A STUDY OF THE COGNITIVE AND AFFECTIVE IMPACT OF THE COCKPIT PHYSICS CURRICULUM ON STUDENTS AT THE UNITED STATES AIR FORCE ACADEMY

by

HEIDI MAUK GRUNER

B.S., United States Military Academy, 1981
M.S., University of Washington, 1990

A DISSERTATION

submitted in partial fulfillment of the

requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Curriculum and Instruction
College of Education

KANSAS STATE UNIVERSITY
Manhattan, Kansas
1997

Approved by:

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ABSTRACT

The standard introductory college physics course has remained stagnant for over thirty years. Course texts have had few significant revisions, and the course has typically been taught in a lecture, laboratory, and recitation format. Studies show, however, that the majority of students do not learn physics well in this environment. Cockpit Physics at the United States Air Force Academy is an innovative computer-centered introductory physics course which abandons the traditional lecture-lab format in an effort to improve the standard introductory course.

Cockpit Physics uses small cooperative learning groups, the computer as an integrated learning tool, and the context of flight and Air Force applications. The purpose of this study was a control group comparison to determine if an interactive student-centered environment provides the social context and community for learning needed by students who do not traditionally purse a career in science. In light of the under-representation of women in physics, this study examines whether Cockpit Physics results in a more positive attitude toward physics for female students. Considered also are the experiences of the instructors.

To address these issues research questions related to student attitudes and academic performance were formulated. Answers to the attitudinal questions were sought with survey instruments, classroom observations, analysis of journals and individual interviews. Student learning of physics was assessed through class examinations and an inventory widely used in the physics community. A comparison is made to similar innovative curricula at other universities.

This study concludes that Cockpit Physics provided more peer interaction and a more hands-on environment for learning than the control classes but provided less one-on-one student teacher interaction. This lack of interaction with the teacher was a significant source of frustration for nontraditional students. Female students in particular struggled with the course and showed considerable attitudinal losses. Significant cognitive gains were not found. Data from this study indicates that cooperative learnig with computer lessons may not be significantly superior to small traditional classes, while a comparison study indicates that it may be superior to the large lecture-lab-recitation format.

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DEDICATION

To my children, who are the heart and soul of my life.

CHAPTER I: INTRODUCTION

The standard introductory college physics course has remained stagnant for over thirty years. Course texts have had few significant revisions, and the course has typically been taught in a lecture, laboratory, and recitation format. Studies show, however, that the majority of students do not learn physics well in this environment. Evidence does not support that lectures or lecture demonstrations contribute to critical thinking, the understanding of concepts, or problem solving (Laws, 1991(a)). Thus, how students learn or do not learn physics provokes much educational research today. One result of this research is an array of educational initiatives in the past five years to improve the standard introductory college physics course.

In the spring of 1996 the United States Air Force Academy Department of Physics introduced an innovative computer-centered physics course called Cockpit Physics, which abandons the traditional lecture-lab format. Cockpit Physics uses small cooperative learning groups and the computer as an integrated learning tool, and teaches physics in the context of flight and Air Force applications. This study reports on the first full trial of Cockpit Physics in the classroom. Considered are both the cognitive and affective impact of the course on students and instructors, as well as the potential for the curriculum to be implemented in place of the current, traditional course, Physics 110. This study was conducted with the full cooperation of the Department of Physics and The Office of the Dean of Faculty at United States Air Force Academy.

Introducing new curricular and teaching methods based on sound educational research is laudable, but we must critically study each initiative and evaluate its merits carefully before implementing the curriculum on a broad scale. According to Slavin (1989), educational initiatives tend to be faddish, to come and go like the swing of a pendulum. If research indicates that present teaching methods are inadequate, new initiatives are sometimes adopted without thoughtful evaluation. The results can be disappointing, and educators hop on the next educational initiative to swing by. Technological advances such as computers, CD-ROMs, and world wide networks give the pendulum new momentum and provide a new media for educational fads in the sciences (Slavin, 1989). To insure that Cockpit Physics is not just a passing fad, the results of this study will be taken into account before the Air Force Academy adopts Cockpit Physics as part of the core curriculum.

In light of the under-representation of women in physics, an essential element in the study of any new physics curriculum should be the impact of the curriculum on female students. Thus, the affective impact of Cockpit Physics on the female cadets at the Air Force Academy is a focus of this study. Improving opportunities for women in physics will improve opportunities for all students. The minimum acceptable standard is a curriculum that provides equal access to a future in physics for both male and female students.

When I taught physics at the United States Military Academy at West Point, I was frustrated with the lack of progress that the Academy had made with its integration of female cadets in the 10 years since I had graduated. Even more frustrating was the fact that my colleague and I were the first women to teach physics-- and the year was 1990. A superior officer told me to be patient, social changes are slow, and the only social changes that come quickly are through revolution.

Following is a brief history of the introductory college physics course and Physics 110 at the Air Force Academy which serves as a control for this study. I discuss the impact of physics education research and technology on the introductory course, and elaborate on the details of Cockpit Physics by tracing its educational roots and implementation at the Academy.

A. The Introductory College Physics Course

Today, as for the past thirty years, the introductory physics course at most universities is taught with some combination of lecture, laboratory, and recitation. A typical lecture is conducted in a large facility with as many as 300 students. The instructor most often speaks from the front of the room and movement about the classroom is restricted to stairs and paths up the sides and center of the lecture hall. Overhead projectors, chalk boards, and demonstrations are the main media for presenting visual information. Demonstrations of physical phenomena are conducted at the front of the room. The importance of the introductory lecture varies from physics department to physics department. In some departments the quality of the introductory lecture is a priority, and the best teachers are reserved for the introductory course. At other schools, teaching the introductory course is a necessary evil rotated among faculty who would rather be doing research or teaching upper-level classes.

Laboratory activities are conducted in smaller groups, usually around thirty students per section. The rooms in which instructional laboratories are conducted frequently have large tables to hold experimental equipment and computers for the collection and analysis of data. Generally, laboratory sections meet once a week or once every other week. Students typically work in groups of two to four, conducting experiments designed to reinforce lecture material. Grades for the laboratory component of a course are normally based on some type of formal written lab report. Instructors in the laboratory are often graduate or undergraduate teaching assistants.

For students the primary focus of an introductory physics course is the assigned problems. A correct solution to these word problem requires an understanding of the physics concept and some mathematical manipulation. The recitation section focuses on helping students apply physics concepts to solve these problems. In recitation, students have the opportunity to ask questions about assigned homework or other problems from the course text. The problems may be worked out on the board by the instructor or by other students. Recitation sections typically have about thirty students and meet once or twice a week. Recitation, like lab, is often conducted by graduate teaching assistants, but some universities have faculty or senior graduate students assigned to recitations. Two lectures, a lab, and one or two recitation meetings per week is a typical course load for an introductory calculus-based course.

The Air Force Academy, however, prides itself in not relying on large lectures. The Air Force Academy Catalog states "The small class size of most classes, usually 15 to 20 cadets, makes the discussions practical and popular. The relaxed classroom atmosphere encourages free communication between the instructor and cadets" (United States Air Force Academy Catalog, 1995-1996, p.42). In keeping with this approach the Department of Physics at the Air Force Academy uses small class lectures to teach its introductory course, Physics 110.

Physics 110 is a calculus-based introductory course required of all students for graduation, along with Physics 215. Classes meet every other day for one hour, with an average of twenty-one students per class with one instructor. Ten of the forty-two classes are two-hour lab periods. As with the traditional course at other universities, lecture is the primary mode of instruction, and laboratories are not integrated with the lecture. However, recitation style problem solving is an integral component of the Physics 110 lecture. Essentially, Physics 110 is a lecture, lab, recitation course with the exceptions of smaller class sizes and one instructor for all three components of the course. Sixteen sections of Physics 110 were offered at the Air Force Academy in the Spring of 1996; four of these sections served as a control group for this study.

The topics covered in Physics 110 are typical of a calculus-based introductory course at most universities. They include the fundamental forces, Newtonian mechanics, energy, momentum, special relativity, and the kinetic theory of gases (United States Air Force Academy Catalog, 1995-1996.). Physics 110 emphasizes the use of vectors and calculus for problem solving with emphasis on contemporary applications (United States Air Force Academy Catalog, 1995-1996).

B. Physics Education Research in the Cognitive Domain

Current physics education research concentrates on cognitive processing and application. Systematic observations and questioning of students as they solve physics problems shows that students come to their first college physics course with deep-seated explanations for physical phenomena (Arons, 1990). These ideas often do not match scientific models of nature accepted by the physics community. Initially, these students' ideas were labeled "misconceptions." Fortunately, the less elitist term "alternate conceptions" is becoming more common. Students' initial physics knowledge is based on their experiences. Each student constructs his or her own concept of reality to fit his or her experiences (Segal, 1986).

An example of an alternate conception is shown in repeated studies of the ball toss experiment. In an interview, an interviewer throws a ball up and asks a student to diagram the forces acting on the ball as it moves up (after it has left the interviewer's hand). Many students include an upward force on the ball. The student's logic is, if the ball is moving up, then an upward force must be acting on the ball. Yet, Newtonian mechanics tells us that once the ball has left the interviewer's hand, the only force acting on the ball is downward and due to gravity. Based on personal experience, the student has developed an alternate conception of an impetus force (Clement, 1982 & Gruner, 1990).

Studies similar to this one inform us that students do not come to the introductory physics course with Locke's *tabula rasa*, and that a teacher who chooses to profess the truths of physics in the fashion of mental discipline is unlikely to have a long-term impact on student conceptual understanding. (Biggie & Shermis, 1992). Interviews with students show that alternate conceptions do not change by traditional teaching methods (Clement, 1982 & Gruner, 1990). In order for students to question their own beliefs, they must confront observations that contradict their beliefs, and use accepted physics concepts to explain their observations.

> This inferred structuring of mental models is distinctly different from what we usually assume when teaching physics. We usually assume that our students either know something or they don't. The view of mental models we learn from cognitive scholars suggests otherwise. It suggests that students may hold contradictory elements in their minds without being aware that they contradict. Redish (1994)

As Arons (1990) points out, the teacher's role is to find out what students think, and present them with situations that challenge their alternate conceptions. This reflection-centered problem solving is based on a conflict of ideas (Biggie & Shermis, 1992). However, many physicists still teach physics by rote practice or mental discipline.

Two of the most significant changes in physics education as a result of cognitive research are an emphasis on physics concepts as opposed to rote problem solving and the introduction of the "less-is-more" philosophy. "Less-is-more" means that a student will learn more depth in physics concepts by being required to learn less physics content. The philosophy is: learning small quantities well is better than a survey of many topics. The hope is if a student learns basic concepts and problem solving techniques well for one physics topic, then he or she will transfer those skills to other topics.

An example of this approach is the recently completed Introductory University Physics Project, an effort to develop new curricula to emphasize physics concepts. The four Introductory

University Physics Project instructional models also bring modern physics into the curriculum, and develop a story line or cohesiveness for the introductory course.

The Air Force Academy's Introductory University Physics Project model, A Particles Approach To Introductory Physics, reorders the traditional curriculum to emphasize the particle (versus wave) aspects of nature and to eliminate the physics of rigid bodies from the curriculum. The course text assigned for Physics 110 and Cockpit Physics in 1996, was Principles of Physics by Serway which was recently restructured based on A Particles Approach (Serway, 1994). The results of the Introductory University Physics Project curriculum assessment indicate that A Particles Approach successfully incorporates modern physics concepts. However, no measurable differences between A Particles Approach and the comparison courses at the other test sites were noted (Di Stefano & Holcomb, 1995). The restructuring of a major commercial text based on a curriculum that was still in the evaluation phase is an example of the swing of Slavin's educational pendulum (Slavin, 1989).

C. Physics Education Research in the Affective Domain

The goals of the Introductory University Physics Project to incorporate modern physics into the curriculum and to develop a storyline or cohesiveness for the course are, in part, an attempt to make physics more interesting and palatable for all students. Ask a group of college students about their introductory physics class, and many will tell you that they hated it. A common attitude is that physics is something to be endured because it is a required course for many majors. When people ask what I did before graduate school, I say "I taught physics." A common reaction is for people to make the sign of the cross, hold it up in my face, and hiss as if to ward off the physics vampire. Laws at Dickinson College writes of similar experiences such as people mumbling "you must be a genius" when they learn that she is a physics teacher (Laws, 1991 (a)).

Until recently, many physics instructors were either unconcerned or simply unaware of the affective impact of their course on students. They were content to attract students likely to be physics or science majors. Tobias, in They're not Dumb, They're Different: Stalking the Second Tier, defines students who like physics, and who would likely learn physics no matter how it was presented, as first tier students. First tier students are a younger version of the science professorate today. Second tier students are those who are able to do science, but choose not to or who avoid science. The competitive nature of the class, lack of community, and threatening environment are the most significant deterrents to science for second tier students (Tobias, 1990).

Based on the number of women in physics today, female students are not likely to major in physics, and in most cases are second tier students. This study specifically considers the impact of Cockpit Physics on the female students. If a new curriculum or teaching method can inspire the female students to a future in science, then it is likely to inspire other second tier students too. Women are a subset of second tier students. By making physics more accessible to women we automatically make physics more accessible to the general student population.

The Air Force Academy places strong emphasis on physics education and teaching. The Physics Department has a research component, but its main mission is teaching and education. Faculty are hired for their potential to contribute to teaching excellence, not for their potential to bring in research funds.

