thought it was interesting using the graphing calculator to check the results with the traditional labs, even though in reality it's the other way around. Also, students were asked to construct vectors based upon the graphing calculator's output.

Michael Harmon, from *Texas Instruments* had developed a vector program for TI 81 graphing calculator and posted it on the TI's web-site(1994). The program was nice but was limited to vectors from 0° to 90°. During the 1997 summer, Jeff Chorny, a fellow summer teacher researcher, and I modified the program to work for 0° to 360°. Also, the program did not allow a student to enter a negative number of vectors or just one vector, It would just repeat the first screen to ask for the number of vectors. This was to prevent students from being confused or frustrated. Most vector problems use positive magnitude and account for negative in the directional part of the vector.

Because there were only ten graphing calculators, I had students work in small groups of two to three. This also limited the program access to only the experimental group students. Also, it avoided the possible problem of the program not running on TI 85, 92, or other graphing calculators that some students had for their math classes. Also, down loading the programs allowed the students to not have to learn programming the TI calculator. This allowed students to get to the labs. However, if a student happened to erase the program or parts of the program, I was able to download it from my calculator or one of the other ten calculators with graph link cable. This did happen during the study, especially when students had to see the source code for the program though the edit program menu. Some did not know how to exit program properly and erased one or more line of code. In addition, I chose not to have students key in the program because of the time involved and the potential student and teacher frustration that would ensue.

Students thought this lab was easy and interesting. Many students' measurements were close to the calculated values. If students had difficulties, it was usually drawing the right direction from the program output and creating a data table that reflected the data.

Because the program had relatively few equations and students worked in small groups, the lab questions were not difficult to answer. Some students seemed to skip them altogether. This happens in the traditional labs as well. For a sample program run and additional teacher's notes (see Appendix B-1). Most students finished the lab in one day.

Vector Experimental Lab 2

This lab required students to work back from the resultant vector, to determine the component vectors that created it. This was done in a similar fashion as the experimental vector lab 1, where students recorded their vectors in a data table and diagramed the vectors in their lab notebooks.

This program was also developed in collaboration with Jeff Chorny, since there was no modifiable program from the TI web-site. Microcomputers were unavailable, the *Interactive Physics* software program that has vector demonstrations and simulations could have been used.

Generally, students did not have a problem with the program or lab. Some students needed help interpreting the output screen. They were not used to seeing the horizontal vector component labeled Vx and vertical component Vy. Also, if a student entered in a negative resultant vector, it would repeat the first screen to vector magnitude, since negative resultant vectors were not allowed for this program.

Also, this program was a check on the first program or method of finding a vector's resultant and components. There is a sample problem that shows the check of the first experimental vector lab 1 in Appendix B-II. Most students finished the lab in one day.

Projectile Motion Experimental Lab 1

This was quite an involved lab and challenging at the conceptual level. This lab used the parametric features of the graphing calculator. It required students to enter equations, and use the graphing features i.e., window, trace, and draw feature.

Before students broke up into their lab groups, we worked through a sample problem. This problem was based upon Chuck Vonder Embse's baseball problem of whether or not a hit ball will clear the wall of a baseball field. (Appendix B-III). Conversions from miles per hour to feet per second (Mr. Embse's problem used English units), keeping track of equations, window settings, and accounting for new variables, i.e., initial height the ball was thrown were concerns for the students.

First we talked about parametric equations, where a person can see three variables on the same graph. In our case, it was range (X), height (Y), and time (T). More importantly, parametric equations solved using graphing calculators allowed students to separate the horizontal component from the vertical component vector.

Parametric equations used to be very time consuming to learn in mathematics because of the paper and pencil graphing involved. The graphing calculators made parametric equations a lot easier to solve in mathematics because paper and pencil graphs were not required, although some teachers required paper and pencil graph for the first problem only (Cieply, 1982). In physics, the graphing calculator also helped solve projectile motion problems that can be solved with parametric equations (Embse, 1990; Flynn and Sumerix, 1994; Stump, 1995) and polar equations (Demana, 1990).

Then we went through a sample problem together on the overhead. (Appendix B-III)

Projectile Motion Experimental Lab 2

Students worked in groups found that the range, height, and time of flight of an object when g value, initial velocity and angle of flight were entered into the graphing calculator program. (Appendix B-IV has the lab, teacher's notes that includes a sample run)

The groups also answered questions from projectile motion program PROJYVST. The name is an abbreviation for a program that can find the path of a projectile (PROJ). The Y represents the height of a projectile and the T represents the projectile flight time. We wanted to add R for range; however, TI graphing calculator programming only allows for eight characters for a name.

Students were asked to graph and find the relationship between the initial angle and the range. Also, a graph to find relationship the maximum height and the angle was done by the students. This required the students to run the PROJYVST program several times and record their results in a data table. For this relationship between angle and range, the students had to keep the initial velocity constant and change the angle. Some students were surprised to find out that 45° was not the angle for maximum range even though their textbook said 45° was the angle for maximum range. Two articles in *The Physics Teacher* point out that 45° is the angle for maximum range when firing an object on a flat horizontal surface in the absence of friction (Brown, 1992; Inouye and Chong, 1992). Moreover, they point out that most projectiles are fired from some height, h, above the surface. Ron Brown then points out that "In this case, the angle launch for maximum horizontal travel will then become dependent on the height, h, and is in general less than 45°."

They were to graph and find the relationship between the maximum height and the angle and the relationship between maximum height and initial velocity. Students had to vary the initial angle and keep the initial velocity constant. This was opposite of what was asked of them before.

Finally, students graphed and determined the relationship between the angle and the time and the relationship between maximum height and time.

On the second day, I discussed the similarities of this lab with the previous lab that used parametric equations. Both labs found the same information through different means.

Overall, the lab was easy. However, one detraction was that all of the graphs were the same size on the screen, so that when a student entered an initial velocity of 20 m/s with varying angles (i.e., 20° graph looked like a 60° graph). In comparison, the 20° graph should have looked smaller than a 60° graph.

Vector and Projectile Motion Control Demos

The vector demo was based on one from *The Physics Teacher*, where students cut out and laminated vector arrows of all shapes and sizes to demonstrate vector addition and subtraction (Snyder and Faulstick, 1991). These authors indicated; "We'd draw pictures [of vectors] on the board and use all sorts of examples, ...students still seemed unable to grasp the vectors." Also, James Helmick had difficulty having students visualize vectors, so he created a mobile frame of reference made out of wood and paper arrow tips (1993). The students cut out various size vectors, and asked some questions to guide their activity (see Appendix C-I). The majority of the students found it beneficial to visualize and manipulate the vectors.

The potato and rope demo, illustrated and reinforced vector addition and subtraction and vector components and resultant vector. This demo was a modification of a problem from Hewitt and Merrill. In this problem, a person with a rope or chain tries to pull the rope or chain straight horizontally when a weight is suspended in middle. Students with heart or other physical problems did not participate. In one class ten students on each side could not pull the rope horizontally taught to lift the bag of potatoes. After the demo, students were asked questions about the force vectors involved and about the types of applications that related to the demonstration (see Appendix C-II).

The 2-Dimensional demonstration used a number of variations of showing the independence of horizontal and vertical motion. An example of a question related to this demo is: "At the instant a horizontally-held rifle is fired over a level range, a bullet held at the side of the rifle is released and drops to the ground. Which bullet—the one fired down-range or the one dropped from rest—strikes the ground first?" (Hewitt, 1992) Another variation of this demonstration is to use either washers or coins on a ruler that spin freely on a piece of wood nailed down; however, I chose to use the traditional 2-D launcher, which propels one bearing horizontally and drops another vertically (see Appendix C-III). Students had to listen very carefully for one or two hits on the floor. I do this demo on a ladder to allow students to hear and see both bearings hit at the same time. Students have a hard time with this. One or two will always think they heard two separate hits.

The monkey shoot illustrated the independence of horizontal and vertical motion. The setup had an electromagnet which held up a tin can with a painted monkey, hence, the name the monkey shoot. The electromagnet was turned off when a bearing broke a circuit coming out of the barrel. Because the bearing is going horizontally and the can is going vertically at the same time, they hit each other in mid-air. The question that is always asked is, "Where does one aim the gun to hit the monkey: above, at, or below?" A lot of students focus on the setup and demonstration more than the concept. (Appendix C-IV)

Vector and Projectile Motion Experimental Demos

Using the videolaser disc for demonstrations in small groups was a challenge. In the past, the videolaser disc was used to introduce to the whole class concepts, show video clips (i.e., bungee jumping, ripple tank demos, Tacoma Narrows Bridge Collapse, etc.), and review. (Appendix D-I has detailed teacher's notes)

This unit, I wanted students to be active in finding the topics and demonstrations. Since there was only one laserdisc player, I had students work in small groups of two to three. All groups were given a quick lesson on "how to use" the scanner and/or remote control, videolaser discs and TV monitor. Most students liked the big remote. However the scanner frustrated a lot of groups.

For this unit, we used two videolaser discs, *Physics At Work* and *Cinema Classics*. Groups cycled through using the videolaser disc, which was in front of the class; students were able to work on another assignment (see Table 1-4) in back in the lab area. All groups were given questions to answer before using the videolaser disc. Students were to go through the videolaser disc material without taking notes. The second time through they were to take notes after viewing the disc and answer questions. I got a lot of blank answers for the questions before the students used the videolaser disc, especially if they did not take notes and answer questions from the text prior to this activity. Students were hesitant at first in using the videolaser disc player. I had to remind groups to go and use the videolaser disc player when it was not in use.

The videolaser disc material should have simply reinforced their notes on vectors from the classroom text. Using the disc was also to help students who did not take notes from their textbook.

For the 2-Dimensional Motion Demos (Projectile Motion), students answered three questions prior to viewing the videolaser disc (see Appendix D-II for questions). Just like the vector section, students also were given questions after viewing the laserdisc. Moreover, they took notes describing how the demonstration was done and documented the purpose of the demonstration. Of the three demonstrations, the most misunderstood one was the snowmobile and flare. There were several shots of the snowmobile moving with the flare being launched at different positions of the snowmobile moving.

Students were prepared for the posttest by answering questions on constructing vectors with a ruler and protractor. We went over projectile motion calculations. Finally, to help students with concepts and terminology, a concept map was given the day before the posttest and gone over the day of the posttest (see Appendix E-I and E-II). The review was the same for both experimental and control groups.

EVALUATION

Overview

The pretest and posttest were the same and designed to have conceptual level, construction, and calculation questions (see Appendix E-III for pre/posttest). Open-ended or free response questions were not used to reduce the subjectivity in grading. There were a total of twenty questions, where twelve questions were vector related and eight questions were projectile type questions. The analysis was based upon separating the questions that relate to vectors from the questions on projectiles and finding their pretest and posttest means, respectively. Furthermore, the means and standard deviations were separated by group (control vs experimental), gender (all female students vs all male students; included both control and experimental group students), and then by group and gender. From the means, the variances were determined and utilized in repeated measures analysis of variance, the Wilks' Lambda test, the F test and the P value. The means and standard deviations are not directly involved in calculating the Wilks' Lambda test, the F test and the P value. Generally, the higher the F-value and a p-value of less than 0.05, the more confident the investigator is in rejecting the null hypothesis. The null hypothesis in this study was that all students should be able to learn at the same level regardless of teaching method used. Conversely, students learning via technology will perform better than those learning via traditional methods or worse.

The investigator focused on the p-value. Therefore, if the p-value was greater than 0.05, the null hypothesis was not rejected, regardless of the F-value. The F-value is just an indicator of the ratio of variance.