The Academy also has a reputation for testing new curricula and teaching methods. In the early 1980s students solved a series of fundamental problems in order to pass the course. These fundamentals are the basis of the current Physics 110 learning objectives. The required fundamental problems led to Microcomputer-Delivered Problems which were a series of supplemental but required homework problems administered and scored by computer. These problems were a natural starting point for the extensive use of the local area network in 1989 (Department of Physics, 1989). An informal evaluation of the Microcomputer-Delivered Problems showed significant problem solving gains (Enger, 1995). In the mid 1980s the Department also experimented with a curriculum that offered the students alternative learning modes or clusters. Students received points for lab, tests, computer problems, and extra credit papers (Department of Physics, 1985). Enger recalls that the students liked the clusters approach and that their performance was on par with a traditional course, but the faculty workload was overwhelming (Enger, 1995).

D. Technology and The Introductory Physics Course.

Modern technology is having a tremendous impact on the teaching of introductory physics. In the past twenty years, introductory physics students have gone from using slide rules to calculators to spread sheets to real time data acquisition and analysis tools. The use of technology varies from school to school. At Kansas State University, Zollman (1994) made extensive use of digital video in teaching his Concepts of Physics class. At Dickinson College, Laws (1991 (b)) has abandoned lecture completely in favor of computer centered laboratories. Yet, schools on restricted budgets are just beginning to use spread sheets for the analysis of lab data.

At the time of this study the Academy Physics Department was also experimenting with another technology-based curriculum. A course based on the *Physics InfoMall* CD-ROM was tested concurrently but independently from Cockpit Physics (Fuller, & Zollman, 1995).

In his recent Millikan Medal Presentation, Zollman noted that many of his colleagues who use technology to teach physics are also moving toward a more student-centered environment. Zollman feels that the use of technology has the potential to expand teaching opportunities by bringing physics content into the real world of the student, and by opening learning paths for students with a variety of learning styles (Zollman, 1995). Student-centered learning and real world applications are essential components of Cockpit Physics.

E. Cockpit Physics at the United States Air Force Academy

Cockpit Physics is a direct spin off of Studio Physics developed at Rensselaer Polytechnic Institute (Wilson, 1994). Studio Physics involves small learning groups and the computer as the primary learning tool. Studio Physics is based on the Comprehensive Unified Physics Learning Environment, a combination of computer based tools, laboratory experiments, and video recordings based on the software product *Toolbook* (Assymetrix, 1994). The Academy Physics Department Head, Rolf Enger, saw Studio Physics as a promising strategy for the introductory course at the Academy but also wanted to teach physics in the context of Flight and Air Force applications (Enger, 1995).

On the Academy faculty at that time was Gregor Novak, an expert on materials delivered via the World Wide Web. Using a commercial Web browser and the Hypertext Markup Language, Novak had created multimedia instructional materials which include information such as formatted text, graphics, audio, and video. The Academy Department of Physics wanted to create physics lessons based on the context of flight and Air Force applications to be used in a studio setting, and they also wanted to stay on the cutting edge of technology, which meant using the Internet. For these reasons and because of the availability of Novak's expertise, the Academy Physics Department decided to teach a studio style course with Netscape Navigator and the Hypertext Markup Language as the platform rather than the *Toolbook* based Comprehensive Unified Physics Learning Environment (Enger, 1995).

The context of flight and Air Force applications for Cockpit Physics grew out of a desire to teach physics in a context that matches students' daily or real world experiences. The objective in teaching real world experiences is to increase the likelihood of transfer, to increase student motivation by having students study their own problems, and to increase retention by introducing meaningful material (Biggie & Shermis, 1992). According to this model, the teacher should emphasize the transfer potential between text book and real life applications (Perkins & Salomon, 1988). Thus, the Air Force Academy chose to teach physics in the context of flight and Air Force applications, which is the real world for an Air Force cadet.

Cockpit Physics was developed under the umbrella of Physics 2000, an Academy initiative to improve physics teaching. Similar initiatives are underway in other departments at the Academy. Experimental courses of varying formats are offered in English, Mathematics and Engineering. The goals of Cockpit Physics are to emphasize the fundamental physics concepts that form the foundation of Air Force operations, to improve cadet attitudes and interest in science, to develop a direct connection to Air Force issues, and to hone cadet skill with technology in the lab (Gurley, 1995). Cockpit Physics is a revision of the Physics 110 curriculum with a series of thirty-two computer lessons, each scheduled for two hours. (The Cockpit Physics Syllabus is reproduced in Appendix I-A.)

The learning objectives of Cockpit Physics and Physics 110 are closely matched, and assigned readings and homework problems are nearly identical. (The syllabus for Physics 110 is in Appendix I-B.) Cockpit Physics and Physics 110 students took identical examinations.

The main components of Cockpit Physics are small cooperative learning groups, the computer as the primary learning tool, and the context of flight and Air Force applications. The most significant difference between the Cockpit Physics lessons and the Studio Physics lessons at Rensselear is the context. The pedagogy for Cockpit Physics incorporates elements of the learning cycle and is based on a hands-on, laboratory approach to learning physics (Karplus, 1977). Each Cockpit Physics class starts with a review of assigned homework and questions from the previous lesson or assigned reading. The students then move to the computer lesson and a hands-on activity. The computer exercises, in hypertext format, lead students through an exploration, theory development, and theory application phase (Gurley, 1995). Imbedded in the computer lessons are multimedia examples and demonstrations. For example, students click on the video icon and view a short video sequence of a physics principle. Or, the students do a computer simulation of a laboratory activity. These simulations in some cases resemble video games. The students can also access a spreadsheet, Quattro Pro, and a data analysis software tool, Lab View.

Students, working in groups of two or three, choose their own workgroup at the beginning of the semester and stay with that workgroup unless the instructor sees a reason for change. At each student work station is a computer and the day's lab equipment.

The Cockpit Physics classroom has one large lab table at the front of the room and six smaller tables in three parallel rows of two. On the large lab table is the instructor's computer, which is networked to the students' computers. When the students answer a question in the computer lesson, the instructor can read each group's answer. The students' computers face the front of the room, and the students sit on swivel chairs. In this way, when the instructor is addressing the class, the students face away from their computer. While the students are doing the lab exercises and answering the application questions or challenges, the instructor is moving about the classroom answering questions and helping to focus the students on the task at hand. At the end of the lesson. the instructor gives a mini-lecture and brings closure to the lesson.

F. Statement of the Problem

At the start of this study my working hypotheses were that the interactive student-controlled environment of Cockpit Physics and small cooperative learning groups would provide the social context and community for learning that second tier students need. and, that the female students in Cockpit Physics would have a more positive attitude toward physics than the female students in the control classes. First tier students would also flourish in Cockpit Physics. The direct application of the context of flight to a future as an Air Force Officer would provide students a connection between what they are studying and the larger world.

The purpose of this study is to determine if Cockpit Physics provides the interactive student-controlled environment and social community that second tier students need to learn physics. In light of the under-representation of women in physics, this study examines whether Cockpit Physics results in a more positive attitude toward physics for female students. Considered also are the experiences of the instructors teaching Cockpit Physics to identify instructor attitudes and teaching methods which could give insight into student attitudes and performance in the course. This study uses four sections of Physics 110 as a control comparison.

To reach this goal the following specific research questions were addressed by this study.

Research Question 1:

Does the interactive nature of Cockpit Physics provide the social context and student centered learning environment desired by many second tier students?

Research subquestion 1a:

How does the affective impact of the interactive, computer based, cooperative learning environment of Cockpit Physics differ from the small class lecture and lab environment of the control class?

Research subquestion 1b:

Is there a difference in the attitude of the female students in Cockpit Physics as compared to the attitude of the female students in the control class?

Research subquestion 1c:

What is the interactive nature of Cockpit Physics and of Physics 110 Control?

Research question 2:

Do the Cockpit Physics students demonstrate a greater understanding of the Physics 110 learning objectives than the Physics 110 Control students?

Research subquestion 2a:

Do Cockpit Physics students score higher than Physics 110 Control students on periodic exams that test matched learning objectives?

Research subquestion 2b:

How do Cockpit Physics and Physics 110 Control students compare on the Force Concept Inventory, a conceptual assessment instrument also used in the study of Studio Physics (Appendix III-E)?

Research question 3:

How does teaching Cockpit Physics compare to teaching Physics 110?

Cockpit Physics has all of the components of innovative teaching: employing new technologies, tackling real world problems, encouraging cooperative learning, rewarding good teaching, exploiting every day materials, and teaching teachers to teach better (Culotta, 1994).

CHAPTER II: REVIEW OF LITERATURE

Several physics courses have components similar to Cockpit Physics. Further, the design and implementation of Cockpit Physics rely on research related to student attitudes towards physics, women in physics, cooperative learning, and teacher preparation. Each of these components contains elements of others. For example, studies involving student attitudes towards physics overlap greatly with studies of women in physics. Thus, each of the sections below have descriptions of studies which overlap with those in other sections.

A. Attitudes Towards Physics

In They're Not Dumb They're Different Stalking the Second Tier, Tobias (1990) documents the experiences of students in introductory college physics and chemistry classes, and provides insight into the affective domain of these students. Tobias' students had already been academically successful in advanced study in other academic areas. Thus, she labeled them "second tier" students--ones who could complete a science curriculum but had chosen not to.

The students recorded in journals their experiences with the instruction, the course material, and their classmates. The second tier stand-ins struggled with the introductory physics courses emotionally and identified many features of the traditional science lecture that were not conducive to their learning. These students were accustomed to learning as a class, through group discussions, and consensus. In science courses they felt that they were mere receivers of knowledge and had nothing to contribute to the course. They perceived that their role was to sit passively and receive knowledge from the "experts."

With one exception Tobias' students were successful in their audit course in terms of grades. These students were not dumb, they just wanted to learn in a different environment than they found in introductory science. Tobias proposes that if we are to encourage students to become future scientists then we need to pay attention to the kind of community that would encourage second tier students to stay in the sciences.

An example of a second tier student is Eric, a summa cum laude literature graduate from Berkeley, who audited the summer session of introductory calculus-based physics at the University of Arizona. Eric had a full compliment of high school math and science courses in his back ground and had entered college with some motivation to pursue a career in science but the summer session of physics was Eric's first experience with science since high school. He had initial anxiety about the class, and recorded in his journal that the other students looked 'bored" or "scared." His own math ability concerned him, and his anxiety was reinforced by the instructor's attitude. On the first day of class the instructor implied that since *he* had made it through the "elementary grind" so must *his* students (p.20). Eric immediately perceived the introductory course as something to endure rather than enjoy.

Eric noted early on that each lecture was a series of problem-solving sessions with a focus on "how" questions rather than "why" questions. Neither the instructor nor Eric's classmates seemed interested in anything more than the mechanics of obtaining the solution to a problem. Eric felt patronized by the teaching style (p. 21).

> I still get the feeling that unlike a humanities course, here the professor is the keeper of the information, the one who knows all the answers. This does little to propagate discussions or dissent. The professor does examples the "right way" and we are to mimic this as accurately as possible. Our opinions are not valued, especially since there is only one right answer, and at this level, usually only one [right] way to get it.

Though Eric eventually became accustomed to the lecture and problem solving style, he continued to be plagued by his need to know "why" physics principles worked, not just that they worked. Eric suspected that physicists invented "fictitious" forces, such as the normal force, to make their theories work.

Eric noted that the interest of other students in the class seemed to be limited to solutions of homework problems or comparing exam grades. Eric wrote "Nobody seems particularly interested in making friends or seeing each other outside of class. This may be one reason people dislike math and science classes, their lack of community" (p. 23). The lack of community in the class was something that made Eric uncomfortable. In fact, the community seemed hostile and competitive. Eric earned an A on the first exam and discovered that his classmates saw him as a threat to the grade curve. The class actually was not being graded on a curve, but the students were fixated on grades. Eric wrote that this competition for grades precluded the desire to work cooperatively with anyone. Despite the hostile environment, Eric was impressed with the other students' perseverance. "People think, 'yes, this is dull, but I have to complete this course to get my degree or to get a good job'(p.24)".

Eric was also frustrated by the pace of the course and the lack of identifiable goals and linkage between concepts. He identified the need for a story line. The pace of Eric's course was accelerated because of the summer session, but Eric still identified the need for more understanding and less content, i.e. "less-is-more." "I wonder how much they, or rather we, will retain. I think that a slower pace and more in-depth discussions of the contents would, in the end, prove [more] beneficial" (p. 25).

Despite his frustrations, Eric did well in the course. He maintained a 92 average going into the final exam. Eric is an excellent example of a student who can do physics but chose not to, and still would choose not to based on his experiences auditing an introductory course. The lack of cohesive identifiable goals and links within the subject matter kept Eric from feeling that he had truly learned the course material. The lack of student involvement and a feeling of being "talked at" kept Eric from enjoying the course. The "classroom culture" was competitive and non-supportive.

Jacki's experiences auditing a regular semester of introductory physics were similar to Eric's. Jacki was a graduate student in creative writing and majored in English as an undergraduate at Yale. Unlike Eric, Jacki started the course without anxiety and actually looked forward to satisfying her intellectual curiosity. Jacki's enthusiasm died quickly as she was frustrated by the "missing overview" of the course. She felt that the exclusive problem solving aspect of the course lacked an intellectual application of the concepts of physics. Jacki, like Eric, felt belittled by the lecture experience and lack of student participation. "Lectures in physics can be incredibly passive experiences for students, particularly dangerous for those who believe [as Jacki sometimes did herself] that if they can follow the professor, they've mastered the material" (p.36).

> I never really knew where we were heading or how much, in the real scheme of things, we had already covered. Each topic the professor discusses feels like it's being pulled out of a hat. So the general feeling I was left with was that physics was endless, that there would always be one more complex way of describing motion...I was made to feel too much like a naive child, whose parent tells me one small thing at a time, making everything seem equally mysterious" (p. 38.).

The pattern continued with the experiences of Michele and Vicki and many others. All of the second tier stand-ins commented on the lack of community within the introductory course, and shared a frustration with a lack of cohesion or story line to the course.

> "For our auditors, that focus produced a certain *tyranny of technique*. They hungered --all of them- for information about how the various methods they were learning had come to be, *why* physicists and chemists understand nature the way they do, and *what* were the *connections* between what they were learning and the larger world" (p.81).

After reading the experiences of these students, one is left wondering if "more cooperative and interactive modes of learning" were part of the introductory course, would the second tier stand-ins, and other students like them, have pursued a future in physics? (p.70)

B. Women in Physics

The number of women in physics is startlingly low. For the academic year ending in 1994 only seventeen percent of all physics bachelor recipients were women. The statistics become increasingly discouraging at higher levels in academia. Only thirteen percent of all physics graduate students are women, and less than five percent of the Full Professors in Physics departments offering doctorate degrees are women (American Institute of Physics, 1994, & American Institute of Physics, 1995). The reasons that so few women start and continue with a career in physics are complex. The experiences of women in physics are not unlike those of women in medicine, engineering, the military, or other nontraditional fields, yet, the percentages of women earning degrees in physics is consistently lower than these other fields (American Institute of Physics, 1995).

Female physics students especially suffer from an absence of community or social learning atmosphere in their introductory science courses. Female students repeatedly express not only the lack of a supportive community, but the presence of a hostile community. Vicki's story, documented in They're Not Dumb They're Different Stalking the Second Tier, exemplifies what Tobias refers to as the female factor. Vicki was a fifth-year senior majoring in anthropology at the University of Nebraska when she audited the standard calculus-based introductory physics course with seventy students enrolled in the class. Unlike the other second tier stand-ins, who were clearly above average students, Vicki was an "average" student. She was a triple minority in her physics class, she was a woman, a social science major, and a participant observer. The need for a social learning climate for the female students was evident even to the course instructor, who noticed by mid semester that the female students had begun to "cluster".

Vicki's experiences reveal what makes introductory physics difficult, even alienating, for many students, especially women. She was put off by the "attitude of the discipline" that she felt her instructor imparted in lecture and that she felt in the competitive nature of the class. The instructor spoke of the accomplishments of great Nobel Prize winners, mostly men, who worked independently. Vicki characterized the nature of the classroom as "destructively competitive". "People act differently in physics. The seating arrangement militates against being social, integrated. There are lots of atomized individuals with desks placed between them. Physics is not a place where people befriend one another" (p. 64).

Vicki documented frustration with trying to study with her male classmates. When she was trying to read the text during a study session, one of her male classmates responded "You are too worried about the concept...Let's just do the problem" (p. 66). Vicki, like Eric, wanted to know the "why" to a problem, not just the "how". The significant difference between Vicki and Eric, however, is that Eric assumed the problem was with the discipline and teaching method. Vicki assumed the problem was with herself. She assumed that her interest in concepts was not serving her well and vowed to change her habits: "She was impressively self-critical of her own failure" (p.68).

Vicki's story reminded me of a recent conversation with an Army Lieutenant. She had been a physics student in my class at West Point several years earlier. I recognized her at a social gathering, and introduced myself. She said, "Oh, I am so embarrassed, I was terrible in physics." This woman is successful and self confident by any societal standard. She graduated from West Point and is serving her country as a career military officer. Yet, over four years later, she still internalizes her perceived failure in physics.

Vicki's observations that physics class is an "unfriendly" place correspond to the findings of a University of Michigan study on why women do not choose to major in math, science and engineering. Women, more than men, tend to be uncomfortable working in a highly competitive environment (Manis, Thomas, Sloat & Davis, 1989). Female students in an activity-based course at Dickinson College noted that the stress of an introductory physics course can overwhelm even good friends. " My lab partner and I are best of friends but...when we had physics, and again sometimes when we'd do our homework, we hated each other" (Laws, 1995, p.83).

The second-tier students in Tobias' study felt like receivers of knowledge. Their only choice was to be passive bystanders receiving knowledge from the experts. This mode of learning has been identified in the work done by Perry (1970) and Belenky, Blythe, Clinchy, Goldberger and Tarule (1986). In Forms of Intellectual and Ethical Development in the College Years (1970), Perry identifies basic dualism as an initial epistemological stage for male college students. The student sees the world from two perspectives, black and white, right and wrong, we and they (Perry, 1970). Physics students get the right or wrong answer; the students are the we, and the professors are the they.

In Women's Ways of Knowing, Belenky and colleagues identify the epistemological stage of received knowledge or listening to voices of others, which corresponds to Perry's dualism. Received knowers can be open to what others have to say yet have little confidence in their own ability to speak. Belenky and her colleagues found most of the women who held this position were young students just starting college. The significant difference between male dualism and female received knowledge, however, is that the male students tend to identify with the authority figures dispensing knowledge, while female students do not (Belenky, *et al*, 1986).

> That women identify less with authorities might be accounted for by the fact that the authorities they meet do not include women in their "we." The women we interviewed spoke, for instance, of science professors who communicated their beliefs that women were incapable of making science.

On the other hand, the problem of identification goes both ways. Older male professors were students in a time when family roles and structures were dramatically different. Smith, a male chairman of the physics department at Princeton University said "It makes it very difficult for older males to relate to the situations young women face. And they probably don't identify with us very well either" (Raffalli, 1994).

The feeling of separateness from their classmates and professors creates an unfriendly physics classroom because female epistemology is rooted in a sense of connection, (Belenky, *et al*, 1986). An example of the unfriendly classroom and its impact on one female student is illustrated by the actions of a research professor at the University of Washington. On the first day of class he told all of his students that he was teaching because it was required for tenure and that he would rather do research. On the second day of class he used a red marker on the overhead projector. A female student raised her hand and politely asked him not to use a red pen because it was hard to read. On the third day of class, the professor again used a red pen. Again the same student asked him not to, and he switched to a black pen. On the fourth day of class, the professor started again with a red pen. The student walked out of class. On the fifth day of class the professor caught himself using the red pen, looked up and said "Oh good, she is gone" and continued to use the red pen.

Tobias' second tier stand-ins were also frustrated that the other students in the class were not interested in the "why" questions of physics and only wanted to know the right answer. Possibly because the second tier stand-ins were older students, they had developed beyond a dualistic or received stage of knowing. The other students in the class were perhaps comfortable receiving knowledge.

There are absolutes in math and sciences. You feel that you can accomplish something-by getting something down pat. Work in other courses seems to accomplish nothing, just seems so worthless. It doesn't really matter whether you are right or wrong. Um-hm. [Laughs.] You can't say. It's all guesswork" (Belenky, *et al.* 1986, p.42).

Although female students in physics may mature out of the received stage of knowing as they move to more advanced courses and graduate school, their need for connectedness and a social context for learning does not change. The results of the 1993 Department Climate Study conducted by the American Physical Society and the American Association of Physics Teachers recorded these needs. The report also clearly shows that the academic climate in most physics departments has a more negative effect on the female students than on the male students. For example,

> - Only about one third of the physics graduate students surveyed rated their department as encouraging self-confidence. Fewer women who are U.S. citizens rated the environment as encouraging self-confidence compared to men and non U. S. citizens.
>
> - U. S. females were less likely than U.S. males to report that their principal advisors, the physics faculty, and other graduate students treated them like colleagues.
>
> - U.S. females were less positive about the ease with which physics faculty, other graduate students and other students in their research groups discussed ideas with them.
>
> - Females are more likely than males to belong to study groups and find them more useful. This result was consistent with both undergraduate and graduate students.

The report concentrates on graduate student responses. For a variety of possible reasons related to sampling procedures essentially no gender differences appeared among undergraduates who responded to the study. The findings of the Climate Study are based on surveys completed by graduate students in physics and by undergraduate members of the Society of Physics Students. These are first-tier students. If only a third of these students find the climate in their physics department encouraging, what is the climate in the Physics Department doing to the self confidence of the second tier students? (American Institute of Physics, 1995).

A study of female science and math majors at an all women's college conducted by Rayman and Brett (1985) identified factors which helped female students persist in math and science. Although the Rayman and Brett study and Tobias have different research methodologies, they identify similar trends. Tobias identifies the lack of community in science as a major factor in why students do not continue past an introductory level. Rayman and Brett identify the presence of a supportive community as the reason so many of their students stay in science. Tobias identifies students who left science because they felt isolated and unprepared. Rayman and Brett identify students who stay because they are not isolated and are well-prepared. Competition was a key negative factor for Tobias' students (Tobias, 1990). Competition was less of a negative factor for the women in the Rayman and Brett study. Women historically have difficulty competing with men, a phenomena known as the Horner Effect (Kerr, 1985). In an all women's college students do not have this additional emotional obstacle.

Tobias' second tier students, both men and women, identified similar negative classroom characteristics. In creating an environment that is more supportive for female students we are likely to be creating an environment that is more supportive for all students. Equity is essential for excellence in schooling (Shakeshaft, 1986).

C. Computers as an Integrated Learning Tool in the Physics Classroom

Computers have been used to varying degrees in physics classrooms and laboratories for over two decades. Many recent initiatives in the introductory physics course specifically involve the integration of computers in the classroom. Studio Physics at Rensselaer, Workshop Physics at Dickinson College, and Concepts of Physics at Kansas State University are examples of major physics education projects integrating computers into the classroom. This review focuses on the use of the computer as a integrated learning tool in the classroom, not simply for a demonstration or as a data analysis tool.

Wilson at Rensselaer has been teaching physics for over 20 years and recognized that although attempts to spice up lecture were commendable, they were not enough. A group of national experts was convened to develop a novel approach to the introductory course at Rensselaer. The group consensus was "to reduce the emphasis on lecture, to improve the relationship between the laboratory and other components of the course, to scale up the amount of doing while scaling back the watching, to include team and cooperative learning experiences, to integrate rather than overlay technology into all of the courses, and above all to do so by reducing costs!"(Wilson, 1994, p. 519-520). Studio Physics was designed to meet these lofty objectives.

In Studio Physics lecture is de-emphasized and technology is emphasized by making the computer the primary learning tool in a small group setting. The approximately 700 students are divided into twelve sections of fifty to sixty students. Previously students met with instructors for six hours a week in lectures, labs, and recitations. Now, the students meet for four hours a week, all in the same setting--a studio classroom. The studio is configured so that students work in groups of two at six-foot long work stations. The groups expand to four sometimes out of necessity for the use of available equipment, and sometimes by the choice of the students to have more collaboration. Studio Physics was field tested with a limited number of students during the academic year 1994-1995 and has since been adopted for the entire introductory course.

In Studio Physics the student computer workstations form concentric ovals about the instructor's table and face away from the instructor. The students sit on swivel chairs so that they can face the instructor without the distraction of the workstation. Also, the instructor can quickly see which students are paying attention, or at least facing the instructor (Wilson, 1994).

A typical Studio Physics class is 100 minutes long. The class begins with a discussion of assigned homework, similar to a traditional recitation period. Next, the laboratory activity of the day is introduced with a demonstration. For example, if the class is studying projectile motion, a student will throw a ball. The ball's motion is captured on video, digitized into the computer, and made available over the network to all workstations. The students can then analyze the data using spreadsheets and graphing tools. Lab reports are submitted electronically. While the students are working at the computers, the professor, a graduate student, and two undergraduate physics majors roam the room answering questions. The class ends with a closing discussion of the theory developed in the lab activity (Wilson, 1994).

A common fear of the Studio Physics format is that the computer is replacing the professor (Wilson, 1995). However, the students spend at the most forty minutes of class time on the computer. The students still have assigned text readings, written homework, and exams. They also have twice the number of hands-on learning opportunities as in the standard course (Wilson, 1994). This balance of teaching methods may be the healthy mix of instructional techniques needed for a successful course (Taylor, 1988).

Another fear of the Studio Physics concept is financial. Wilson; however, reports cost savings over the traditional lecture format. A significant portion of the cost savings is in the reduced person-hours that the professor spends in the classroom (Wilson, 1995). Skinner (1988) contends that student and instructor attitudes towards the use of computer-aided instruction may be just as important as cost factors. Although expense is a significant consideration in any educational development, the Air Force Academy is not implementing Cockpit Physics as a cost saving measure.

In 1994 Cooper used qualitative and quantitative techniques to study Studio Physics. The students were given the Force Concept Inventory as a pre- and post- test (Appendix III-E). The Force Concept Inventory is a twenty-nine item multiple choice evaluation tool developed by Hestenes, Wells, and Swackhamer, to measure student understanding of force. Force is the central concept of Newtonian mechanics, and Newtonian mechanics is a central concept of most introductory physics courses (Hestenes, Wells, & Swackhamer, 1992, & Hestenes & Halloun, 1995, & Halloun & Hestenes, 1995). Rensselaer did not use a control group but compared its results to the national data base of scores on the Force Concept Inventory. The mean pre-test score for the Studio Physics students on The Force Concept Inventory was 51.6%, with a standard deviation of 18.9%. The mean post-test score was 62.2% with a standard deviation of 19.2%. These results are consistent with those from traditional classroom settings but below those expected by the authors for successful interactive teaching (Cooper, 1994).