Table 1 and subsequent tables represent the statistical analysis for the unit. First the means and the standard deviations are provided for pretest and posttest for group, gender, and group and gender combined. The Wilks' Lambda test is one of the many standard multivariate tests done with statistical computer software programs (i.e., SPSS or SAS; SAS was used for this unit) that analyze the variances or eigenvalues. It is beyond the scope of this study to discuss the details of the formula for the Wilks' Lambda test (see Rao, 1952 for formula and meaning). The F value part of the Wilks' Lambda test is a ratio of the variance, where Num DF is the degrees of freedom for the numerator and Den DF is the degrees of freedom for the denominator. The F value is an estimation test and is not heavily weighted as compared to the next part. The Pr > F part of the Wilks' Lambda test is the last part and is known as the p value that is a proportionality test for the variances. If the p value is less than 0.05, the test or experimental value is significant. The F value may or may not be a large value ($F > 1.00$), which is also a good indicator of significance. All of the tests used in the study are widely accepted statistical analysis for life science and social science research studies involving multivariate analysis.

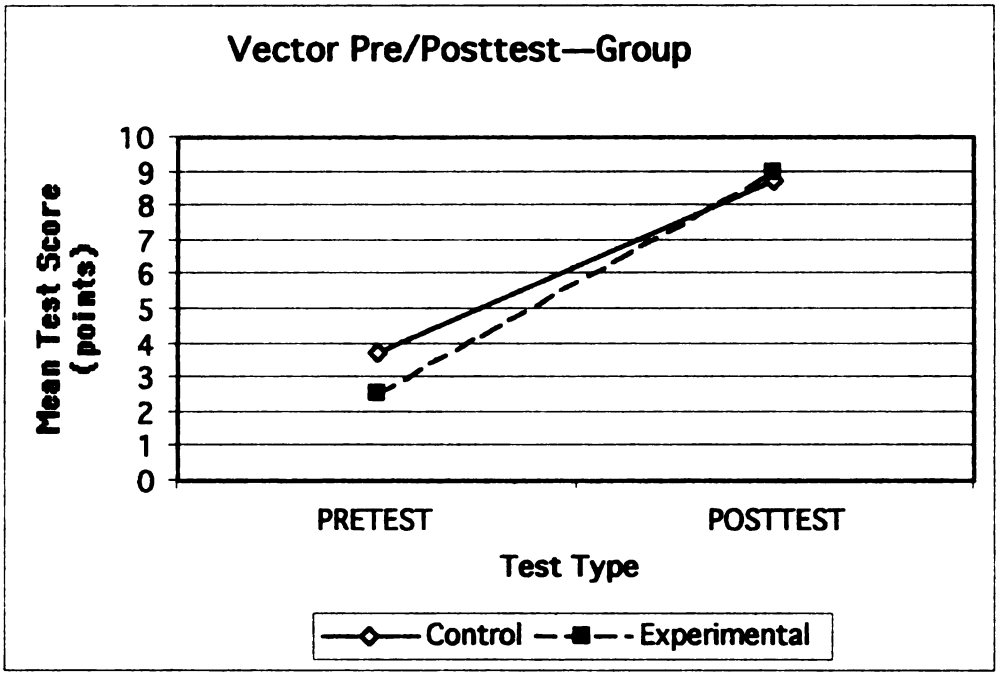
TABLE 1: VECTOR PRETEST/POSTTEST STATISTICS BY GROUP

C = CONTROL; E = EXPERIMENTAL; N = NUMBER OF STUDENTS;
SD = STANDARD DEVIATION

		------PRETEST-----		-----POSTTEST-----		
GROUP	N	Mean	SD	Mean		SD
C	37	3.76	1.57	8.76		2.12
E	28	2.57	1.51	8.96		2.18
Statistic		Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda		0.92739998	4.7753	1	61	0.0327

FIGURE 1

Pretest and Posttest mean scores by Group



Based upon the p value being 0.0327 (less than 0.05 is significant), the null hypothesis can be rejected. Hence, the experimental group out performed the control group in the vector part of the unit. Moreover, having a large F value also indicated significance. In Figure 1, a greater slope for the experimental than for the control supports the Wilks' Lambda test. Finally, Figure 1 shows a positive slope for both the experimental and control indicated improvement from pretest to posttest.

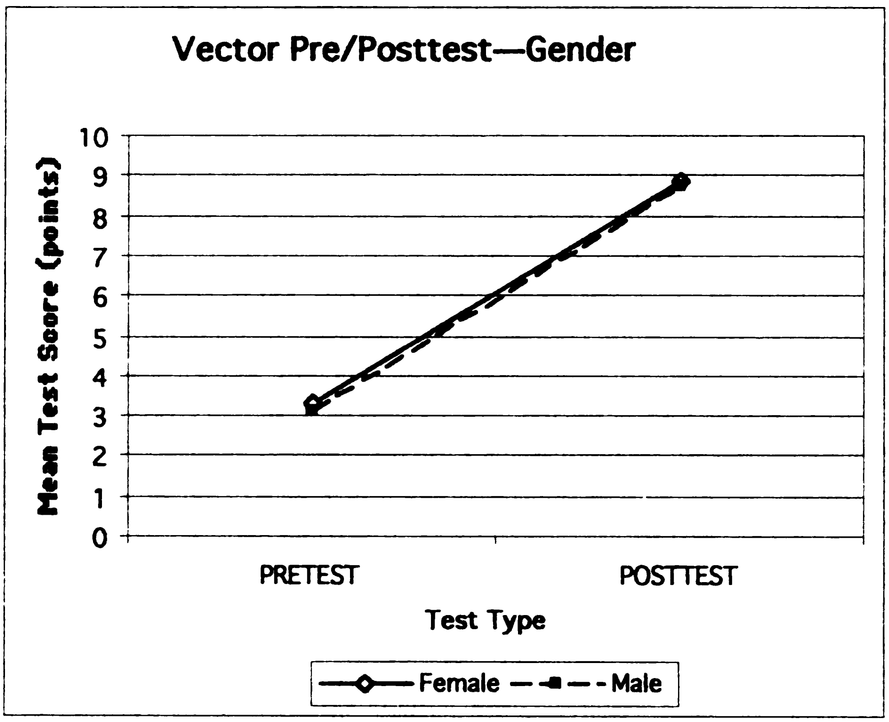
TABLE 2: VECTOR PRETEST/POSTTEST STATISTICS BY GENDER

N = NUMBER OF STUDENTS; SD = STANDARD DEVIATION;
M = MALE; F = FEMALE

		------PRETEST-----			----POSTTEST-----	
GENDER	N	Mean	SD		Mean	SD
F	32	3.34	1.84		8.90	2.13
M	33	3.14	1.54		8.79	2.17
Statistic		Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda		0.99914093	0.0524	1	61	0.8196

FIGURE 2

Vector Pretest and Posttest mean scores by Gender



Based upon the p value being 0.8196, the null hypothesis cannot be rejected. Hence, the female students performed about the same as the male students in the vector part of the unit. Figure 2 shows about the same slope for the female students and the male students, which supports the Wilks' Lambda test. Finally, a positive slope in Figure 2 for both genders indicated improvement from pretest to posttest.

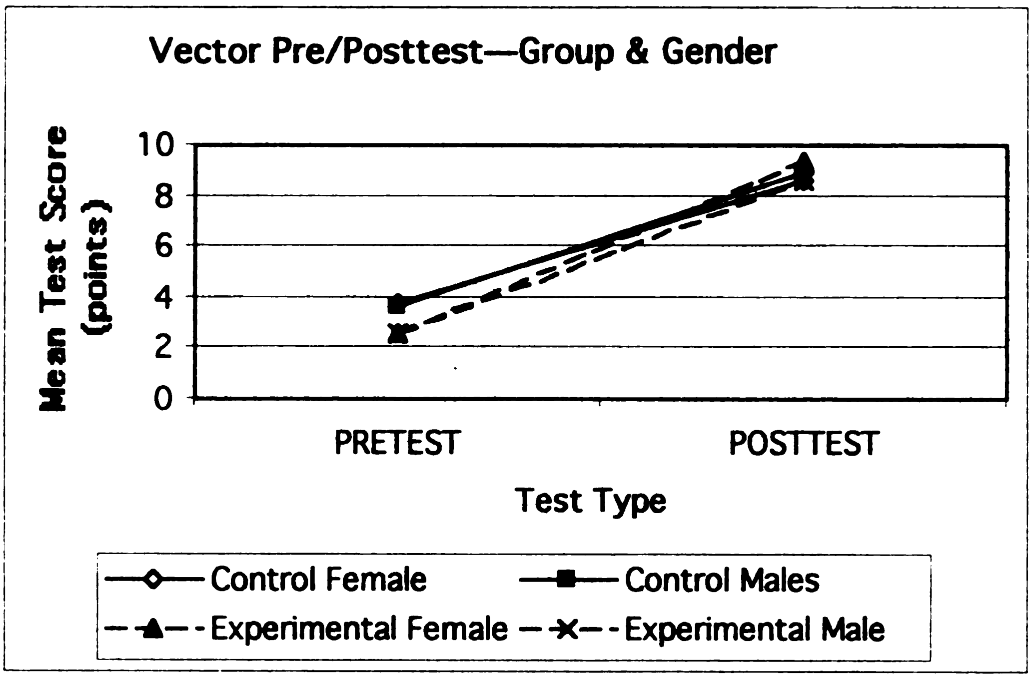
TABLE 3: VECTOR PRETEST/POSTTEST STATISTICS BY GROUP AND GENDER

C = CONTROL; E = EXPERIMENTAL; N = NUMBER OF STUDENTS;
SD = STANDARD DEVIATION; M = MALE; F = FEMALE

			------PRETEST-----		-----POSTTEST-----	
GROUP	GENDER	N	Mean	SD	Mean	SD
C	F	20	3.80	1.82	8.55	2.13
C	M	17	3.70	1.25	8.88	2.17
E	F	12	2.58	1.57	9.33	2.14
E	M	16	2.55	1.63	8.59	2.24
Statistic		Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda		0.99134151	0.5328	1	61	0.4682

FIGURE 3

Vector Pretest and Posttest mean scores by Group and Gender



Based upon the p value of 0.4682, there was no significance between group and gender. The null hypothesis cannot be rejected. This indicates that both the group and the gender effect did not agree on significance. Figure 3 shows the experimental female students having a different slope than the experimental male students, which shows the non-significance between gender and group.

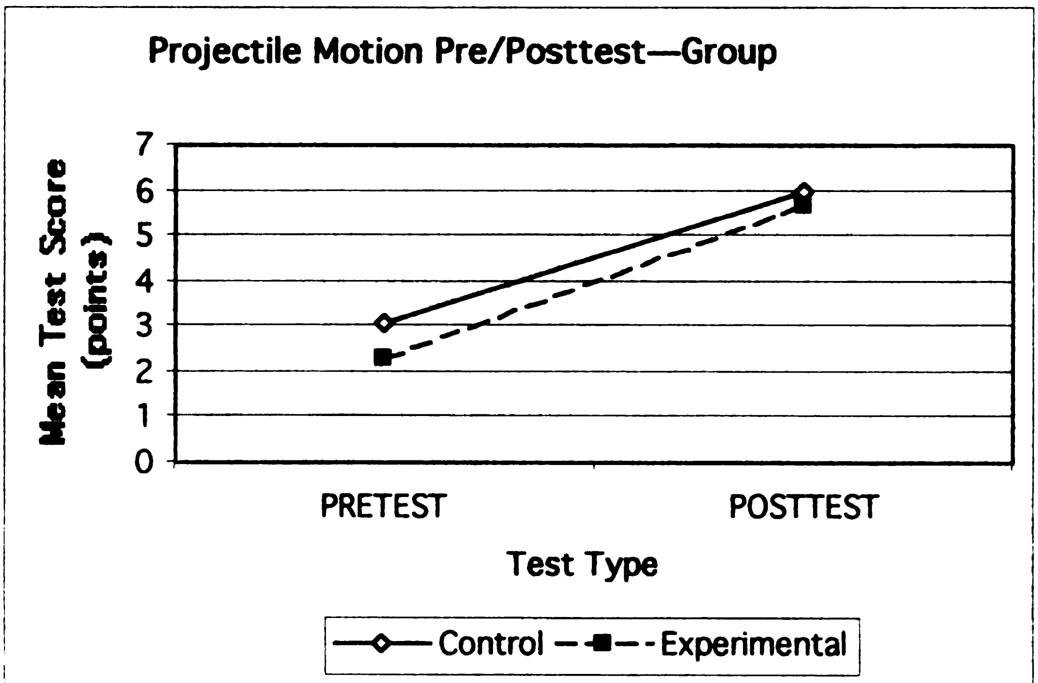
TABLE 4: PROJECTILE MOTION PRETEST/POSTTEST STATISTICS BY GROUP

C = CONTROL; E = EXPERIMENTAL; N = NUMBER OF STUDENTS;
SD = STANDARD DEVIATION

		------PRETEST-----		-----POSTTEST-----		
GROUP	N	Mean	SD	Mean		SD
C	37	3.08	1.59	6.00		1.49
E	28	2.32	1.35	5.86		1.67
Statistic		Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda		0.97648732	1.4688	1	61	0.2302

FIGURE 4

Projectile Pretest and Posttest mean scores by Group



Based upon the p value being 0.2302, the null hypothesis cannot be rejected. Hence, the experimental group performed about same as the control group in the projectile motion part of the unit even though the F value is greater than 1.00 (1.4688). In Figure 4, the slopes for the experimental and for the control, are the about the same as opposed to the slopes in Figure 1. Finally, Figure 4 shows a positive slope for both the experimental and control indicated improvement from pretest to posttest.

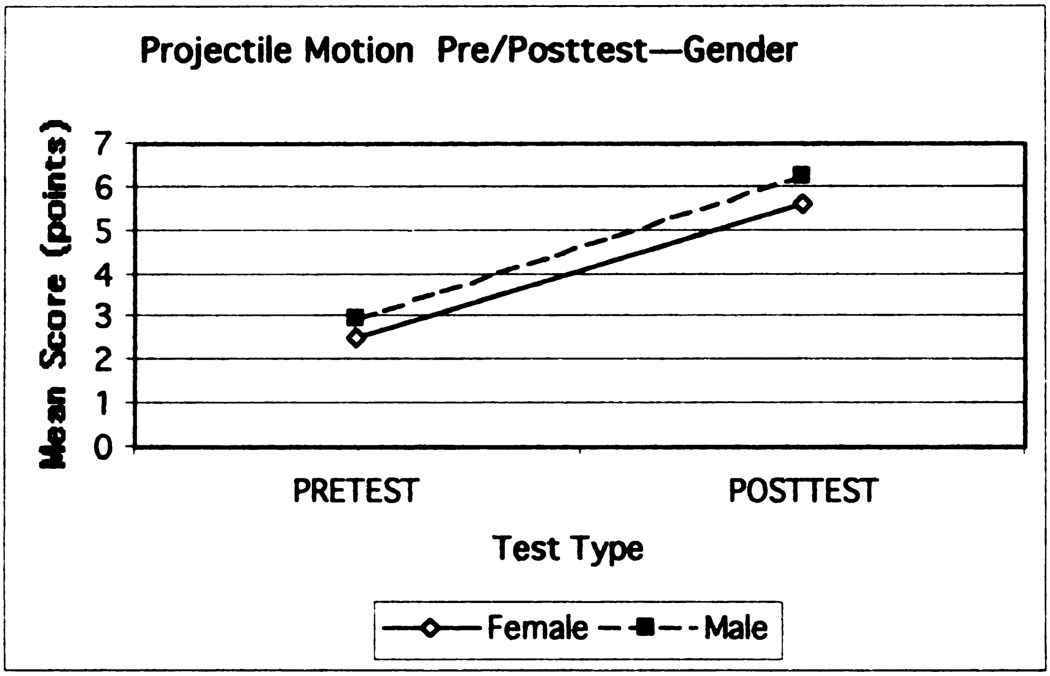
TABLE 5: PROJECTILE MOTION PRETEST/POSTTEST—GENDER

N = NUMBER OF STUDENTS; SD = STANDARD DEVIATION;
M = MALE; F = FEMALE

		-----PRETEST-----			----POSTTEST----	
GENDER	N	Mean	SD		Mean	SD
F	32	2.53	1.22		5.62	1.60
M	33	2.97	1.78		6.24	1.48
Statistic		Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda		0.99818235	0.1111	1	61	0.7401

FIGURE 5

Projectile Pretest and Posttest mean scores by Gender



Based upon the p value being 0.7401, the null hypothesis cannot be rejected. Hence, the female students performed about the same as the male students in the projectile motion part of the unit. Figure 5 shows about the same slope for the female students as the male students, which supports the Wilks' Lambda test. Finally, a positive slope in Figure 5 for both genders indicated improvement from pretest to posttest.

TABLE 6: PROJECTILE MOTION PRETEST/POSTTEST STATISTICS BY GROUP & GENDER

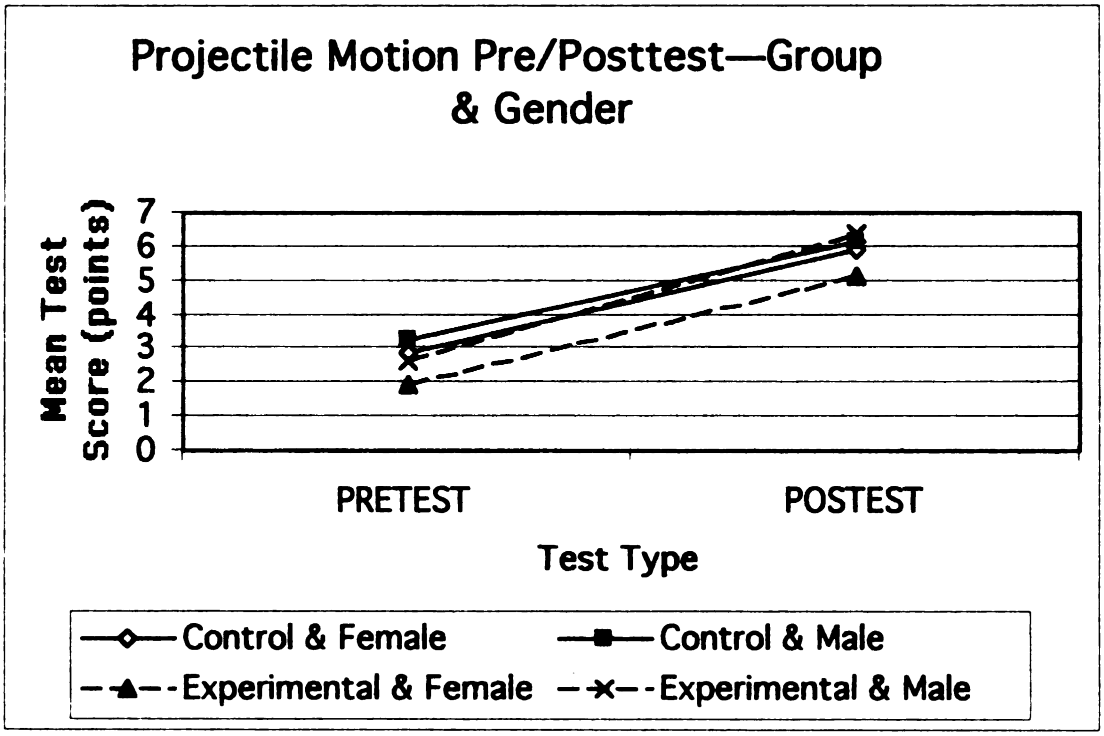
C = CONTROL; E = EXPERIMENTAL; N = NUMBER OF STUDENTS; SD = STANDARD DEVIATION; M = MALE; F = FEMALE

			------PRETEST-----		-----POSTTEST-----	
GROUP	GENDER	N	Mean	SD	Mean	SD
C	F	20	2.90	1.29	5.90	1.58
C	M	17	3.29	1.89	6.12	1.41
E	F	12	1.92	0.79	5.17	1.59
E	M	16	2.62	1.63	6.37	1.58

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.99210181	0.4856	1	61	0.4885

FIGURE 6

Projectile Motion Pretest and Posttest mean scores by Group and Gender



Based upon the p value of 0.4885, there was no significance between group and gender. The null hypothesis cannot be rejected. This indicates that both the group and the gender

effect did not agree on significance. Figure 6 shows the experimental female students having a different slope than the experimental male students, which shows the non-significance between gender and group.

DISCUSSION and CONCLUSION

Teaching a unit on vectors and projectiles was informative, challenging and fun at times. I learned a lot about physics education, and new labs and demonstrations and working with technology, in the form of graphing calculators and videolaser disc. The goal of this unit was to quantitatively compare student performance using two different teaching methods for labs and demonstrations: using technology, the graphing calculators (TI-83) and the video laserdisc, or using traditional conceptual physics format.

The analysis showed that the experimental group did improve over the control group from pretest to posttest on the vector part of the unit. All other tests proved to be not significant. Finally, both group and gender test revealed improvements from pretest to posttest. This means that the students in the projectile motion experimental group were not disadvantaged nor were the students in the vector control group.

Based upon the findings, the graphing calculator programs on vectors may have been easier to learn and understand or the control labs were not as easily understood. Using the videolaser disc may have been more effective for demonstrating or reinforcing vector concepts than the traditional demonstrations. Finally, the actual pretest/posttest may have not been reliable or designed effectively to test for the unit. Maybe I could have designed a test to utilize the *Mechanics Baseline Test* developed by David Hestenes and Malcolm Wells, which tested Newtonian concepts (1992). Another assessment test was the *Force Concept Inventory*, which tested on the same topics as the Mechanics Baseline Test (1992). Both are excellent tests and were used by some researchers to improve active learning and deeper understanding of physics concepts (Pinkerton, 1996; Novodvorsky, 1997), but most covered one semester of college level physics. My unit was only four weeks. Because of the time differences and how I usually design my test, I chose not to use the above mentioned tests. However, some of the concepts pertaining to my unit were covered on the pre/posttest.

This unit may have been improved many ways. One such way would be a student survey. This would be a way of finding out if students felt they learned more from the labs or demonstrations or both. Such a survey would have determined their likes and dislikes regarding the labs and demonstrations. This would help me improve for next year. Finally, I would like to find out what they thought about the TI graphing calculators and the video laserdisc likes and dislikes.

Using the programmable calculators had some limitations. The TI graphing calculator graphs for physics should show units both on their x and y-axis. Also, the graphs looked the same for the projectile experimental lab 2 regardless of angle used (see appendix B-II). That is, a small angle did not show a small curve relative to a larger angle.

The videolaser disc should have been designed so one would not have to take the disc out to view material on the other side. Also, the video audio part should not start out with multiple languages. A lot of the groups fumbled around to get only English audio, although some liked the Spanish option.

Future studies could include a student survey as well as use a different form of technology , CBLs (Calculator Based Laboratories) or MBLs (Microcomputer Based Laboratories), to compare with traditional labs and demonstrations at the conceptual physics level. Moreover, future studies could just focus on laboratories and not include videolaser disc demonstrations. Future studies could also use DVD or CD-ROM laboratories and/or demonstrations, instead of using a videolaser disc player. Finally, other future studies could evaluate the effectiveness of using the Internet in physics education for on-line labs and/or demos or long distance learning.

Technology is just a tool for learning physics. There is no doubt that different forms of technology will continue to appear in physics meetings and journals. Along with the new technologies will be the need for comparative studies like this one and others to determine their effectiveness in getting students more active in learning and understanding physics at a deeper level.

APPENDIX A-I

Vector Control Lab 1—Vector Addition Lab

Purpose: To learn how to construct resultant and components vectors using the parallelogram method and vector addition using the graphical or the analytical method.

Background: Write a paragraph or two about the concepts learned in this lab. Use your text or other resources for this section.

Materials: 2 one-meter sticks, 3 half-meter sticks, protractor, and metric ruler

Diagram: Make a sketch of one of your vector setup and label the materials used.