However, a dialog on what the Force Concept Inventory actually measures is underway (Huffman & Heller, 1995 & Heller & Huffman, 1995). Huffman and Heller of the University of Minnesota (1995) conducted a factor analysis on the Force Concept Inventory. They found that the items on the Force Concept Inventory are loosely related on a variety of ambiguous factors, not grouped into the six conceptual dimensions that the Force Concept Inventory authors claim to be measuring. Huffman and Heller caution that although the Force Concept Inventory is a reliable means for evaluating learning, it might measure bits and pieces of student knowledge, and familiarity with a context, rather than a conceptual understanding of the central concept of force.

Cognitive understanding of physics concepts in Studio Physics was also assessed using student interviews during problem solving sessions. The problems were adapted from many sources but were chosen for their depth and richness of content. Cooper found that as the semester progressed, students were more able to explain the physics behind their mathematical problem solving. She recognized, however, that at this point the students also had considerable practice in explaining their solutions. More detailed explanations may have been a result of a greater understanding of physics concepts, or a result of practice in articulating the concepts.

The cognitive gains of Studio Physics may on the surface seem unimpressive. However, the students performed as well as previous classes, with a one third reduction in class time (Wilson, 1994). The real gains of Studio Physics, and the basis of the decision to switch to the studio format for the entire course at Rensselaer, are affective gains (Wilson, 1995). Cooper assessed student and instructor opinions about the course with interviews and questionnaires. Seven of nine students interviewed would choose the studio format over a traditional course. Immediacy and a variety of applications and interactions were the main reasons given. In an end of course survey 60% of the students said that they would choose a studio physics course, 37% would choose a traditional course, and 3% were undecided (Cooper, 1994).

When describing Studio Physics as the guest speaker for the Kansas State University Provost Lecture Series, Wilson asked the audience what came to mind when they thought of a studio (Wilson, 1995). My first image was of an artist's studio, of potters working with clay. The people in a studio do not just sit there, they are active and they are creating something. In the case of Studio Physics, they are hopefully creating knowledge of physics. Wilson indicated that instructor ratings continued to be significantly higher than for the traditional course, dispelling the possibility that the novelty of the course was the reason for positive feedback (Wilson, 1995).

Laws had been a teacher of physics for about 20 years when in 1985 she began to question traditional teaching methods. She recalls the bored expressions on the faces of her students in a physics lecture. The lecture class at Dickinson College was being taught by one of the college's most talented lecturers. If a recipient of an award for distinguished teaching couldn't inspire students, then who could? At the same time, Laws and her colleague Boyle were successfully using motion, temperature and light sensors interfaced with Atari computers to allow students to collect real time data in the laboratory. The students in these labs were enjoying the activities, enjoyment was something that Laws had not observed in lectures. The dismal performance of Dickinson's students on the Force Concept Inventory in the fall of 1985 motivated Laws and her colleagues to look for a new way to teach the introductory physics course (Laws, 1991).

A decision to abandon lecture completely was comfortable only with clearly established goals for the new course:

1) Students should master enough physics to continue their studies successfully in physics, engineering, or other sciences.

2) Students should learn enough about the process of doing physics to continue learning without formal instruction.

3) Students should be able to use computers and other tools used by physics researchers.

4) Students should have motivation towards learning more about science.

These goals are similar to the goals of Studio Physics and Cockpit Physics (Laws, 1991).

Laws and her colleagues collaborated with Thornton on the incorporation of computer-based laboratories. Similar to Studio Physics and Cockpit Physics, Workshop Physics brings the laboratory, lecture and recitation into one classroom. Workshop Physics was implemented for the first time in the fall of 1987, and has been used at Dickinson College since. Workshop Physics has abandoned lecture completely in favor of hands-on experience. Students meet for three two hour sessions a week with up to twenty-four students working in groups of four.

Workshop Physics curricular materials are units which involve about one week of instruction. The course content is reduced by approximately twenty-five percent from the standard course. This decrease in content is a reflection of the "less is more" concept-- that students are better off learning fewer topics well than doing a survey of many topics. A major component of Workshop Physics is the Student Activity Guide which has explanations, questions, instructions and blank spaces for students to make notes and record data. The Activity Guide can be used with a number of standard texts or can stand alone. Students begin by considering their own preconceptions about the day's lesson, and then make qualitative observations with the experimental equipment. In this process of guided inquiry, the student has time to consider and discuss differences between his or her own ideas and observations. The next step is, with the help of a teacher, development of mathematical models and theories. The week ends with a quantitative experiment verifying the mathematical development (Laws, 1994). Periodic two-hour examinations assess the students' understanding of concepts and data analysis, as well as traditional text book problems (Laws, 1991(b)).

An interesting recent addition to the Workshop Physics experience is kinesthetics. Students are physically incorporated into experiments investigating Newton's Laws and other physical phenomena. For example, a student sits on a wheeled cart, holding the end of a bungee cord or garage door spring, in each hand. The other end of the bungee cord or spring is attached to opposite walls in the room. The student on the cart is placed into simple harmonic motion. The horizontal oscillation of the student on the cart is recorded with a motion detector, and displayed on a computer screen within the student's view. The student observes the graphical representation of the sinusodially varying forces as he or she physically experiences the forces (Pfister & Laws, 1995). The student is not listening to a lecture about a simple harmonic oscillator or watching a demonstration, the student *is* the simple harmonic oscillator.

Laws and her colleagues have used a variety of methods to evaluate the cognitive and affective success of Workshop Physics. About two thirds of the students who have taken Workshop Physics at Dickinson College prefer the workshop format to what they imagine a lecture would be. Students at Dickinson College also have shown some gains in conceptual understanding as measured by the Force Concept Inventory. Workshop Physics students at the University of Oregon however, have not shown gains on the Force Concept Inventory (Laws, 1991).

Laws has looked specifically at the impact of Workshop Physics on the female students, and contends that an important issue in evaluating the efficacy of a new curricula is whether it has the potential to close the gap between the number of males and females who choose to major in physics. At Dickinson women are choosing to major in physics at a slightly higher rate than men. However, results of a survey conducted with twenty-four men and twenty-two women in 1990 show mixed results. One of the most positive results of Workshop Physics is that freshman and sophomore women showed much less reluctance to use computers after just one semester of Workshop Physics. Only slight gains in comfort with computers were shown for male students and female juniors and seniors. Grades for male and female students were about the same, but female students reported valuing their learning experiences more than male students.

The big exception to the gains of Workshop Physics is that the female junior and senior students who answered the survey became very negative about the laboratory experience. Many of the frustrations of the female students involved stressful group interactions. Some of the groups were single sex, others involved men, but all involved competitive interactions and dominance. These women were confronted first hand with the competitive, condescending environment that Tobias' second tier students had experienced in a group setting, "My lab partner and I had two very overbearing male lab partners in our group...They even went so far as to suggest that she go to the snack bar to get us food when they thought she came up with a silly answer" (Laws, 1995, p.84).

Concepts of Physics at Kansas State University is an introductory level physics course which serves students who are preparing to teach in elementary school. Each year approximately 110 students enroll with a goal of obtaining the physics background needed to teach in elementary schools. While this course addresses a different audience than Studio, Workshop or Cockpit Physics, it shares techniques and overall goals--attitudinal as well as cognitive (Zollman, 1990 & 1994).

The instructional model used in the course is the learning cycle, which includes three different types of activities. The first activity, exploration, requires the student to explore a concept by performing a series of short experiments. Students are given a general goal, some equipment, and some general ideas about the concepts involved. They are asked to explore the concept experimentally, in as much detail as they can, and to relate it to other experiences they have had. During the second phase of the learning cycle, concept introduction, the instructor provides a model or concept to explain observations of the exploration. Frequently, the concept-introduction stage is not an experimental activity but expository statement, with student interactions, of concepts and principles. Following the concept introduction, the students move to concept application. Here, they use the concepts that were introduced and apply them to new situations. This application of the principles and concepts leads to further understanding of the theories and the models. The complete cycle has been used successfully to teach a wide variety of topics to students at all grade levels.

Because of the emphasis on student-centered activities, a learning cycle class usually has an enrollment of less than thirty students. However, the economics associated with small class size has limited adoption of this method at many universities. To overcome this difficulty, Zollman adapted the learning cycle for a class of about one-hundred students with one faculty member assigned to teach it. During the past nineteen years the course has evolved into one with an emphasis on the nature of science and on learning science by doing scientific activities. Students complete explorations and applications on a self-paced basis and in small groups. The equipment for these activities is available for approximately thirty hours each week. During Monday, Tuesday, and Wednesday the students complete about five short exploration activities. Wednesday's large class is devoted to the concept-introduction. Then, the students apply the newly learned concepts, again in self-paced groups. Friday's and the following Monday's classes complete the cycle with further application, a summary and a lead in to the next cycle.

An important component in all three phases of the learning cycle in Concepts of Physics is the use of technology. During both the exploration and the application phases, students frequently use interactive video to make observations, take measurements, and see the physics in the context of everyday experiences. During the concept introduction phase and parts of the application phase, students use a classroom response system so that they and the instructor can interact even though they are meeting with a class of about one-hundred students.

A component of the computer aspect of Studio Physics, Workshop Physics, Cockpit Physics, and Concepts of Physics is the use of digital video, which has been studied extensively by the Physics Education Research Group at Kansas State University. For many years interactive video has allowed students to analyze data from real world events. The problem has been, however, that because videodiscs are relatively expensive to create, the videos that students analyze are of canned experiments and are provided by the instructor. Digital video capture programs have now made it possible for students to capture data from their own experiments (Chaudhury & Zollman, 1994).

Video digitizing boards digitize the analog signal from a video source and store the information on a computer disk (Zollman, 1994). One of the advantages of digital video is that students can capture on computer disk an everyday event and examine the motion one frame at a time. Interactive digital video allows the student to control the speed of the investigation, and allows the student to choose the motion to investigate (Zollman & Fuller, 1994).

A potential benefit of the computer as an integral tool in the learning process is the requirement for student hands-on activity. A study of at-risk high school students conducted by Swan and Mitrani (1993) proposes that significant changes in educational structure as a result of the use of computers will appear first at the level of the student. Although the Swan and Mitrani study does not involve the use of computers specifically in the physics classroom, it emphasizes the interactive nature of the computer as an integrated learning tool. The study "demonstrates that teaching and learning in computer-based classrooms is significantly more student-centered and individualized than teaching and learning in traditional classroom settings" (Swan & Mitrani, 1993).

Swan and Mitrani recorded the interactions between matched pairs of students and teachers in a traditional classroom setting and a computer-centered setting. The study found significant differences in the ratios of teacher-initiated interactions to student-initiated interactions ($p<.05$), and in the ratios of group to individual interactions ($p<.01$). The study showed that in the computer classroom, the teachers initiated interactions only slightly more than the students, while in the traditional classroom the teachers initiated interactions 2.5 times as often. Also, the students initiated all interactions with the computers. Swan and Mitrani concluded that the student control over the computer, and the greater student control over student-teacher interactions, make learning more student centered in the computer classroom (Swan, & Mitrani, 1993).

D. Teaching Physics in a Context

Physics concepts presented with an application is contextual learning. The objective of contextual learning is to gain the students' interest with the context, and then teach the physics. Cockpit Physics is being presented in the context of flight and Air Force applications. The Introductory University Physics Project developed a model for contextual learning. Physics in Context was designed to motivate the introduction of physical concepts, and to provide an immediate application and significance for those concepts. A goal of the Physics in Context model development team was "to show students how physics, modern technology, the environment, and societal issues are interrelated" (Di Stefano, 1995, p. 21). These goals are similar to the goals of Cockpit Physics, Studio Physics, Workshop Physics, and Concepts of Physics.

The Introductory University Physics Project model was tested at Georgia Tech and California State at Fullerton, during the 1991-92 academic year. The first quarter of Physics in Context presented mechanics in the context of interplanetary travel. The second quarter used interplanetary communications to teach electromagnetism. The third quarter presented elements of quantum theory with the context of interference of particles (Di Stefano, 1995).

Student feedback on Physics in Context was not positive due to the early developmental stage of the curriculum materials. Yet, one of the most robust findings reported in the Introductory University Physics Project evaluation is the success of a context in providing coherence to the introductory course. Student journal keepers studying mechanics in the context of interplanetary travel frequently mentioned the context, and indicated that the context provided cohesion to the course (Di Stefano, 1995, & Di Stefano & Holcomb, 1995). The context was not as strong in subsequent sections but Di Stefano and Holcomb (1995) attribute this to the state of the course materials, not to the idea of teaching with a context.

Teaching physics in context was also the topic of a paper presented at the Annual meeting of the National Association for Research in Science Teaching in 1995. Baumert, Haubler & Hoffmann (1985) reported on three studies of gender and science interest conducted with fifth through tenth grade students. They found that the female students preferred to learn physics in the context of the human body. For example, when asked about their interest in learning more about pumping oil from great depths, only about 35% of the girls were highly interested. However, when the same physics concepts were posed in the context of pumping blood by an artificial heart, over 70% of the girls were highly interested. More importantly, topics interesting for girls are also interesting for boys, but not the reverse is not true (Baumert, Haubler & Hoffmann, 1985). A curriculum can be designed to peak the interest of the female students, and still maintain the interest of the male students. However, one that interests boys may not interest girls.

E. Cooperative learning

The second tier stand-ins in Tobias' study were put off by the competitive climate of a traditional physics environment. Cooperative learning has the potential to change this "classroom culture" of physics (Tobias, 1990). Bruffee proposes that the foundation of cooperative learning is a need to rid the traditional classroom of competition (Bruffee, 1995, p. 16).

> Cooperative learning began with the observation that competition among students sometimes impedes learning. According to the Johnson brothers and Karl Smith, when students enter a classroom, they tend to say to themselves either, Who do I have to beat in this course to get an A? or, There's no way I'm going to beat these guys-why not drop out? Cooperative learning is designed to change those questions. It wants students to ask instead, Who in this classroom can give me some help, and How can I help someone else in here?

Cooperative learning techniques have long been employed by innovative teachers. The elements of cooperative learning are (Rhem, 1992):

1) Positive Interdependence: Students must feel that that they need each other, that the success of the group depends on a group effort.

2) Face-to-Face Promotive Interaction: Students must promote each others learning. They must confront, discuss, and teach each other.

3) Individual accountability: All individuals must be held accountable for group performance. For example, the Cockpit Physics students work in small groups in class but are individually accountable on exams. This assures that all members of the group are active learners.

4) Interpersonal and Small Group Skills: Students working in cooperative groups by necessity develop a set of social skills including leadership, decision making, trust-building, communication, and conflict-management skills.

5) Group Processing: Cooperative learning groups must develop a team building mentality to succeed. Part of this mentality is taking a step back and looking at what makes the team work.

Cooperative learning has been the objective of traditional introductory physics laboratories, but has rarely been used in the lecture or recitation. In a study that did look at cooperative recitations Heller, Keith, and Anderson (1992) investigated group problem solving skills on content rich physics problems. They found that "in well functioning cooperative groups students can share conceptual and procedural knowledge, and request clarification, justification, and elaboration from one another, so a better solution emerges than could be achieved by individuals working alone" (Heller, Keith, & Anderson, 1992, p. 635). The study found that group problem solutions were significantly better than the individual solutions of even the best students, especially with respect to the qualitative analysis of the problems (Heller, Keith, & Anderson, 1992).

The gender balance of the problem solving groups was important. Homogeneous gender groups, or groups of three, with two women, solved problems better than groups with two men and one woman. In groups of three, with two men and one woman, the two men dominated the group (Heller & Hollabaugh, 1992, p. 641).

> This was true even when the female member was articulate and the highest-ability student in the group. For example, during work on a projectile motion problem, a group with a lower-ability male, a medium-ability male, and a higher-ability female had a vigorous discussion concerning the path a projectile would follow. The men insisted on a path following the hypotenuse of a right triangle, while the woman argued for the correct parabolic trajectory. At one point, she threw a pencil horizontally, firmly commenting as it fell to the floor, "There, see how it goes-it does *not* travel in a straight line!" Even so, she could not convince the two men, who politely ignored her arguments.

Cooperative learning is a form of social constructivism. A social constructivist views the continuous flow of communication and ideas as central to the creation and viability of knowledge. Language is the medium of our cognitive existence. For a social constructivist, knowledge is not viable for an individual alone, but becomes viable through communication of ideas and consensus in a community of knowers. In social constructivism, knowledge is important for its social, historical, and political impact. A social constructivist constructs community knowledge at the risk of the exclusion of the individual (von Glasersfeld, 1995). "What students do first in collaborative learning is construct knowledge socially in small groups. Then they test socially the knowledge they have constructed, first in the larger community of the class as a whole and then in the much larger professional community represented in the classroom by the teacher" (Bruffee, 1995). In cooperative learning the teacher is a coach, a guide, and a facilitator of learning. In cooperative learning, student groups are responsible for the construction of knowledge.

A 1994 study considered the impact of group composition on graded projects. The investigators explored five group compositions. Students were grouped by interests and academic performance except for one which was self-selected. The study concluded that group selection had little impact on graded performance, but had significant impact on student attitudes. The self-selected groups had the poorest attitudes about the course, their instructors, the group projects and their classmates (Brickell, Porter, Reynolds & Cosgrove, 1994). Thus, instructor-student dynamics have long been recognized as an important aspect of the traditional physics classroom. This study indicates that student-student dynamics are an additional factor in developing student attitudes.

F. Teacher Preparation

The main components of Cockpit Physics are the use of the computer as the primary classroom resource, cooperative learning, and teaching in the context of flight and Air Force applications. The implementation of cooperative leaning and technology-based learning is likely to be successful only with careful planning and preparation of the teachers (O'Donnel, 1996). Without appropriate training, teachers are apt to ignore vast amounts of significant research concerning the educational process and continue to do their absolute best at teaching the way they had been taught. Educational attitudes of both teachers and students took years to develop and will also take time to change (Hoff, 1994). "Anything new and nontrivial involves a learning curve, and the curve may be particularly steep for you and your students when you first try active learning. Students whose teachers have "spoon-fed" them since first grade resent sudden withdrawal of this support; complaints start echoing through the corridors: S/he never teaches us anything-we have to do it all ourselves." (Felder, 1996).

Sullivan (1996) indicates that making a smooth transition from a teacher-directed program to a research-based structure, such as the modified learning cycle of Cockpit Physics, requires both the adoption of new research skills and the knowledge of the rules and procedures of implementing the group process. These rules and procedures include training on all of the elements of cooperative learning discussed above and how best to implement them in the classroom. The students and teachers should develop short term goals which should be reviewed and modified periodically. Both the teachers and students should understand the goals of the learning process, one of which is to develop independent thinkers (Sullivan,1996).

The use of computers as the primary means of instruction adds another layer of complication and another requirement for teacher preparation. Kaufman et al. (1989) believes that adequate teacher training is one of the ten commandments of computer based education. Sullivan (1996) feels that this training should take place in segments over regular intervals during the school year. The training needs to include not only the use of the software and hardware, but also staff development workshops which attempt to blend theoretical information with hands-on-activities related to computers (Kaufman et al., 1989). Hurst (1994) suggests involving both teachers and administrators in the planing of training. The exact structure and content of the training depends on the subject being taught and the goals of the course, but appropriate teacher preparation is essential to implementing cooperative computer based learning (Sullivan, 1996 & Kaufman, 1989).

In developing the methodology for the study of Cockpit Physics at the United States Air Force Academy I drew on research and development in each of the areas discussed in this chapter. The studies of second tier students and women in physics led to a desire to assess the affective impact of Cockpit Physics on the female cadets. The desire to quantify the interactive nature of the classroom is based on studies of previous courses which used technology and hand-on activities. And, a cognitive assessment is necessary to show that the curriculum does not result in decreased learning.

CHAPTER III: METHODOLOGY

This study was conducted in accordance with guidelines set forth by the National Science Foundation (Stevens, Lawrenz, & Sharp, 1992). Of concern were issues of credibility and creditability. A credible study was conducted to protect the anonymity of the students and instructors, and to increase the likelihood that the results will be published in open journals. Characteristics of a credible study include the use of both qualitative and quantitative research methods, the use of previously validated measurement tools where possible, and the use of both a formative and summative evaluation.

A creditable study must ask questions that are worth asking. Studies of this nature are frequently not able to answer conclusively the question, "Which group learned more physics?" Of more interest is the question, "In the eyes of the students did Cockpit Physics provide a more conducive learning environment for the study of physics than the Physics 110 Control classes?" Although the cognitive impact of Cockpit Physics is considered, the most interesting aspect of this study is the affective impact of the course. Historically, Air Force cadets can do physics, and historically, Air Force cadets do not like introductory physics (Enger, 1995). A truly successful physics course, in my opinion, is one in which students learn physics, <u>and</u> learn to like physics.

A formative evaluation assesses an ongoing project and provides feedback during the development and implementation process. A summative evaluation is an assessment of a project's success (Stevens, Lawrenz, & Sharp, 1992). The objective of this study was a summative evaluation of Cockpit Physics.

A formative evaluation was conducted in the fall of 1995 as the Cockpit Physics lessons were developed and tested in the computer classroom with regular Physics 110 students. An example of feedback given to the course developers during the formative evaluation is that the original Cockpit Physics lessons were sequential and the instructors needed more flexibility to move about in a lesson. The instructors and students were not able to complete an entire lesson in a normal one hour class period and wanted to do only selected parts of a lesson.

A preliminary trial of the evaluation methods used in this study was conducted during the formative period. The preliminary trial of evaluation methods is a step often skipped in educational studies in the interest of time but is essential as a test of the instruments and as a test of the entire data collection process (Galtung, 1967, & Stevens, Lawrenz, & Sharp, 1992).

A. Student Population

Five hundred and thirty-six Air Force Academy cadets took Physics 110 in the spring semester of 1996. The students were freshman except for a few who were taking physics later due to a course failure or other academic delay. The cadets were assigned to twenty-four classes-- three honors sections, sixteen regular Physics 110 sections, two sections of the CD-ROM course based on *The Physics InfoMall*, and four Cockpit Physics sections. Four of the sixteen regular Physics 110 sections served as a control group for this study. All students except those in the honors and the CD-ROM course were randomly assigned by the scheduling office.

B. Data Collection on Student Attitudes and Interactions

Research question 1 is related to the interactive learning environment in Cockpit Physics as compared to the control classes. Collection of data to address this research question involved several steps. The questions and its subquestions are:

Research Question 1:

Does the interactive nature of Cockpit Physics provide the social context and student centered learning environment desired by many second tier students?

Research subquestion 1a:

How does the affective impact of the interactive, computer based, cooperative learning environment of Cockpit Physics differ from the small class lecture and lab environment of the control class?

Research subquestion 1b:

Is there a difference in the attitude of the female students in Cockpit Physics as compared to the female students in the control class?

Research subquestion 1c:

What is the interactive nature of Cockpit Physics and of Physics 110 Control?

To address research question number one data were collected using the Purdue Master Attitudes Scale, student journals, student interviews, the Maryland Physics Expectations Survey, and the Swan and Mitrani fifteen minute observation protocol. The later was used to analyze the character of the interactions in the classes. The research methods for this study also made extensive use of electronic mail. Cadets at the Air Force Academy are issued personal computers and are required to read their electronic mail daily.

Data Collection via the Purdue Master Attitudes Scale

To assess the affective impact of Cockpit Physics the Purdue Master Attitudes Scale was administered to all Cockpit Physics and Physics 110 Control students as a pre- and post-test. Both the pre- and post-test were administered by electronic mail. Students completed the pre-test before they attended their first physics class and the post-test just before the final exam.

The Purdue Master Attitudes Scales measure students' attitudes toward any school subject, vocation, institution, defined group, proposed social action, practice, home-making activity, and high school, and measure individual and group morale. The validity of the Purdue Master Attitude Scales has been established in numerous studies (Remmers, 1960). In this study the students completed the Scale for Measuring Attitudes Towards any School Subject, Form B. This instrument can be completed in five to ten minutes, is suitable for group use and can be used to measure attitudes toward many school subjects at one time (Sweetland & Keyser, 1986).

The forty-five question survey asks students to identify with a plus sign each statement with which they agree. The attitude score is the median scoring scale value of the statements marked with a plus sign. The Scale for Measuring Attitudes Towards any School Subject, Form B, the accompanying instructions to students, and the scoring table are in Appendix III-A. Because the attitudinal survey can be used to measure attitudes toward many school subjects, it was used in this study to measure attitudes toward math, physics, and computer science. Math was included because the calculus required in an introductory physics course is an obstacle for many students. Math anxiety is a significant problem for women in particular (Tobias, 1990,1993). Computer science was included in the survey because the role of computers is significantly different in Cockpit Physics from Physics 110.

To create an inventory which is appropriate for a college-aged audience several modifications to the original survey were necessary. These modifications were: The terms "Boy" and "Girl" were replaced with "Male" and "Female." The Air Force Academy cadets are of an age that "Boy" and "Girl" are not appropriate terms. The term "grade" was replaced with "USAFA Class." The line "The person in charge will tell you the subject or subjects to write in at the head of the columns to the left of the statements." was omitted because the subjects were indicated before giving the scale to the students. On question five, the term "high school" was changed to "college", and the term "pupils" was changed to "students". On question fifteen, "boys and girls" was changed to the generic term "students." These modifications were not expected to impact the validity of the Master Attitudes Scale because they did not alter the substance of the questions. The same wording and format was used in the pre-and post-test of the Master Attitudes Scale so that the validity the two observations was not compromised (Stevens, Lawrenz, & Sharp, 1992).

Preliminary trial of the Purdue Master Attitudes Scale:

In the fall of 1995 the Scale for Measuring Attitudes Towards any School Subject, Form B, was sent by electronic mail to a random sample of sixty-three cadets. Nineteen students completed the survey. No students chose to print the survey, complete it anonymously by hand, and return it through campus distribution, thus this option was deleted in the instructions for spring 1996. Also, this option would have prohibited tracking pre- and post-test attitudes of an individual student. Five students deleted the electronic survey before reading, perhaps because the message did not have a subject in its header. Also, many students may have permanently lost access to the message when the communications system was temporarily severely degraded. A similar problem with the communications network was not experienced in the spring of 1996 as the construction and relocation which caused the degradation was complete (Hoferer, 1995.). All Cockpit Physics and Physics 110 Control students in the spring of 1996 received a survey to insure a sufficiently large sample size.