Procedure:

Part 1: Use combinations of two-meter sticks; one-meter and half-meter sticks; or two half-meter sticks to construct two components. Record your direct measurement vector magnitude and directions in the data and calculations section of lab (cm = 0.25 m). Determine the resultant vector by the head-to-tail method in your notebook. Record the resultant vector using the two methods.

Part 2:

Next use a one-meter stick as a resultant vector and find its associated components (0° is north). Record the direct measurement vector components and resultant in data and calculations section. Diagram the vectors in your lab notebook (use scale factor of1 cm = 0.25 m).

Part 3:

Finally, use one meter and two half-meter sticks to form a zigzag pattern (not a right triangle or one straight-line pattern). Use both the head-to-tail or geometric method and the analytic method. Make a diagram of your vectors in your lab notebook (use scale factor of1 cm = 0.25 m) and show work for any calculations and use correct units

Data and Calculations: (Displacement vectors measure to 0.001 m and 0.5°)

Part 1

Dx = ___________m at ______ Dy = ___________m at ______

D_A = ___________m at ______ (Method 1:_____________________)

D_B = ___________m at ______ (Method 2:_____________________)

Difference: $D_A - D_B$ = ___________m at ______ (Note: subtract the angles as well)

Part 2

Dx = ___________m at ______ Dy = ___________m at ______

D = ___________m at ______

Part 3 Show Work (include units)

D_1 = ___________m at ______

D_2 = ___________m at ______ D_R = ___________m at ______
(D_R is the resultant vector)

D_3 = ___________m at ______

Analysis: Write the following questions in laboratory notebook and write response in complete sentences.

Q1) Why is a scale factor important; provide three examples where scale factors are used in today's society; finally, what was your scale factor? *Ans. Diagramming physical events; maps, carpentry, architectural designing.*

Q2) Component vectors can only be what directions? *Ans. Components must be 0°, 90°, 180°, or 270°.*

Q3) When adding two or more vectors, describe two different ways to find the sum of these vectors? *Ans. Students should describe the head-to-tail method or graphical method or analytic method.*

Q4) In part one of the lab, which method did you think was more accurate? Explain. *Ans. Student answers will vary.*

Q 5) Explain what were some of your sources of error. *Ans. Some sources of error could be accuracy of reading measurements and angles, movement of meter stick during measurement, calculation error, chipped or warped meter stick, etc.*

Teacher's Notes:

This was an easy lab to setup. I was fortunate to have both meter sticks and half meter sticks. It's important that student are familiar with vector terminology. I had them take notes and answer some questions prior to lab day; other teachers may just want to have a prelab discussion on terms and vector addition methods. I did talk about scale factors in my prelab discussion and quickly reviewed terminology and methods.

Some students had difficulties with directions or vector angles. Some of the protractors were circular and some semi-circular. I also encouraged students to be creative for the three vector addition problem. For question 4, most students thought the method that they used was the most accurate way to add vectors. Some students had a hard time with question 5, I got some blank answers when you ask students to account for error. Overall, I thought the lab was effective.

APPENDIX A-II

Vector Control Lab 2—Equilibrium Lab

(Based upon *Addition of Force Vectors* by Kramer, 1995)

Purpose: Apply the laws of vector addition to resolve forces in equilibrium.

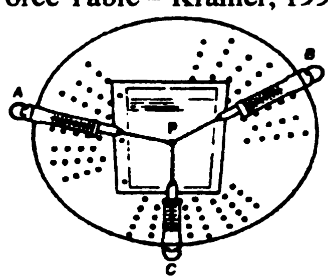
Background: Write a paragraph or two about the concepts learned in this lab. Use your text or other resources for this section.

Materials: Force table and 3 spring scales, protractor, metric ruler

Diagram:

Figure 1

Force Table—Kramer, 1995



Procedure:

1) Setup the apparatus so that the spring scales are in equilibrium (make sure the ring is centered with the post). (Figure 1 has Force Table setup) Check to see that each scale needle or bar is zero before attaching to table. If the scale reading is not zero, then you will need to add the needle value to the final reading. Attach spring scales to the force table so that each scale registers a force at approximately mid-range.

2) Place a piece of paper beneath the spring scales. Using a sharp pencil, mark several points along the line (the string) of action of each force. Trace the ring.

3) Remove the paper and, using the points that you marked, construct lines all the way to the edge of the paper and label A, B, and C, each representing the direction of force action for scales A, B, and C. Mark a point in the center of the traced ring.

4) Record the lengths, angles, and readings of each spring scale next to its corresponding line into your data table. Measure lengths to 0.1 cm and angles to the nearest degree.

Data and Calculations:

Vector	Resultant (cm)	Components				Force(dynes)
		Horizontal		Vertical		
		Length (cm)	θ	Length (cm)	θ	
A						
B						
C						

Calculate the following vectors:

$\vec{B}x = \vec{B}\cos\theta =$ ________ = ____ $\quad$ $\vec{C}x = \vec{C}\cos\theta =$ ________ = ____

$\vec{B}y = \vec{B}\sin\theta =$ ________ = ____ $\quad$ $\vec{C}y = \vec{C}\sin\theta =$ ________ = ____

$\vec{B} = \sqrt{\vec{B}x^2 + \vec{B}y^2} =$ ________ = ____ $\quad$ $\vec{C} = \sqrt{\vec{C}x^2 + \vec{C}y^2} =$ ________ = ____

$\vec{F}_A = (A_{mass}) x 980 cm/s^2 =$ ________ = ____

$\vec{F}_B = (B_{mass}) x 980 cm/s^2 =$ ________ = ____

$\vec{F}_C = (C_{mass}) x 980 cm/s^2 =$ ________ = ____

Note: A_{mass}, B_{mass}, and C_{mass} are read directly off the spring scale. The 980 cm/s^2 is the value of g for the cgs system.

Analysis: Write the answer to these questions in your lab notebook in complete sentences.

1) Write the algebraic notation for A, B, and C vector addition. *Ans.*

$$\vec{A} + \vec{B} = \vec{C}$$

2) Compare the magnitude and direction of the computed resultant force of A + B with the measured or known magnitude of force C. Explain your findings. Calculate the relative error in the magnitudes using force C as the reference value. *Ans. The resultant of A + B should be nearly equal to and opposite of C.*

3) Suppose that you had added B to C. What result would you expect?

   Ans. If B is added to C, the resultant should be the negative of the value of A.

4) What result would you expect if you added C to A?

5) Draw a vector representing the vector sum of A + B, the resultant. *Ans. The addition of C + B should give the same result as the addition of B + C + A. The resultant is zero.*

6) Explain some sources of error. *Ans. If the circle is not centered, an error in calculations will result; calculating incorrectly is a source of error; reading the scale wrong; if the measuring needle did not start at zero, etc.*

Teacher's Notes:

This lab was also an easy lab to setup. Some students will experience difficulties in the calculations. There may be error in reading the scale, zeroing the scale, or drawing the correct lines with the links in place. Students should be familiar with the trigonometric functions cosine and sine to understand how get the components. Otherwise the lab becomes a lesson in pushing buttons. Many of the students did not answer the questions correctly, even question 1 was missed a lot. A lot of the questions were simply just applying the commutative property of addition.

There were students with calculations close to their measurement. The direct measurements were easier for most students. Overall, this lab was harder to implement than the first control lab and harder to understand its meaning. The number of student questions and lab report scores reflected this.

APPENDIX A-III

Control Projectile Motion Lab 1—Bulls Eye Laboratory (Robinson, 1992)

Name ________________________________ Date ___________ Hour _________

Chapter 6 Vectors   Projectile Motion

Purpose

To investigate the independence of horizontal and vertical components of motion. To predict the landing point of a projectile.

Required Equipment/Supplies

Ramp or Hot Wheels track
0.5 inch (or larger) steel ball
empty ketchup container from fast food restaurant
meter stick
plumb line
stopwatch

Discussion

Imagine a universe without gravity. In this universe, if you tossed a rock in outer space, it would just keep going—forever. Because the rock was going at a constant speed, it would cover the same amount of distance in each second. The equation for distance traveled when motion is uniform is

$$d = vt$$

The speed is

$$v = d/t$$

Coming back to earth, what happens when you drop a rock? It falls to the ground and the distance it covers in each second increases. Gravity is constantly increasing its speed. The equation of the vertical distance d fallen after any time t is

$$d = 0.5\ gt^2$$

where g is the acceleration of gravity. The falling speed v after time t is

$$v = gt$$

What happens when you toss the rock sideways? The curved motion that results can be described as the combination of two straight-line motions: one vertical and the other horizontal. The vertical motion undergoes the acceleration due to gravity, while the horizontal motion does not. The secret to analyzing projectile motion is to keep two separate sets of "books": one that treats the horizontal motion according to

$$d = vt$$

and the other that treats the vertical motion according to

$$d = 0.5\ gt^2$$

Horizontal motion

- When thinking about how far, think about $d = vt$.
- When thinking about how fast, think about $v = d/t$.

Vertical motion

- When thinking about how far, think about $d = 0.5\ gt^2$.
- When thinking about how fast, think about $v = gt$.

Your goal in this experiment is to predict where a steel ball will land when released from a certain height on an incline. The final test of your measurements and computations will be to position an empty ketchup container can so that the ball lands in the container the first time!

Step 1: Assemble your ramp. Make it as sturdy as possible so the steel balls roll smoothly and reproducibly. The ramp should not sway or bend. The ball must leave the table horizontally. Make the horizontal part of the ramp at least 20 cm long. The vertical height of the ramp should be at least 30 cm.

Step 2: Use a stopwatch to measure the time it takes the ball to travel from the first moment it reaches the level of the table top to the time it leaves the table top. Divide this time interval into the horizontal distance on the ramp to find the horizontal speed. Release the ball from the same point (mark with tape) on the ramp for each of three runs. Do not permit the ball to strike the floor! Record the average horizontal speed of the three runs.

Horizontal speed = __________

Step 3: Using a plumb line and a string, measure the vertical distance h the ball must drop from the bottom end of the ramp in order to land in an empty ketchup container on the floor.

1. Should the height of the container be taken into account when measuring the vertical distance h? If so, make your measurements accordingly.

h = ______________

Step 4: Using the appropriate equation from the discussion, find the time t it takes the ball to fall from the bottom end of the ramp and land in the container. Write the equation that relates to h and t.

equation for vertical distance: = ____________________________

Show your work in the following space.

t = ___________

Predict the range. Step 5: The range is the horizontal distance of travel for a projectile.

Analysis

2. Compare the actual range of the ball with your predicted range. Compute the percentage error.

3. What may cause the ball to miss the target?

4. You probably noticed that the range of the ball increased in direct proportion to the speed at which it left the ramp. The speed depends on the release point of the ball on the ramp. What role do you think air resistance had in this experiment?

Teacher's Notes:

Students found this lab fun and exciting, especially those that hit the mark the first time. In order to obtain a reasonable value for horizontal speed, students took three timings and average. Also, students used a plum bob to make certain of target. Most students never heard of such a tool as a "plum bob." After the lab, we talked about what would be some of the variables involved, i.e., height of ramp, height of table, distance of roll on table, etc.

To check student calculations, Brian Drobert, a *Michigan State University* intern, and I developed a program using the graphing calculator. Students were not given access to this program from either the control or experimental group.

Below is an example of a student's data and screen shots:

value of g = 9.8 m/s^2;

horizontal distance (distance the ball rolled on lab bench) = 1.00 m

vertical distance (distance from the ramp to the floor) = 0.75 m

Time (Used to calculate the horizontal speed)

1.52s 1.56s 1.55s

Below are the screens for a sample student's data.