Analysis of The Purdue Master Attitudes Scale:

An analysis of covariance was conducted with the post-test as the dependent variable, type of instruction as the independent categorical variable, and pre-test as the covariant to insure that no bias occurred because of unmatched groups (Wildt & Ahtola, 1978). Independent t tests (α=.05) were used to compare the post-test scores of the Cockpit Physics students to the post-test scores of the control classes.

Data Collection via Personal Journals:

Student journals which were a combination of the intimate diary and solicited compositions were kept by student volunteers. Student journal keepers were solicited during class visits at the beginning of the course, and journals were collected in the last week of class. "The intimate diary is an excellent source of data because of the level of intimacy and because it contains reflections on one's immediate experiences." (Bogdan & Taylor, 1975, p. 98) Although student journals do not approach the intimacy of a personal diary, "they can provide an important source for understanding how people structure, and comprehend their worlds." (Bogdan & Taylor, 1975, p. 98) Solicited compositions or short narratives that are composed especially for the investigator have the advantage of focusing on a single event (Bogdan & Taylor, 1975)." Solicited compositions in conjunction with the personal diary helped to focus the students on the journal keeping process. The context of flight and Air Force applications was assessed through solicited composition questions. A copy of the instructions for journal keepers, and an example of a solicited composition question are in Appendix III-B.

Preliminary trial of student journals:

In the fall of 1995 journals were kept by student volunteers in the trial Cockpit Physics class. Students had the option to keep the journal daily or weekly, but were asked to spend at least fifteen minutes per lesson on the journal. Journal keepers were given the option to send each entry by electronic mail, or to submit the entire journal at the end of the semester. Journals from six of the eighteen original volunteers (three women) were submitted. One journal contained eight entries, two journals contained two entries and three journals had only one entry. Because of the small number of journal entries received during the formative evaluation, the volunteer journal keepers in the spring of 1996 were asked to submit their entries every two weeks. Also, a reward was implemented to encourage more volunteer participation. With the cadet's permission I sent a letter to his or her Air Officer Commanding to request extra privileges for participation in the study. A sample letter to an Air Officer Commanding is in Appendix III-C. An example of a privilege that a cadet might receive is the ability to go off base on a Friday night.

Excerpts from the journals received during the formative evaluation are examples of the richness of the content of student journals. These students were responding to the solicited composition question: In which class setting (Cockpit Physics or lecture/lab) do you learn more and why? Can you give an example?

> Student # ZJ9 10/12/95 (male)
>
> "...I like the cockpit physics classes better than the lecture classes because in the lecture classes we discuss problems that the class had on problems from the previous night or over a weekend. In the cockpit physics classroom, however, we address problems that the class is having at that moment and the problems are more often explained with visual/hands-on demonstrations of whatever concept we are working on..."

> Student # ZJ1 10/29/95 (female)
>
> ".... I think I learn better in a lecture/lab setting. It's not because I pay attention in class or anything, except for when I have questions to ask. It just gives me time to read the book and I usually learn everything I need to know from the book and asking questions once in a while. Cockpit physics just makes it harder to pay attention to the book because you have to play around on the computer. Computers really can't answer thoughtful questions and sometimes you just have "gee whiz" questions you'd like to ask once in a while that the teacher can answer...."

> Student # ZJ15 10/13/95 (female)
>
> "I liked the lessons in the Cockpit Physics room, they were very interesting and we could go at our own pace. So if we needed to spend more time on one concept or the other, we could without dragging the rest of the class behind...The only problem with learning the lessons on your own is that you don't get the benefit of hearing all the other questions people ask, like you do in a lecture setting...."

One male cadet articulated frustration with his perception that only some of his female classmates were interested in learning.

> Student # ZJ6 12/5/95 (male)
>
> "First off, I think our class was a little stacked compared to a normal USAFA class room. There was as many girls as there were guys. This is not normal here. When we made groups, the girls all went together and the guys usually went together....with a few drifters....The girls made the class drag at times because of there many irrelevant questions. Also, they were harder to keep quiet than the guys. There was always 4 girls in the back who would just giggle and whisper the whole lessons, and it distracted everyone. Some girls though were very interested in learning like almost all the guys."

Analysis of student journals:

The student journals were read initially to identify attitudinal comments. Attitudinal comments were identified by key words such as like, hate, enjoy, fun, and learning. These comments were then analyzed for attitudinal trends and gender differences. Quotations representative of the attitudinal trends were selected to summarize the journal data (Bogdan, & Taylor, 1975 & Wolcott, 1990).

A trend with student journals is a computer based analysis such as a word frequency count (Pfaffenberger, 1988). The student journals for the Introductory University Physics Project were analyzed in this way. The journals were searched for key words, for example "interesting", or "story line"; and the surrounding sentences were excerpted. Journal readers combined all of the excerpts and summarized trends (Di Stefano, 1995). As a journal reader for this project, I had the unique opportunity to read many of the journals in their entirety, and to participate in the computer-based analysis of the journals. Much of the story that the students told in their journals was lost in the computerized effort to quantify their responses. Similar to Pfaffenberger (1988), I fear that taking words out of context poses the threat of dehumanizing content. For this reason, and because of the relatively small number of journal keepers and entries, the journal analysis for this study was done manually.

The use of volunteers for the Purdue Master Attitudes Scale and journal keepers does not guarantee a representative sample of the student population. However, the potential negative perception of being required to participate in this study could have had severe attitudinal effects.

Data Collection via Private Interviews:

After each exam private interviews were conducted with Cockpit Physics and Physics 110 Control volunteers and randomly selected students. During the interviews students articulated the mental process and physics concepts that they used in solving a selected exam problem, and discussed how they felt about the exam and the course in general. Focusing on the solution of exam problems was potentially less intimidating than solving a novel problem, and exams were the primary measure of success or failure in the courses. The objective was not to determine if the exams were an accurate measure of what the students learned, but to assess the affective environment through the students' discussion of an important aspect of the course.

Creative interviewing as explained by Douglas (1985) is a combination of investigative methods and interviewing. Douglas places great importance on the interview environment to include, location, attire, and the use of recording instruments. The objective is for the interviewee to feel in control, and not threatened. The subject (the student in this case) should not feel dominated or threatened by the interviewer. Ideally the interviewer would engage in small talk or chit chat with the interviewee for a period of time to insure that the interviewee is comfortable and to establish camaraderie and trust (Douglas, 1985). In this study the students who volunteered to be interviewed were made comfortable and reassured of their anonymity, but a relaxed environment of camaraderie is almost impossible to attain at a military academy. The cadets are trained to call everyone with potential authority "Sir" or "Ma'am". The entire structure runs on a hierarchical system, and Academy freshman are dominated and under the control of nearly everyone with whom they come in contact. Comfort and a relaxed interviewing environment are difficult to attain when the cadet in the interview is sitting at attention until you tell him or her to "please relax."

In an ideal situation the students would choose a neutral interview location to give them a sense of control (Douglas, 1985). Unfortunately, most available neutral locations at the Academy are too public to assure anonymity. The cadet living area is not available. the library is a small and very public place, and time is a factor. Cadets would not volunteer if they had to go to an obscure building for the interview. Therefore interviews were conducted in an office which was physically separated from the Physics Department. The office space did not contain diplomas and military memorabilia which can be intimidating and a sign of authority to a cadet. Thus, the focus of the interview was the student.

Mixed opinions exist on the use of tape recorders and note taking in interviews. Douglas feels that the use of a tape recorder is less intrusive than hand written notes, but that the use of the recorder should be introduced gradually in the chit chat phase (Douglas, 1985). Dexter (1970) went from thinking that recording interviews was a waste of time to thinking that the recording of interviews was essential for verifying hand written notes which may rely heavily on abbreviations or shorthand (Dexter, 1970). With the cadet's permission interviews were recorded.

The interview protocol began by asking students to explain the physics of their problem solution. When they were able, they stated the component of the course that they used in solving the problem (see sample protocol in Appendix III-D). I then asked them to tell me about the exam and course in general. A Socratic dialog enticed the students to display their knowledge. Physics terms were not introduced unless they were used first by the student. For example, if a student said "Well the forces are equal," my response was "tell me more about the forces" or words to that effect. I scheduled interviews at least an hour apart. The interview was designed to take half an hour, but were scheduled so that students could take a longer time.

Preliminary trial of student interviews:

A pre-test of the interview protocol was conducted with two students. Each interview had a duration of approximately fifteen minutes. The interviews were not recorded due to technical difficulties. A back up recorder was secured for the spring interviews. The low number of interview volunteers in the fall of 1995 confirmed the need for a reward system and the random selection of interviewees for the spring of 1996.

Analysis of student interviews:

Once attitudinal trends had been identified through the Purdue Master Attitudes Scale and student journals the interview tapes were listened to as a third source of attitudinal information. Student quotations which verified the trends indicated by the other two data sources were selected.

Data Collection Approach via the Maryland Physics Expectations Survey :

In the summer of 1996 the Marvland Phvsics Expectations Survev (Appendix III-E), became available for general use. This survey is designed to identify what students expect to happen in their upcoming physics course. Just as students may have alternate conceptions about the physics concepts that they learn they may also hold alternate conceptions about learning. The Survey was designed to identify misconceptions about learning physics and to see how classes affect student beliefs and attitudes (Saul et al., 1996).

Although the other data for this study had already been collected, knowing what the students expected to happen could provide insight into their attitudes. The Marvland Phvsics Expectations Survev was administered as a pre- and post-test to two sections of Cockpit Physics in the fall of 1996. Although this was not the original student population, the students were also randomly assigned freshman. The pre-test responses can be generalized to this study. The post-test responses can not be generalized to this study as many aspects of Cockpit Physics were changed in the fall of 1996. A preliminary trial of the Marvland Phvsics Expectations Survev was not conducted.

Analysis of the Marvland Phvsics Expectations Survev:

The Marvland Phvsics Expectations Survev was scored by the survey authors at the University of Maryland, College Park. Questions number six, eleven, nineteen, and thirty five indicated student expectations that were not compatible with the design and pedagogy of Cockpit Physics.

Data Collection via the Swan and Mitrani Fifteen Minute Observation Protocol:

To determine the interactive nature of the Cockpit Physics and Physics 110 Control classrooms, fifteen minute observations were made using the Swan and Mitrani observation protocol (Appendix III-F). The Swan and Mitrani protocol was developed and verified for a study with at-risk high school students in Brooklyn and Staten Island during academic year 1989-1990. The observation procedure consists of recording each separate interaction that occurs in a fifteen minute time period. Each interaction is recorded by indicating if it is teacher or student initiated, applies to the whole group, small group, or is individual, if it involves content, a process, or is miscellaneous, and, if it is a question or a comment. If an interaction has a duration of more than one minute, it is recorded in each minute of the duration. For example, if the teacher lectures for five minutes it is recorded as "teacher-initiated", "whole group", and "content" for each of five one minute recordings. Tables III-1 through III-4 clarify the observation categories for the fifteen minute classroom observations (Swan, & Mitrani, 1993, pp. 44-46).

Table III-1
Distinctions between Teacher-Initiated
and Student-Initiated Interactions

	Defining Properties	Example Behaviors
Teacher-Initiated	Teacher initiates interaction and sets agenda.	Teacher lectures, teacher manages classroom activities, teacher asks question and/or solicits comments on specific topics, teacher provides unsolicited help and/or comments, student provides requested comment on specific topic, teacher engages student(s) in conversation of any sort.
Student-Initiated	Student initiates interaction and sets agenda.	Student asks a question, student requests help, student(s) offer unsolicited comments, student requests comments, teacher answers questions, teacher gives requested comments, student(s) engage teacher in conversation of any sort.

Table III-2
Distinctions Between Whole-Group, Small -Group and Individualized Interaction

	Defining Properties	Example Behaviors
Whole Group	Interaction involves two or more student groups and generalized content.	Teacher lectures whole class, teacher gives general directions to whole class or to more than one student group, teacher disciplines whole class, teacher uses specific student example to explain general principle to whole class.
Small Group	Interaction involves one student group and generalized or specific content.	Teacher answers a group question or discusses the work of that group.
Individual	Interaction involves no more than two students and content specific to them.	Teacher gives help to a student or student pair, teacher comments on individual work, teacher engages student in personal conversation, teacher carries on multiple conversations on specific topics with two or more students or student pairs.

Table III-3
Distinctions Among Interactions Concerning Content
Process, and Miscellaneous

	Defining Properties	Example Behaviors
Content	Interaction is directly concerned with subject area content or skills being taught.	Teacher lectures, teacher helps student with content related problem, student comments on specific content, student answers content-related question.
Process	Interaction is concerned with management of the educational process.	Teacher gives directions, teacher discussed grading procedures, student requests help with technical problem.
Miscellaneous	Interaction is concerned with discipline and/or other issues extraneous to instruction	Teacher disciplines student(s) or whole class, teacher engages student(s) in personal conversation, student makes personal request.

Table III-4
Distinctions Between Questions and Comments

	Defining Properties	Example Behaviors
Question	Interaction specifically requires a response.	Teacher asks a student or group of students a question and waits for a response. Student asks the teacher, group of other students or one other student a question which requires a response.
Comment	Interaction does not require a response but is simply a statement of fact or opinion.	Teacher or student makes a comment which does not require a response. For example a student says "this is fun." Or a teacher says "Example 15 is difficult."

Observations were made of Cockpit Physics during the introductory lecture and with the students in small groups at the computers. Control classes were observed in the lecture setting. Observations of Physics 110 Control were not made in the lab setting because the number of students in each lab group varied from week to week. Sometimes Physics 110 Control lab groups had as few as two students, and often as many as six. The composition and frequency of the Physics 110 Control lab was not consistent enough for reliable observations.

Preliminary trial of observation protocol:

A preliminary trial of the fifteen minute observation protocol was also conducted in the fall of 1995. Observations during the formative evaluation identified the need for a small group observation category and the distinction between questions and comments. Appropriate modifications were made to the original survey.

Analysis of fifteen minute observations:

Independent t-tests (α =.05) were conducted to compare the ratios of number of interactions for all thirteen observational categories comparing Cockpit Physics small group to Physics 110 Control whole group, and Cockpit Physics whole group to Physics 110 Control whole group.

C. Collection of Data Related To Student's Understanding of Physics

Research question 2 addresses the amount of understanding that the Cockpit Physics and control group attained during the course.

Research question 2:

Do the Cockpit Physics students demonstrate a greater understanding of the Physics 110 learning objectives than the Physics 110 Control students?

Research subquestion 2a:

Do Cockpit Physics students score higher than Physics 110 Control students on periodic exams that test matched learning objectives?

Research subquestion 2b:

How do Cockpit Physics and Physics 110 Control students compare on the Force Concept Inventory ?

To address research question number two, data were collected using periodic course examinations and the Force Concept Inventory.

Data Collection via periodic course examinations:

Cockpit Physics and Physics 110 Control students took the same periodic examinations testing matched learning objectives. These examinations were administered in a typical university setting and were closed book. No preliminary trial of this data collection method was completed.

Analysis of periodic course examinations:

The exams were graded by the Air Force Academy faculty in a group grading process. To eliminate any possibility of bias I did not participate in grading. Independent t-tests (α =.05) were conducted to compare the scores of the Cockpit Physics students to the students in the control class on each exam.

Data collection via the Force Concept Inventory :

The Force Concept Inventory (Appendix III-G) was administered as a pre- and post-test. The Air Force Academy currently uses the Force Concept Inventory to study Physics 110 each semester but instructors have the discretion to not use class time for the test. Because some of the Physics 110 Control instructors elected not to administer the Inventory, the control group for the Force Concept Inventory is all of the Physics 110 sections to which the Inventory was administered. Although Cockpit Physics is not designed specifically to teach the concepts evaluated by the Force Concept Inventory, the Inventory authors feel it may still be a valid measure of general student learning (Hestenes, Wells, & Swackhamer, 1992, Huffman, & Heller, 1995). Also, because the Force Concept Inventory was a primary evaluation method for the 1994 study of Studio Physics, a comparison of the scores from Cockpit Physics, Studio Physics, and Physics 110 Control can be made. A preliminary trial of the Force Concept Inventory was not conducted.

Analysis of the Force Concept Inventory:

The Force Concept Inventory was scored by the Academy faculty. Independent t tests (α=.05) were conducted to compare the post-test scores of the Cockpit Physics students, physics 110 Control students, and Studio Physics students.

D. Data Collection on Aspect Relating to the Teaching of each Course

Research question 3 addresses the instructors' attitudes toward Cockpit Physics and Physics 110.

Research question 3:

How does teaching Cockpit Physics compare to teaching Physics 110?

Research question number three was addressed through evaluator observations and instructor journals.

Data collection via Instructor Journals:

The Cockpit Physics and Physics 110 Control instructors kept journals of their teaching experience. The role of the Cockpit Physics instructors in cooperative learning is an area of interest. Instructions for volunteer faculty journal keepers are also in Appendix III-B.

Preliminary trial of instructor journals:

Instructors for Physics 110 participating in the formative period of Cockpit Physics kept journals. The instructors gave me one journal entry each. The teaching and grading requirements for instructors made it difficult for them to commit time to keeping a journal for this study. In the Spring of 1996 I used solicited composition questions to focus the instructors on the journal keeping process, and asked them to submit their journals every two weeks. During the formative evaluation in the fall of 1995 the teachers, in general, were not acting as coaches but were maintaining an authority position. When students had questions, they raised their hands, and the teacher rushed from group to group answering questions, rather than focusing discussions to find an answer within their group. A common complaint of the teachers was that they couldn't possibly get to all of the questions. The course was not designed for the teachers to answer all of the questions.

Analysis of instructor journals:

The instructor journals were read to identify instructor attitudes and teaching methods which could give insight into student attitudes and performance in the course. Selected quotations document the Cockpit Physics instructors' experiences teaching a new course with new methods on which they had received no formal training.

E. Summary of Research Design

Table III-5 summarizes the research questions, data collection approach, respondents, and data collection schedule.

Table III-5 Summary of the Research Design

Research Question 1:
Does the interactive nature of Cockpit Physics provide the social context and student centered learning environment desired by many second tier students?

Subquestion	Data Collection Approach	Respondents	Schedule
1a: How does the affective impact of the interactive, computer based, cooperative learning environment of Cockpit Physics differ from the small class lecture and lab environment of Physics 110 Control.	<u>Purdue Scale for Measuring Attitudes</u>	Administered to all Cockpit Physics and control students (voluntary).	1/3/96 pre-test 5/3/96 post-test
	Student Journals	Volunteer journal keepers	week of 1/8/ 96 requested journal keepers 5/3/96 collected journals
	Maryland Physics Expectations Survey	Fall 1996 Cockpit Physics students	week of 10/12/96
	Student interviews	Cockpit Physics and Control Student volunteers	weeks of 2/12/96 3/18/96 4/22/96
1b: Is there a difference in the attitude of the female students in Cockpit Physics as compared to the female students in Physics 110 Control?	See 1a.		
1c: What is the interactive nature of Cockpit Physics and of Physics 110 Control?	Observations Swan and Mitrani worksheet for recording 15 minute student-teacher interactions	NA Principal Investigator	1 Cockpit Physics 1 Physics 110 Control per week.

Research question 2: Do the Cockpit Physics students demonstrate a greater understanding of the Physics 110 learning objectives than the Physics 110 Control students?

Subquestion	Data Collection Approach	Respondents	Schedule
2a: Do Cockpit Physics students score higher than Physics 110 Control students on periodic exams testing matched learning objectives?	Scores of periodic exams	All students Exam grading done by USAFA faculty	2/8/96 3/14/96 4/18/96 Final Exam
2b: How do Cockpit Physics and Physics 110 Control students compare on the <u>Force Concept Inventory</u>?	<u>Force Concept Inventory</u>	All students administered by USAFA Physics Department faculty	pre-test post -test discretion of the instructor

Research question 3: How does teaching Cockpit Physics compare to teaching Physics 110?

Data Collection Approach	Respondents	Schedule
Instructor journals	Instructor volunteers	1/3/96 started keeping journals 5/3/96 collected journals
	Evaluator observations	

F. Informed Consent and Student and Instructor Anonymity:

Throughout this study every effort was made to protect the anonymity of the students and the instructors. All students and instructors were told about the purpose of the research and were provided a written letter of informed consent (Appendix III-H). The names of all student and instructor volunteer journal keepers and interviewees were not released. Volunteers are referred to by number in this study as they will be in subsequent publications. For example, student # ZI1 stands for Cockpit Physics student #1 in an interview (For registration purposes Cockpit Physics was known as Physics 110Z). Interviews were conducted in an office away from the physics department, and all materials with identifying features have been kept in a locked area. The only exception to maintaining volunteer anonymity was for those students who granted me permission to notify their Air Officer Commanding of their participation. The content of the student's participation was not revealed, only that the student participated.

G. Summary

The purpose of this study is to determine if Cockpit Physics provides the interactive student-controlled environment and social community to learn physics that second tier students need. In light of the under-representation of women in physics, this study examines whether Cockpit Physics results in a more positive attitude toward physics for female students than the control classes. The <u>Purdue Master Attitudes Scale</u>, student and instructor journals, student interviews, and the <u>Maryland Physics Expectations Survey</u> provide attitudinal information. Instructor journals tell the experiences of the Cockpit Physics and control instructors to identify attitudes and teaching methods which give insight into student attitudes and performance in the courses. The Swan and Mitrani fifteen minute observation protocol assesses the interactive nature of Cockpit Physics and the control classes. An analysis of the periodic examinations and the <u>Force Concept Inventory</u> identify if the students in Cockpit Physics demonstrated a greater understanding of physics than the students in the control classes.

CHAPTER IV: RESULTS AND DISCUSSION

The Purdue Master Attitudes Scale, student journals, student interviews, instructor journals, and the Maryland Physics Expectations Survey helped develop a clear picture of student attitudes about Cockpit Physics. The data sources provided clear attitudinal distinctions between the Cockpit Physics and the Physics 110 control classes. The results of the Swan and Mitrani fifteen minute observation protocol quantified the interactive nature of Cockpit Physics and the control classes, and verified the observations reported by the students in their journals and interviews. The cognitive impact of Cockpit Physics was assessed through periodic course exams and the Force Concept Inventory.

A. Student Attitudes and the Interactive Nature of Cockpit Physics

The Purdue Master Attitudes Scale was administered to all Cockpit Physics and Physics 110 Control students as a pre- and post-test. Table IV-1 shows the pre- and post-test scores in math, physics and computer science of both the Cockpit Physics and Physics 110 Control students. Higher scores indicate a more positive attitude toward the subject. Important results are in bold type.

Table IV-1
Mean pre- and post-test scores for
The Purdue Master Attitudes Scale

Group	Math		Physics		Computer Science	
	pre	post	pre	post	pre	post
Cockpit Physics	8.01 n=20 σ=1.32	8.16 n=18 σ=0.97	8.05 n=20 **σ=0.98**	7.41 n=18 **σ=2.12**	7.37 n=20 σ=1.56	6.85 n=18 σ=2.11
110 Control	8.06 n=19 σ=1.60	7.70 n=16 σ=1.36	8.11 n=19 σ=1.20	7.85 n=16 σ=1.68	7.37 n=19 σ=1.88	7.44 n=16 σ=2.08
Cockpit Physics male	7.87 n=16 σ=1.43	8.11 n=15 σ=1.05	8.17 n=16 σ=0.67	8.01 n=15 σ=1.33	7.53 n=16 σ=1.27	6.91 n=15 σ=1.95
110 Control male	8.32 n=16 σ=1.02	7.94 n=15 σ=0.98	8.35 n=16 σ=0.43	8.01 n=15 σ=1.44	7.74 n=16 σ=1.53	7.72 n=15 σ=1.57
Cockpit Physics female	8.58 n=4 σ=0.31	8.40 n=3 σ=0.27	**7.58** n=4 σ=1.67	**4.40** n=3 σ=2.96	6.70 n=4 σ=2.26	6.57 n=3 σ=2.74
110 Control female	7.11 n=4 σ=2.67	6.98 n=4 σ=1.96	7.21 n=4 σ=2.26	7.36 n=4 σ=2.16	5.99 n=4 σ=2.35	6.59 n=4 sd=3.0

An analysis of covariance was conducted with the post-test as the dependent variable, type of instruction as the independent categorical variable, and pretest as the covariant to insure that no bias occurred because of unmatched groups (Wildt & Ahtola, 1978). *t* tests indicate no significant difference (α=.05) between the attitudes of the Cockpit Physics students and the Physics 110 Control students on any of the three academic subjects tested on the pre- or post-test. Though not statistically significant, the attitudes towards physics scores dropped for both groups, slightly more for the Cockpit Physics students. The variance in the post-test scores of the Cockpit Physics students was also slightly greater than the control group.

The attitudes of the female students in physics are of particular interest. The number of observations (n=3 to 4) is not appropriate for a parametric statistical analysis, and an appropriate nonparametric test (Mann-Whitney-Wilcoxon) indicates no difference between the groups, yet strong trends are indicated (Anderson, Sweeney, & Williams, 1990). On the Purdue Master Attitudes Scale the Cockpit Physics female students' attitudes towards physics dropped from 7.58 to 4.40. This decrease in the female Cockpit Physics students' attitudes towards physics is reflected in the student journal and interview comments. A similar trend was not evident for the female students in the control classes.

To determine the interactive nature of the Cockpit Physics and the Physics 110 Control classrooms, fifteen minute observations were made using the Swan and Mitrani observation protocol (Appendix III-F). Twelve observations of Cockpit Physics were made in the whole group setting and fourteen observations of Cockpit Physics were made in the small group setting with students at the computers. Twenty-two observations were made of Physics 110 Control sections all in the whole group setting (Appendix IV-C). Independent *t*-tests ($\alpha = .05$) were conducted to compare the ratios of number of interactions for all thirteen observational categories comparing Cockpit Physics small group to Physics 110 Control whole group, and Cockpit Physics whole group to physics 110 Control whole group.

In comparing the Cockpit Physics small group setting to the Physics 110 Control whole group setting the most interesting result of the observations is that more teacher-to-student individual interactions occurred in the control setting. A mean of 0.5 (σ=1.09) teacher-to-student interactions occurred in fifteen minutes during Cockpit Physics while an average of 3.0 (σ=4.68) interactions occurred in the control classes.