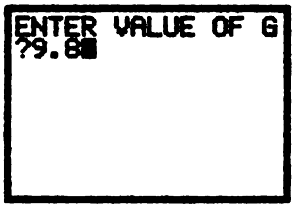


Figure 2

(g value)

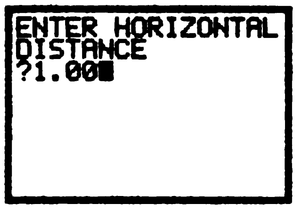


Figure 3

(Travel distance on table)

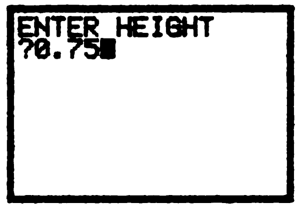


Figure 4

(Distance to the floor)

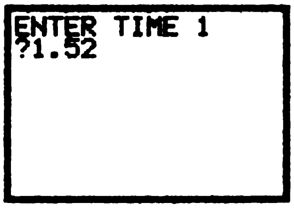


Figure 5

(1st Horizontal Time)

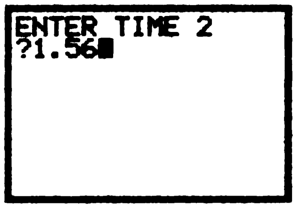


Figure 6

(2nd Horizontal Time)

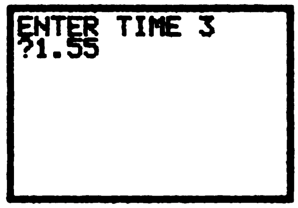


Figure 7

(3rd Horizontal Time)

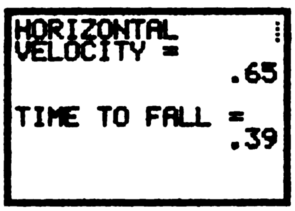


Figure 8

(Horizontal Speed and Fall Time)

Figure 9

(Distance to Hit Target)

This allowed me to check their precision on timing and to check calculations and rounding errors. Most of the students had collected sound data.

APPENDIX A-IV

Projectile Control Motion Lab 2—Softball Throw Laboratory
(Merrill, Lab Worksheet, p.11)

Name ____________________________________ Date ____________ Hour __________

Chapter 6 Vectors   Projectile Motion

The Softball Throw

Calculations

1. Determine the initial values of v_x for each throw.

2. Determine the initial value of v_y.

3. Draw a triangle as shown in your text. Record your value of v_x and v_y.

4. Use the Pythagorean Theorem to find the value of v_i.

Observation and Data

Trial	Range (m)	Time (s)	Vx (m/s)	Vy (m/s)	Vi (m/s)
1					
2					
3					
4					
5					
6					

Analysis

1. Did each person throw at about the same range?

2. Did each person throw about the same speed?

Teacher's Notes:

I took the students out to the football field next to the school to throw a softball for this lab. We had several volunteers to throw the ball; both genders were represented. We had about eight to ten throwers. Several students were markers for ten feet intervals. One student timed the flight of the ball from release to initial hit on the ground. Two more students were the spotters to help determine the range. Finally, one student was the recorder. Our data table also included the angle and height the ball traveled.

In addition to the lab, I had students make two graphs: Total time vs Initial Angle; Initial Angle vs Range. The former graph was to determine if the total time and angle were directly related or inversely related. One student was asked to throw at 90°, 60°, and 45°, respectively. This data was recorded along with the time and range.

To check a student's calculations, Brian Drobert and I developed a program using the graphing calculator. Students from either the control or experimental group were not given access to this program.

Below is an example of a student's data and screen shots.

Example:

value of g = 9.8 m/s^2;

Total time of flight = 2.50 seconds

Range = 85 m

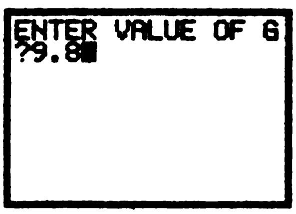


Figure 10

(g value)

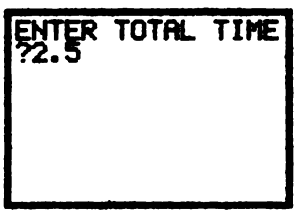


Figure 11

(Travel time in air)

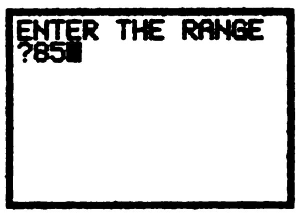


Figure 12

(Travel distance)

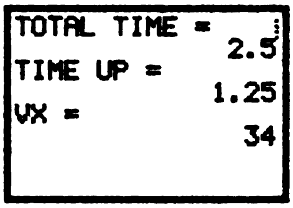


Figure 13

(Time, Time up and horizontal velocity)

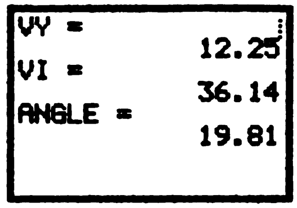


Figure 14

(Vertical and initial velocity and θ)

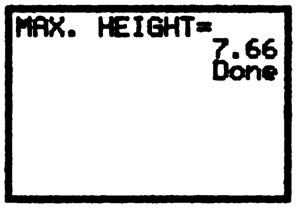


Figure 15

(Maximum height in meters)

Students graphed the initial angle vs the range to determine what angle resulted in the maximum range. We talked about how we did not account for the initial height of the ball being thrown (1 to 1.5 m). Everyone enjoyed this lab.

APPENDIX B-I

Vector Experimental Lab 1 — Finding the resultant vector from the component vectors

Purpose: To determine the resultant vector by two different methods when provided the horizontal and vertical components.

Materials: protractor, graphing calculator, and VECTRES program. (Short for VECTor RESultant program)

Procedures:

Construct four sets of components of varying lengths within each quadrant (i.e., 0° to 90° is quadrant 1; 90° to 180° is quadrant 2; etc.) in your lab book. Measure the corresponding resultant vectors. Then use the TI-83 Graphing Calculator program VECTRES to determine the same four resultants using the same set of components. Record your results in a data table. Finally, reverse the process and use the calculator program first, then draw them out in your lab notebook. Record all component and resultant vectors in data table. Also, use different lengths than what was used in the first part. Write down the source code for VECTRES.

Analysis:

What equation in the program actually determined the magnitude of the resultant?

Indicate in the source code what section determined the direction for the components?

What was percent error? %Error = (measured — calculated)/calculated * 100

What benefit(s) does using the VECTRES program provide(s)?

What problem(s) do/does using the VECTRES program pose?

Teacher's Notes:

Before beginning the calculator based lab, the class reviewed the four quadrants and how they relate to vectors. Lab groups were given a review or taught on vector drawing and how to run the program. I emphasized that all students, not just one student, should run the program. Below is the source code for the TI-83 graphing calculator VECTRES program. This could be used for TI-81, 82, and 85. I did not try to down load it into a TI-92. For TI-81, the program must be keyed in manually since it does not have graph link on the bottom. The program was downloaded to the ten student calculators used for the study only. Having the program on ten calculators avoided incompatibility problems of the program with the TI 85, 92, or other graphing calculators that some students have for their math classes. This also limited the program access to only the experimental group students. This program was developed and tested in the summer of 1997 with the help of Mr. Chorny, fellow teacher researcher, and was based on a program down loaded from Texas Instrument's web site on graphing calculator programs (Harmon, 1994).

This program will determine the resultant vector when provided with the magnitudes and directions of two or more different vectors.

VECTRES—Source Code

```
:Degree
:Func
:Lbl 3
:ClrHome
:Disp "ENTER VECTOR NO."
:Input N
:If N<= 1
:
Goto 3
:0__
:0_X
```

```
:0_Y
:1_Z
:ClrHome
:Disp "VECTOR NUMBER"
:Disp_Z
:Disp "MAGNITUDE ="
:Input M
:Disp_ "ANGLE ="
:Input D
:X + (Mcos(D)_X
:Y + (Msin(D)_Y
:Z+ 1_Z
:N - 1_N
:If N_ 0
:Goto 0
:Sqrt((X^2 + Y^2)_R              (This is equation determines the magnitude.)
:If X = 0
:Goto 5
:If Y = 0
:Goto 6
:If R = 0
:Goto 1
:tan^-1 (Y/X)_ 0
:If Y < 0
:360 – abs(tan^-1(Y/X))          (This section and below is where direction is
:If X< 0                                 determined.)
:180 + (tan^-1(Y/X))__
:Lbl 1
:ClrHome
:Disp "MAGNITUDE="
:round(R, 1)_Y
:Disp R
:Disp "ANGLE="
:round(_, 1)__
:Disp _
:Stop
:Lbl 5
:If Y > 0
:90__
:If Y < 0
:270__
:Lbl 6
:If X < 0
:180__
:End
```

Below is a sample run with corresponding screens. In between each screen, the student would push the enter key.

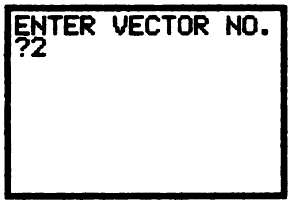


Figure 1

(Enter number of vectors)

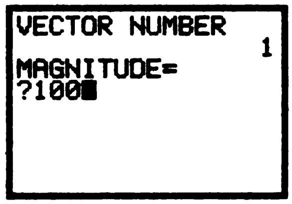


Figure 2

(Entering 1st vector size)

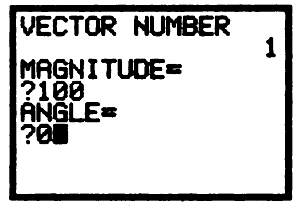


Figure 3

(Entering 1st vector angle)

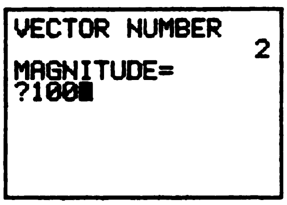


Figure 4

(Enter 2nd vector size)

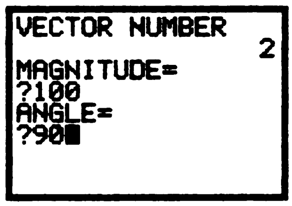


Figure 5

(Entering 2nd vector angle)

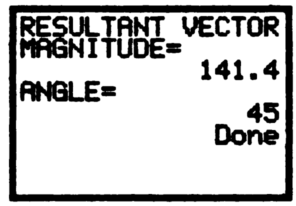


Figure 6

(Resultant vector screen)

Most vector problems have two vectors and students determine the resultant of these two. However, most software programs only address vectors between 0° and 90°, which limits the variety of problems. My program will work with vectors from 0° to 360°. Moreover, it can handle many more than two vectors. I gave an extra credit program to draw and find the resultant vector magnitude and direction for 15 vectors. If done correctly, it traced out an outline of a shape of a duck.

If you should make a mistake (i.e., entering too many vectors), then just press 2nd Quit to exit the program. You can check your answer with the next program, VECTCOMP, which does the reverse.

APPENDIX B-II

Vector Experimental Lab 2—Finding the components from a known resultant vector

Purpose: To determine the horizontal and vertical components from a resultant vector.

Materials: protractor, graphing calculator, and VECTCOMP program. (VECTCOMP is short for VECTor COMPonent)

Procedures:

Construct a resultant vector within each quadrant (i.e., 0° to 90° is quadrant 1; 90° to 180° is quadrant 2; etc.) in your lab book. Measure the corresponding component vectors, using the parallelogram method. Use the TI-83 Graphing Calculator program VECTCOMP to determine the corresponding sets of components. Record your results in a data table. Then use the program to test four different resultant vectors. Find their corresponding component vectors and record in data table and diagram in lab notebook. Write down the source code for VECTCOMP.

Analysis:

What equation(s) in the program actually determined the magnitude of the components?

Indicate in the source code, what section determined the direction for the components?

What benefit(s) does using the VECTCOMP program provides?

What problem(s) does using the VECTCOMP program pose?

Teacher's Notes:

Below is the source code for the TI-83 graphing calculator for the VECTCOMP program. This could be used for TI-81, 82, and 85. I did not try to down load it into a TI-92. This program must be keyed in manually for the TI-81 since it does not have graph link on the bottom. For this lab, I down loaded the program to the student calculators. This program was developed and tested in the summer of 1997 with the help of Mr. Chorny, fellow teacher researcher, and was based upon program down loaded from Texas Instrument's web site on graphing calculator programs (Harmon, 1994).

This program will determine the horizontal and vertical components' magnitude and direction when a resultant vector's magnitude and angle is provided. It should be noted the program will not resolve any vectors with (_) = 0°, 90°, 180°, 270°, and 360°, respectively.

VECTCOMP—Source Code

```
:Degree
:Func
:Lbl 1
:ClrHome
:Disp "ENTER VECTOR"
:Disp "MAGNITUDE"
:Input V
:If V<= 0
:Goto 1
:Lbl 2
:ClrHome
:Disp "ENTER VECTOR"
:Disp "ANGLE"
:Input _
:If _ <= 0
:Goto 2
:0_X
:0_Y
:0_A
```

```
:0_B
:Vcos(_)_X            (This section determines direction for the X component.)
:If X > 0 and (_ >0 and _ <90)
:0_Q
:If X >0 and (_ >270 and _ <360)
:360_Q
:If X <0
:180_Q
:Vsin(_)_Y            (This section determines direction for the Y component.)
:If Y> 0
:90_R
:If Y< 0
:270_R
Lbl 3
:ClrHome
:Disp "VX MAGNITUDE ="  (This equation is used to determine the horizontal
:(round(X,1))_X                   component vector.)
:Disp X
:Disp "VX ANGLE ="
:Disp Q
:Pause
:Disp "VY MAGNITUDE ="(This equation is used to determine the vertical
:(round(Y,1))_Y                   component vector.)
:Disp Y
:Disp "VY ANGLE ="
:Disp R
:Stop
```

Below is a sample run with corresponding screens. In between each screen, the student would push the enter key.

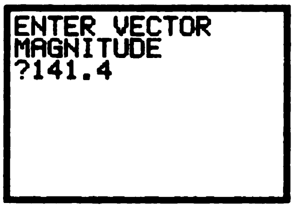


Figure 7

(Resultant vector length)

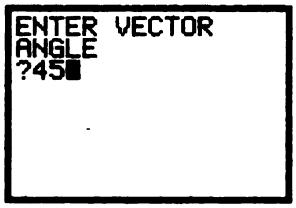


Figure 8

(Resultant vector angle)

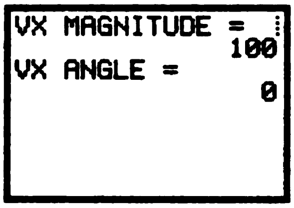


Figure 9

(Horizontal component vector)

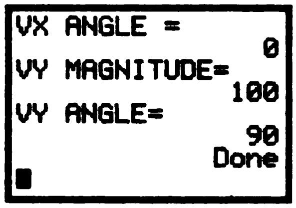


Figure 10

(Vertical component vector)

APPENDIX B-III

Experimental Projectile Motion Lab 1—Baseball Lab
(Parametric Equations to find T, R, and H) (Modified from Vonder Embse, 1990)

Purpose: To simulate the flight of a baseball and determine if the ball can be caught.

Materials: TI-81 to TI-89 graphing calculator and PROJMOT program.

Procedures: Set the graphing calculator's mode to Par (Parametric Equation) and window settings to the below values.

Tmin = 0	Xmin = 0	Ymin = -25
Tmax = 5	Xmax = 430	Ymax= 100
Tstep= 0.05	Xscl = 50	Yscl = 10

Then type in or down load the program PROJMOT. Make sure any conversions are done so the units will cancel. Write down in your lab book your X_{1T}, Y_{1T} and other X= and Y= expressions. Diagram your results in your lab book as well. Answer the questions in the analysis section in lab book.

Problem:

[A baseball player] is at the plate, in the bottom of the ninth inning of the last game of the season, for the Detroit Tigers. This is his last chance to hit his 50^{th} home run of the season. The pitcher serves up a fastball at the waist (3 feet above the ground) and [the batter] hits the ball at a velocity of 150 feet per second at a vertical angle of 20^{o} toward straight away center field. The center field fence is 20 feet high and 400 feet from home plate. At the moment he hits the ball there is a 6 mph wind blowing straight in from center field. Is this hit a home run? Is the ball able to be caught? Use the Line function to draw the wall. (Deamana and & Waits, 1990)

Analysis:

Q1) What would happen to the ball if the wind suddenly died? Or increased to 12 mph? Graph three possibilities at the same time.

Q2) What would happen if the ball were hit at an angle of 25°? Compare this hit with the original hit of 20° with a 6 mph wind.

Q3) A line drive is known as a "rope" in baseball lingo. Consider a line drive to be hit at a 10° angle. What velocity would it take to hit a line drive home run?

Q4) Compare the time of flight of a high fly ball to a line drive using the Trace function. Graph both simulations at the same time.

Q5) What is the best angle to hit the ball?

Q6) What factor is more important in the problem, the angle of the hit or the initial velocity? Why?

Q7) Change the problem situation to a punter on the football field. What should the punter do to produce the best "hang-time" for his punt?

Q8) Change the problem situation to a golfer hitting a golf ball with different types of clubs. For example, a driver has a head angle of 9.5° to 11°. Simulate several different iron shots at the same time.

Teacher's Notes:

The students should have entered the following parametric equations: T = Time in sec.

$X_{1T} = (150\cos 20°)T - 8.8T$

Note: 150ft/s was the initial velocity; and 8.8 was 6 mph converted to ft/s)

$Y_{1T} = -16T^2 + (150\sin 20°)T + 3$

Note: -16 ft/s^2 is half of g value (32 ft/s^2) and 3 ft was the height the ball was thrown.

Below are some of the screens that the TI graphing calculator will show in solving the above problems. If you have access to a view screen that shows your graphing calculator's screen on the overhead, then most of students can follow along. I found a lot of students had difficulties with entering the mathematical formulas for this lab. Conceptually, most students understood. Be prepared to walk around and help trouble-shoot this lab.

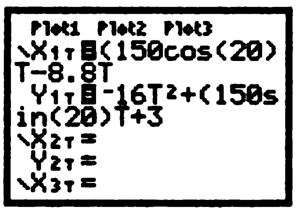


Figure 11

(Entering parametric equations)

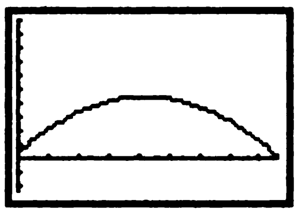


Figure 12

(Graph)

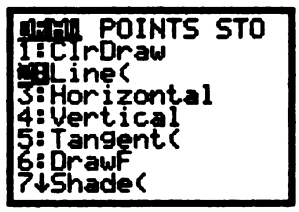


Figure 13

(Drawing the wall)

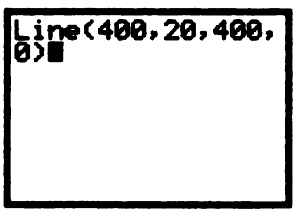


Figure 14

(Entering Line from Draw menu)

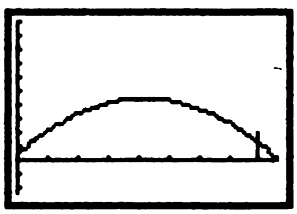


Figure 15

(Graph)

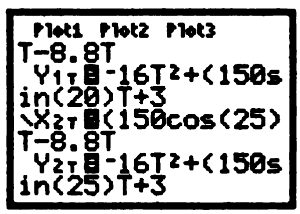


Figure 16

(Entering another set of equation at 25°)

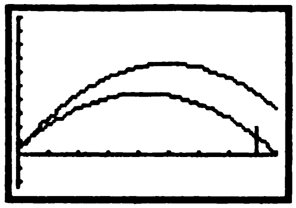


Figure 17

Graph with more than one set of equations

Give your class about two to three days to work on this lab. The questions are a little advanced for conceptual level physics but still worth while.

APPENDIX B-IV

Experimental Projectile Motion Lab 2—V_o and θ to find T, R, and H

Purpose: To determine the angle to obtain the maximum range and the relationship between time vs angle and how initial velocity affect range at a constant angle.

Materials: TI-81 to TI-89 graphing calculator and PROJYVST program. (PROJYVST is short for PROJectile motion YVST program, it also graphs the range)

Procedures:

Make sure your calculator is in parametric (Par) mode. Then use the program PROJYVST to determine the angle that allows for the maximum range or X value. Also, determine the relationship between time vs angle. Finally, find out if the initial velocity affects range at a constant angle. Record all your results in your lab notebook. Include any graphs to help support your findings.

Analysis:

Q1) What was the angle that allowed for the maximum range?

Q2) What relationship existed between time and angle? Were they dependent or independent of one another?

Q3) When the angle is kept constant, what was the relationship between initial velocity and range? Use graphs to support your answer.

Q4) What angle allows for maximum height?

Teacher's Notes:

PROJYVST Lab—Source Code

This program was created with the help of Brian Drobert, an *MSU* intern. The program will create a parametric graph, where the time, height and range can be determined graphically. A person only needs to enter the value of g, initial velocity, and the angle. Note: g can be 9.8 m/s^2 or 32 ft/s^2 or other values if you're on another planet or in an elevator while it is accelerating.

PROJYVST—Source Code

```
:Param
:0_V
:0__
:0_A
:0_B
:0_G
:"0"_X1T
:"0"_Y1T
:Lbl 1
:ClrHome
:Degree
:Disp "ENTER VALUE OF G"
:Input G
:If G <= 0
:Goto 1
:Lbl 2
:ClrHome
:Disp "ENTER INITIAL"
:Disp "VELOCITY"
:Input V
:If V <= 0
:Goto 2
:Lbl 3
:ClrHome
:Disp "ENTER ANGLE"
Input θ
:If θ <= 0
:Goto 3
:If θ >= 90
:Goto 3
:
```

```
:V*(cos(θ))→A
:V*(sin(θ))→B
:
:"A*T"→X1T
:"B*T- 0.5*G*T²"→Y1T
(1.20)B/(0.5*G)→Tmax
**Note: The 1.20 is  to increase the graphing time.**
:(A*Tmax)→Xmax
:(1.05)(B*(Tmax/2)–0.5*G(Tmax/2)²)→Ymax
**Note: The 1.05 is  to increase the graphing time.**
:Draw F Y1T
:Stop
```

Below is a sample run of the program.

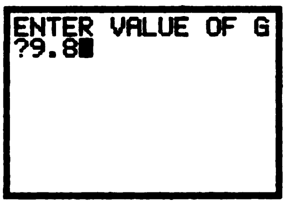


Figure 18
(Entering the value of g)

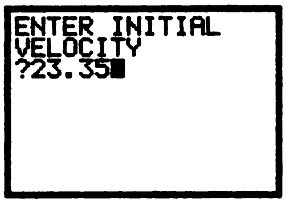


Figure 19
(Entering the initial velocity)

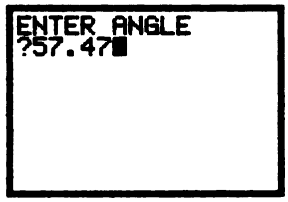


Figure 20
(Entering the initial angle)

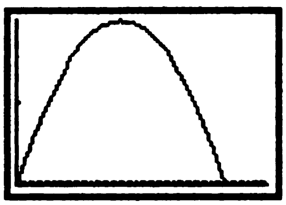


Figure 21

(Displaying the projectile's graph)

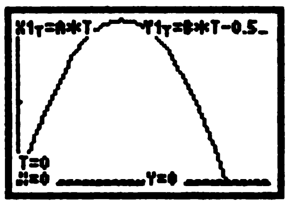


Figure 22

(Displaying the graph, T, X, and Y set to 0)

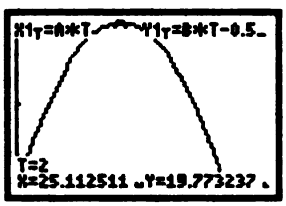


Figure 23

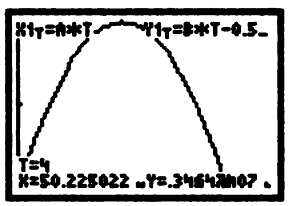


Figure 24

(Displaying T=2.0s,X= 25.00m,Y= 19.6m) (Displaying T=4.0s,X = 50.01m,Y= 0.01m)

APPENDIX C-I

Vector Control Demo—Cut Out Vectors

Concept Demonstrated: Vector's have additive and subtractive properties.

Materials: Poster board or card boxes, markers, scissors, meter sticks. Cutting out paper arrows, which then can be laminated, can easily represent vectors. Various sizes can be made to represent different size components or resultant vectors. I had cut out several size vectors.

Teacher's Notes:

I asked how could I determine the magnitude of one vector. I also asked what direction could I give the vector. Once the students understood what a vector is, I asked them what if one of my vectors represented a plane flying with a certain velocity, having magnitude and direction. Then I added an element of tail wind. How could the velocity vector be represented? Then I added an element of a head wind, where the velocity vector would be smaller. Finally, I added a crosswind. This allowed me to show students what the new plane velocity was. Most students found this to be intuitive, while others seemed to be unsure of components. I found it helpful to have students provide the plane's components and resultant velocities. Moreover, I used 90° for the crosswind so that the Pythagorean theorem could be used.

APPENDIX C-II

Vector Control Demo—Vector Rope and Potato Bag Demo

Concept Demonstrated: A vector can be resolved into its horizontal and vertical component.

Materials: A 5 or 10 lbs. bag of potatoes, 50 to 75 feet rope, and a cheese cloth bag in which to place the plastic potato bag during pulling.

Teacher's Notes:

This demonstration allows students to see vector components and resultants when two or more students try to straighten out a rope with the bag of potatoes in between them. First have two students pull the rope in a tug-of-war fashion. Students should have no problems seeing vectors, where the vectors are equal and not equal in magnitude and opposite in direction. Then place bag of potatoes in a cheesecloth sack and tie with rope. Have the same two students try to pull the bag horizontally. Most likely they cannot. Even if they can, have them allow the bag to sag. This would allow the instructor to ask where are the resultants and components for both sides. If the students were not able to bring the bag to the horizontal, then allow more students to join in to see if the bag of potatoes can be brought to a horizontal position. After the demo, I asked questions to see if students understood terminology and concepts.

Then we go back into the class and have them draw a vector representation of the potato bag and rope labeling the horizontal, vertical, and resultant vector. They were, also, asked to write down in their physics notebook the description of how vectors are involved in clothes on a line, tight rope walking, and hanging pictures.

APPENDIX C-III

Projectile Motion Control Demo—2-Dimensional Motion Demo

Concept Demonstrated: Any projectile motion's horizontal and vertical motion will be independent of one another.

Materials: Projectile Motion Demo launcher, 2 bearings, where one is solid and another has a core section taken out of it. This is a unique device that allows two bearings to be launched at the same time, one horizontally and one vertically.

Teacher's Notes:

I usually place the launcher on a ladder so that both bearings can hit the floor. The objective is to demonstrate the independence of horizontal and vertical motion. This will result in both the horizontally shot bearing and vertically dropped bearing to land at the same time. One could modify this demonstration by using washers or pennies on a ruler that is anchored with a nail in the center and allowed to spin freely.(Edge, 1981)

APPENDIX C-IV

Projectile Motion Control Demo—Shoot the Monkey Demo

Concept Demonstrated: Objects under the influence of gravity will fall together and hit in mid-air together, independently of horizontal and vertical motion.

Materials: An electromagnet connected to a blowgun, where a bearing would break the connection at the end of the barrel, thereby, releasing the object to fall freely at the same time.

Teacher's Notes:

The monkey shoot is a classic physics demonstration. (see Figure 1)

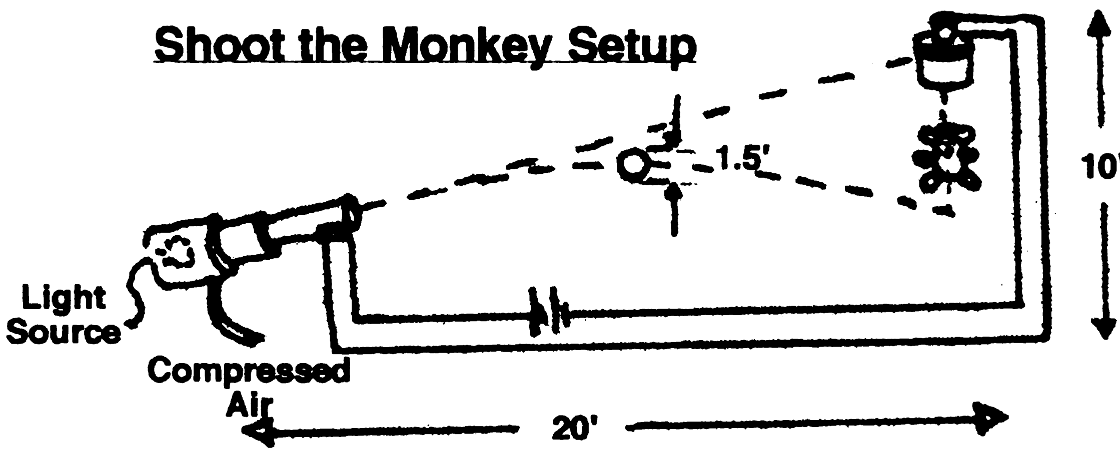
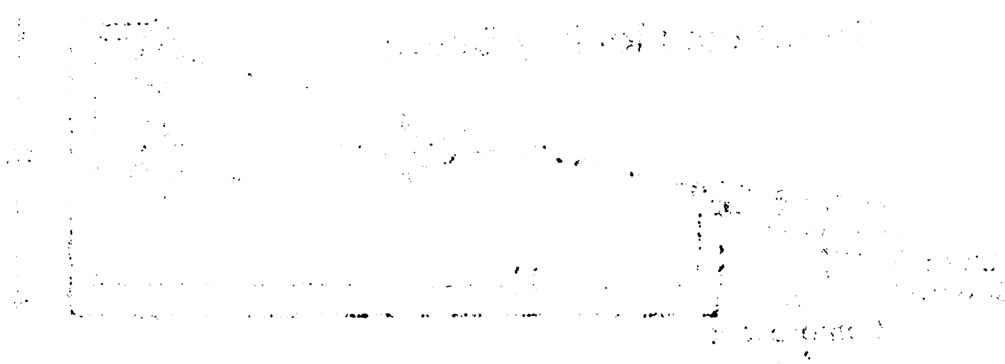


Figure 1

(Shoot the Monkey Setup: Freier, G.D. and Anderson, F.J., 1981)

Rogowski says, "It is a study in mechanics of projectile motion...[containing] elements of geometry, trigonometry, ballistics, projectile mechanics, vector analysis...[within its



solution]." (1982) However, if you're for animal rights, then Yoav Ben-Dov addresses the same problem using apples in his article, *Why the Dart Always Hits* (1993). Rogowski used computer animation on an Atari 800 and another physics teacher used a raised up table along with one meter length corner molding with a V groove as the gun (Brown, 1977). I used an electromagnet, tin can (monkey is painted on it), blow gun apparatus, and bearing. Students are asked where the gun should be aimed: above, at, or below the monkey, if the monkey releases the second the bullet clears the barrel. Most will pick above the monkey due to gravity; however, this is wrong, as is aiming below the target. This demonstration was cumbersome to setup. Moreover, I felt the students were more focused on the apparatus and setup than the concept to be learned.

APPENDIX C-V

Projectile Motion Control Demo—Hall Cart Demo

Concept Demonstrated: Projectiles follow a parabolic pathway.

Materials: The Hall Cart has an upright cylinder to hold a bearing, paper clip, and string. The center part of the Hall Cart is spring loaded and allows the teacher to attach a straightened out paper clip tied to string.

Teacher's Notes:

Once the cart is moving, a quick pull on the string that is attached to the paper clip will release the bearing into the air. This will follow a parabolic pathway and the bearing will land in the cup. If the cart is stopped after the bearing is in the air, the bearing will continue in a parabolic pathway; however, it will not land in the cylinder. The Hall Cart demonstration is good for the topic of inertia (seatbelt safety). This demonstration seems to ring true the saying "If it doesn't work, it has to be physics." This demo worked correctly one in four times.

APPENDIX D-I

Experimental Vector Demo—Vectors by Video Laserdisc Demo

The *Physics at Work* video laserdisc has some very good images of how vectors are utilized in everyday contexts (i.e., bridge and building design, tossing a ball and cannon firing, etc.). I have students work in small groups and go through these images as well as through the animated vector and projectile frames using the video laserdisc. Students are encouraged to take notes from the disc as well as answer the questions in their lab notebook.

Questions asked to write in physics journal prior to viewing the video laserdisc:

Q1) How would you define a vector?

Q2) What are some real life applications that utilize vectors?

Q3) Identify and show two different ways of solving vector problems?
(Use one of your vector addition problems.)

Questions after viewing the video laserdisc:

Q1) How did *Physics at Work* define a vector?

Q2) Describe some real life applications that utilize vectors from the video laserdisc?

Q3) Identify and show two different ways of solving vector problems?

Teacher's Notes:

The video laserdisc allowed students to view the images several times if they were uncertain of the concept(s). The questions given prior to viewing the video laserdisc served as a check to see if students were taking notes and answering questions from their textbook. The questions after viewing served as a review or mode of learning.

APPENDIX D-II

2-Dimensional Motion Demo

The *Cinema Classic* video laserdisc was used to help understand projectile or 2-Dimensional motion. Small group discussions allowed students to make some predictions prior to viewing the video laserdisc.

Predictions:

Q1) If one bullet was fired horizontally and one dropped at the very same time, which one would hit the ground first? (Hewitt, 1992) Explain your answer.

Q2) If a monkey in a tree could release its grip and free fall the instant a bullet cleared the barrel of a hunter, where would the hunter need to aim: above the monkey, at the monkey, below the monkey? Explain your answer. (Rogowski, 1982)

Q3) If you were driving down the road slowly (neglect wind resistance) in a convertible and the instant someone in the back seat tossed a ball straight up, would the ball travel in a parabola even if the car suddenly slowed down or speeded up? Explain your answer.

Analysis

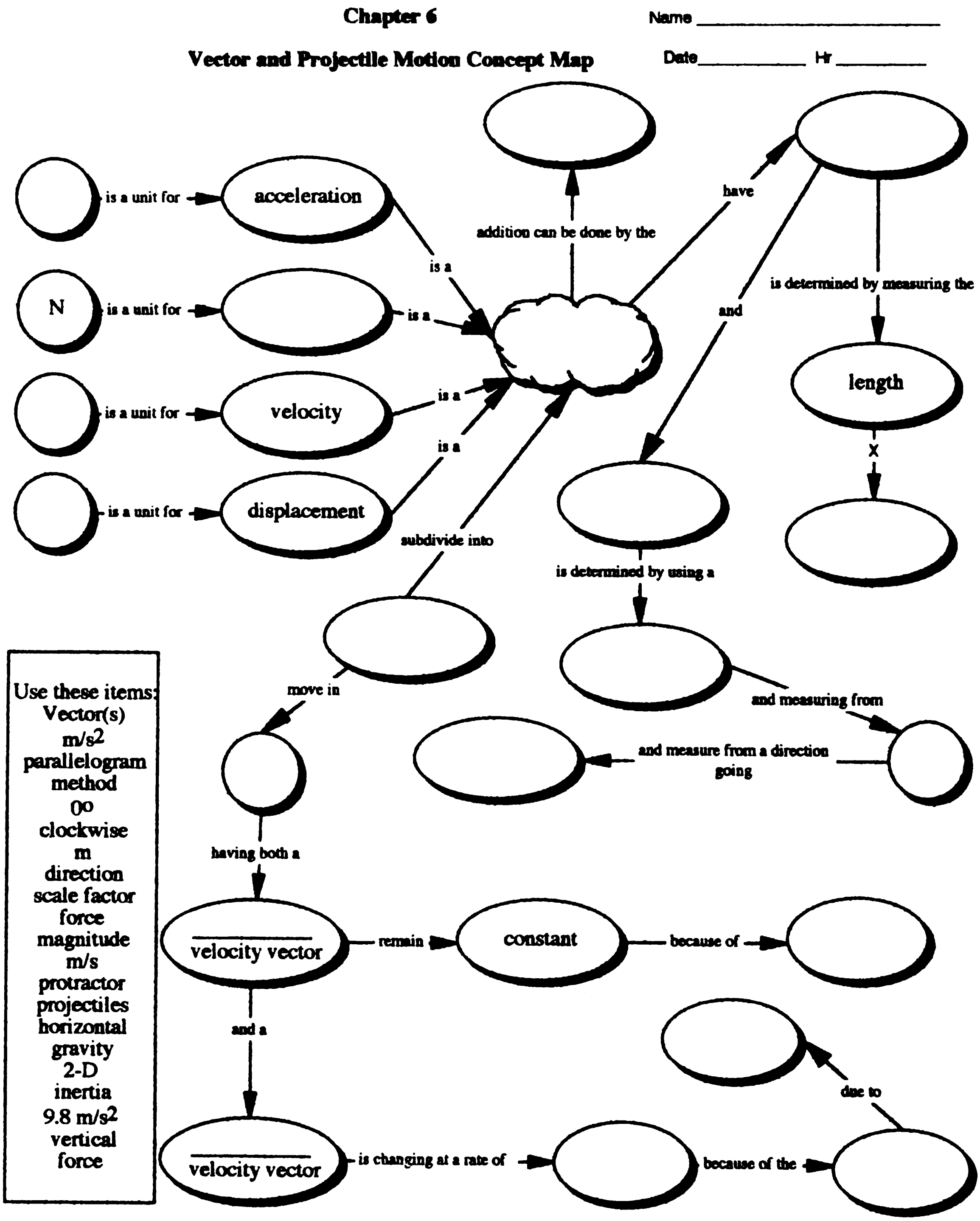
Based upon viewing the *Cinema Classic* video laserdisc, would you change any of your answers from questions above? If so, how would they vary? In your physics lab notebook, describe the setup for each demonstration. Finally, provide what you thought was the purpose of the demonstration.

Teacher's Notes:

The video laserdisc did not show any bullets, monkey, or cars. I wanted them to transfer the concept of the pool balls being fired horizontally and vertically at the same time to the bullet problem. Also, a crossbow arrow dart hitting a pool ball that was suspended by an electromagnet represented the monkey shoot problem. Finally, the ball toss from a convertible was demonstrated by a snowmobile with a flare being fired at the same time the snowmobile moved with varying speeds.

APPENDIX E-I

The concept map below was given the day before the posttest, and any questions were answered the day of the posttest.



APPENDIX E-II

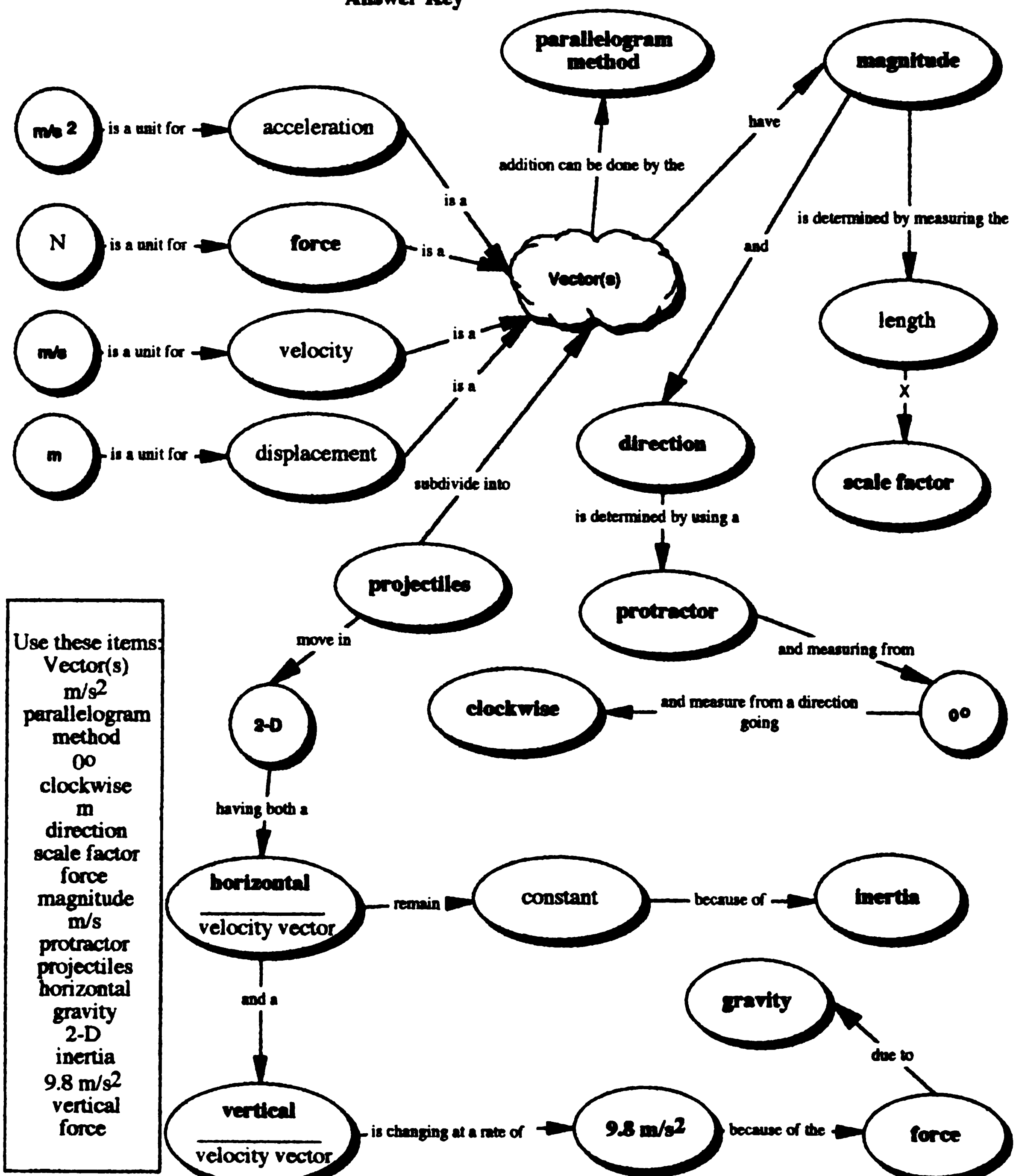
Students are not given the answer key concept map test.

Chapter 6

Name ____________________

Vector and Projectile Motion Concept Map
Answer Key

Date__________ Hr ________



APPENDIX E-III

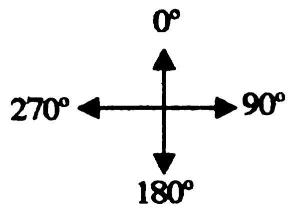
The test questions came from *Conceptual Physics, 2nd Edition*, Chapter Test, and from *Merrill Physics: Principles and Problems*, as well as from the labs and supplemental activities. This is the way I usually design my tests for a unit.

VECTOR AND PROJECTILE PRETEST/POST TEST

Name__________________________________ Date ___________ Hour_______

Introductory Physics— Pretest/Post Vector and Projectiles

____ 58pts



True or False Questions (10pts)
Circle the correct answer.

T F 1. Car speed can be represented as a vector quantity.

T F 2. A single vector can be replaced by two vectors in the X and Y directions. These X and Y vectors are called the component of the original vector.

T F 3. A quantity that has both magnitude and direction is called a vector.

T F 4. The horizontal component of velocity for a projectile varies with time, even with no air resistance.

T F 5. The vertical component of velocity for a projectile does not vary with time, even with no air resistance.

Multiple Choice Questions (20pts)
Choose the best answer to each question and write the appropriate letter in the space provided.

_____ 6. A scalar is a quantity that has

A) magnitude and time. B) magnitude and direction.
C) time and direction. D) only magnitude.

_____ 7. When velocity is represented as a vector

A) the length of the arrow represents the speed.
B) the length of the arrow is drawn to a suitable scale.
C) the direction of the arrow show the direction of motion.
D) all of the above.

_____ 8. What is the maximum resultant possible when adding a 3-unit vector to an 8-unit vector?

A) 24 B) 11 C) 8 D) 5

_____ 9. What is the horizontal component of a vector 5 N at 30°?

A) 5/cos30° B) 5/sin30° C) 5sin30° D) 5cos30°

_____ 10. What is the value of the vertical component of a force vector of 5 N at 30°?

A) 5/cos30° B) 5/sin30° C) 5sin30° D) 5cos30°

_____ 11. Which of the following would not be considered a projectile?

A) A cannonball thrown through the air.
B) A cannonball rolling off the edge of a table.
C) A cannonball thrown straight up.
D) A cannonball rolling down a slope.

_____ 12. The horizontal component of a projectile's velocity is independent of time of flight.
A) time of flight
B) the range of flight.
C) the vertical component of its velocity.

_____ 13. A ball is thrown into the air at some angle between 10 degrees and 90 degrees. At the very top of the ball's path, it velocity is

A) entirely horizontal.
B) entirely vertical.
C) both horizontal and vertical.

_____ 14. In the absence of air resistance, a thrown ball will travel the greatest distance if it is thrown at an angle of about

A) 75°. B) 45°. C) 60°. D) 30°.

_____ 15. In the famous "monkey shoot" or some similar demonstration, where must one aim in order for the two falling objects to hit?

A) directly below
B) directly above

C) directly at
D) doesn't matter

16. Use the graphical method to determine the displacement of a person's trip if they go from the start 40 km east, 20 km south, and 70 km west.
(Use a scale of 1 cm = 10 km) (6pts)

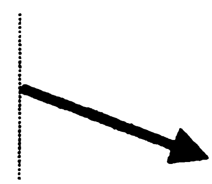
Start

17. Using the following scale: 1 cm = 20 N (4pts)

A) Draw the following vector 60 N at 290°

A

B) Measure R = ______ at ______

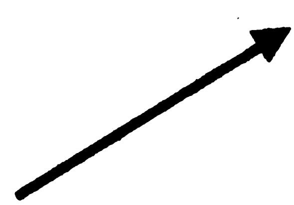


B

18. Draw the component vectors and determine their magnitude and direction.
(1 cm = 30 km/h)) (6pts)

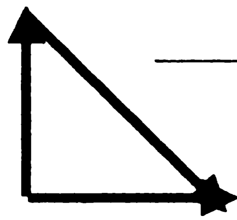
Horizontal component = ______ at ______

Vertical component = ______ at ______



4. Determine the resultant vector using the Analytical Method or Triangle Method (head to tail) for a plane flying North or 0° at 60 km/h while the wind blows towards 90° at 80 km/h. Label each vector and find the resultant vector, R (round to 0.1). Must include units and show work. (6pts) (Hint: $a^2 + b^2 = c^2$)

_______ at _______



_______ at _______

_______ at _______

5. If a softball is thrown a distance of 80 m in 5.00 seconds determine the following: (Note: $g = 9.8\ m/s^2$, round to 0.01) Please show your work below. (6pts)

$t_{up} = t/2$

$\theta = \tan^{-1}(V_y/V_x)$

$V_x = Range/t$

$Y_{max} = V_y(t_{up}) - 4.9(t_{up})^2$

$V_y = g(t_{up})$

$V_i = \sqrt{V_x^2 + V_y^2}$

Work Area:

Place answers on line provided.

t_{up} (s)	V_x (m/s)	V_y (m/s)	V_i (m/s)	θ (degrees)	Y_{max} (m)
_______	_______	_______	_______	_______	_______

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