Table IV-2
Significant Differences for
Fifteen Minute Observations Comparing
Cockpit Physics Small Group to Physics 110 Control Whole Group

Entries are Mean Number of Interactions in Fifteen Minutes
n= number of fifteen minute observations

Group	Teacher Initiated	Student Initiated	Whole Group	Small Group	Individual T-S
Cockpit Physics n=14	6.07 σ=4.5	20.1 σ=7.4	3.43 σ=6.9	5.14 σ=3.1	0.5 σ=1.09
110 Control n=22	18.4 σ=10.3	4.95 σ=4.16	17.0 σ=9.16	0.59 σ=2.77	3.0 σ=4.68

Group	Individual S-S	Content Questions	Content Comments	Process Questions	Process Comments
Cockpit Physics n=14	16.57 σ=8.4	6.79 σ=2.8	4.5 σ=3.1	3.36 σ=2.7	9.43 σ=6.03
110 Control n=22	0	14.1 σ=8.6	1.09 σ=1.66	2.73 σ=2.59	2.77 σ=3.5

These data and other attitudinal trends are reflected in the student journals and interviews. Journals were collected from twenty-six Cockpit Physics students (four female) and ten Physics 110 Control students (two female). The length of the journals varied from one to sixteen entries (Appendix IV-A). Interviews were conducted with thirty-seven (seven female) Cockpit Physics and thirty-three (eleven female) Physics 110 Control students (Appendix IV-B).

The Cockpit Physics students started the course with a mixture of apprehension and excitement. The students were apprehensive about the use of computers, about learning in a new way, and about physics in general. However, they were also excited about being in an experimental course and learning more about computers. By the middle of the course the students were frustrated and struggling. The greatest source of frustration for the students was not having lectures from the instructor. The students perceived that the instructor was not available to them and that they were being required to learn on their own. The results of observations using the Swan and Mitrani fifteen minute protocol verify the students' perceptions. An average of 0.5 (σ=1.09) teacher-to-student interactions occurred during fifteen minutes in Cockpit Physics, while an average of 3.0 (σ=4.68) teacher-to-student interactions occurred in the control classes. Significantly fewer teacher-to-student individual interactions occurred in Cockpit Physics than in the control classes. The following student journal quotations express the students' feelings about "missing" the teacher.

> Student # ZJ42 (female) 4/28/96
> ...If I could choose which course it would probably be a more structured traditional class unless the Cockpit style was changed by adding more teacher involvement....My partner and I worked well together, we were able to communicate well and help each other in areas that we both got stuck.
>
> Student #ZJ45 (male) 1/30/96
> today I learned more from [instructor's name] instruction on the board than from the computer lesson. I find that it's pretty difficult to understand things from labs rather than from asking questions directly to him...
>
> Student #ZJ45 (male) 2/19/96
> the computers broke down last time and we had the most learning ever! [Instructor] just did demonstrations the whole time and it was graet [sic].
>
> Student #ZJ14 (male) 5/5/96
> I don't mean to be so negative towards this class, but I feel I could have done better in a regular physics class where we're actually taught a lesson and where we go over homework problems...

A Cockpit Physics student cornered the Physics Department Head, Col. Enger, at major's night (an evening when the academic departments conduct an open house to answer questions about majoring in that subject area). The cadet expressed his concerns about Cockpit Physics and the next day sent Col. Enger and me an electronic mail message outlining his frustrations. The frustrations that this student expressed in one message are illustrative of comments made by other students throughout the semester.

Student # ZJ18 (male)
My concerns/problems with the Physics 110 Z class I am taking:

- Human/computer interaction - I think this area is a problem because the computers in the classroom are running windows 95 and NetScape 2.06, I believe. most of the students in the class have never used this software, and it took about three lessons before enough of us were comfortable enough to use it properly. Also, I feel that in general, the course may be designed to allow us to work at our own pace, however. this opportunity is greatly diminished by the large amount of problems we seem to have with the computer experiments. It seems that the primary function of the instructor in the class is to fix the computers, not to instruct.

-No lecture - This may be a personal one for me. As I mentioned in our conversation. I get most of my learning done within the classroom. Since we are expected to come to class fully prepared (not an unreasonable expectation - but sometimes unrealistic), there is rarely any lecture time and we usually start right into the computer assignments.

- Ill defined goals/objectives - Once again, I agree that this should [sic] responsibility should fall into the hands of the students, but I personally have never been clear as to what exactly we should know how to do. I do attribute this partially to my own lack of preparation. However, I know I am not the only one who generally understands all of the concepts that have been introduced this far, and who relies very little on the current course teachings and objectives.

This cadet also offered some suggestions for solutions:

-No lecture. Maybe it would be a good idea to have a short ten to fifteen minute lecture at the beginning of each class to define exactly what we will be expected to know by the next lesson. Also, on more that one occasion. I have noticed that the class picks up a concept only after seeing an example on the board. It is possible that we are not yet 'used' to this learning style and have a harder time learning from the computers.

-Ill defined goals/objectives. Once again, I think a short lecture would help tremendously in this area. If I am able to move through the computer lesson very quickly, I often think of myself, 'What did I miss?' If I knew beforehand what I am supposed to take from the lesson, I think I would be much better off.

After talking with this cadet, Col. Enger held a meeting with the Cockpit Physics developers and instructors and asked them to stick strictly to the Studio Physics format of a fifteen minute introduction. the computer lesson, and a fifteen minute conclusion to the lesson. He hoped that the problem of the students missing the teacher and lecture would go away if the instructors followed this format specifically. However the students continued to be frustrated.

At the end of the course the Cockpit Physics students divided into two groups, those students who had adapted to the course and those students who continued to be frustrated and expressed a desire to return to a regular section. This split in the attitudes of the Cockpit Physics students at the end of the semester is reflected by the variance of their scores on The Purdue Master Attitudes Scale. On the pre-test the Cockpit Physics students scored a mean of 8.05 with a variance of .98. At the end of the course the Cockpit Physics students scored 7.41 with a variance of 2.12.

Felder (1996) would expect this response to Cockpit Physics as students forced to take responsibility for their own learning go through some or all of the steps psychologists associate with trauma and grief. "Just as some students have an easier time than others getting through grief, some students enthusiastically embrace active learning and short-circuit many of the eight steps. Others have difficulty getting past the negativity of Step 3" (Felder, 1996, p.2). In general, the students who adapted to Cockpit Physics were students with first tier characteristics, they were male students, students who expressed a desire to major in a technical field, and students who had an expressed interest in science. The students who did not adapt to the learning style in general had second tier characteristics, they were female students, students who had some expressed fear of physics, and students who did not have an expressed interest in a future in science.

Cockpit Physics student # ZJ20 is an example of a student with first tier characteristics who was interested in the course at the beginning, frustrated by the lack of contact with the instructor in the middle of the course, but was acclimated to the course at the end. This cadet intended to major in Mechanical Engineering and wanted a broad technical background. He finished the course with an A. He did not volunteer to take the Purdue Master Attitudes Scale.

> 1/16/97
> I particularly liked the lab because it concerned interpreting graphs and creating functions. It also required us to know the relationship between the three different functions.
> 1/20/97
> One of the main drawbacks is the fact that there is much less teacher-student interaction. This serves to decrease the amount of expertise that the teacher can pass along to their students in the classroom environment.

1/23/97
I feel that one thing is hard to get used to is the lack of lectures. I think that this is just something that I have to get used to. I will let you know how I learn new material, as what we have done thus far has primarily been review for myself.

3/7/97
I think that I am acclimating to this new style of teaching through a process of trial and error. For normal class I had figured out what needed to be done to do well. Now I have to not relearn how to learn, but modify the old way of learning to allow for more individual accomplishment and confidence to grow in plane [sic] of relying on the teacher as much.

The following student quotation indicates the degree to which the lack of contact with the instructor was a problem for students with second tier characteristics.

student # ZJ23 (male) 2/13/96
This course really isn't too bad for someone that has had a background in physics, because it skips over alot of stuff that people presumably know already. However, for someone like me (I should have figured this out a long time ago and gotten into a regular physics class...) who didn't even take physics in high school, the fact that there is basically no teaching in the class really hurts me. I have done most of the reading, and like I said, I understand the concepts, and I'm not too bad in math, either, so if I have the right numbers in the right places I can plug and chug and get something close. But what most of the class does is something I can't - use a background of physics to mentally work through the problem, thereby avoiding all these high school problems I'm having. Like I said before, once the problem is explained, I can see where the answer came from. I'm not that dense. I guess the analysis at this point comes down to: maybe the physics placement test should have something to do with getting into this course, because you definitely need that background. And some teaching at the beginning of class wouldn't hurt, either.

The attitudes toward physics of the female Cockpit Physics students on the Purdue Master Attitudes Scale dropped from 7.58 to 4.40. The range in the female students' pre-test scores was from 4.7 to 8.5. The range of the post-test scores was 2.5 to 8.2. This drop was not observed for the female students in the control classes. Laws saw similar trends for her female students in a limited study of activity-based Workshop Physics (Laws, 1995, p.84).

Cockpit Physics student #ZJ42 is an example of a female student whose experience in Cockpit Physics was less than positive. She was optimistic at the start of the course, frustrated and missing the teacher in the middle of the course, and felt cheated at the end of the course. This student's score on the Purdue Master Attitudes Scale dropped from 8.75 to 2.5.

2/6/96

> Today we had our first over the computer lab. It was fairly interesting. it gave me a new perspective on lab work. I actually enjoyed the lab and felt that I gained the knowledge I need form it. We, the students, were actually involved in the lab, it wasn't one where we just set it up and hope that we are doing it right. In this lab it was up to us. The results were a direct effect of what we did.....So far I would have to say that Cockpit Physics will be a great learning experience.
>
> 2/6/96
> The stuff presented over the computer is great, I see applications for it and realize how it is going to effect me. But I feel at a loss because we don't get lectures and explanations from the teacher. Classroom lectures would help. Sometimes I wish that we could split the period onto two. One half have a normal physics lesson and the other half use the computer lesson. I realize that this is just another teaching method but i[*sic*] sometimes feel as though i [*sic*]am not getting a lot of the information.
>
> 4/22/96
> I generally feel cheated out of physics this year because even though I try to finish all of the homework I still so not understand everything and we are not able to have a normal teacher lecture over the material...

Another female student (student # ZJ2) wrote about her second tier characteristics at the beginning of the course. She remained frustrated throughout the course, specifically at the lack of instruction on how to use the computer.

> class #1
> I think that my negative experience with physics in the past may bias my opinions and want you to understand that in the past I have REALLY REALLY hated physics-in HS I 'skipped' the class at every opportunity. I hope that the computers help my learning and don't confuse me further-I've never used NetScape and am <u>very skeptical</u> about the Internet.
>
> class #3
> I thought that the stuff we did with the sonic ranger was 'neat' but thought that the same understanding could have been done by traditional instruction...I was <u>really</u> confused and [instructor's] explanations didn't help at all. [Partner] and I both commented about how we didn't like to be thrown into computers we didn't know how to use..<u>FRUSTRATING</u>!!!

The most positive attitudinal trend reflected in the Cockpit Physics student journals and interviews was to the hands-on nature of the activities. The following journal quotations are representative of the students' positive feelings about the hands-on activities. The positive response to the hands-on activities in Cockpit Physics is similar to the response to this type of learning at other universities (Laws, 1991). The hands-on aspect of the course kept the students' attention throughout the semester.

> student # ZJ45 (male) 2/29/96
> the little movies that the computer plays aer [sic] neat to watch. They effectively demonstrate the concept in a physical manner. I wish we could also do more physical experiments where WE get to do the stuff.
>
> student # ZJ45 (male) 3/7/96
> today was lots of fun. Little time in the room and little time on the computer.....good stuff. WE went out on the parade field and launched rockets. WE made calculations and stuff and found REAL solutions to REAL problems. IT was a lot of fun and a real educational application.
>
> student # ZJ35 (male) 1/27/96
> On the up side of things, class this week was very interesting. We did a really cool bomb drop simulation onto a tank while in class. It gave us a good chance to put our understanding of the components of velocity and acceleration as well as a fun hands on demo.
>
> student # ZJ48 (male) 1/24/96
> Upon making the calculation, and seeing our "ordinance" hit its target, I was able to better picture the usefulness of physics. Of course computers do most of the calculations with regards to guiding today's bombs, but knowing the principles that provide the input for these computers seems to be a necessary piece of knowledge. If nothing else, the bombing experiment made you feel good after you worked on a problem and then saw your results being applied to an actual circumstance.

Student attitudes concerning the use of computers varied throughout the course. No significant attitudinal trends were evident in the Purdue Master Attitudes Scale or in the student journal or interview comments. Some students liked using the computers and some did not. The majority of the positive comments about using computers related to the hands-on nature of Cockpit Physics. The majority of the negative comments about computers related to the computers taking away from lecture time. The results of observations indicate significantly more process comments in Cockpit Physics. In comparing the Cockpit Physics whole group setting to the Physics 110 Control whole group setting the only statistically significant difference reveals more process comments in Cockpit Physics. In the Cockpit Physics whole group setting there are an average of 10.2 (σ=10.2) process comments in fifteen minutes (n=12 observations), while in the control whole group setting, there are an average of 2.77 (σ=3.5) process comments (n=22 observations). These process comments were often about the use of the computer. Significantly more content questions were observed in the control whole group setting (14.1, σ= 8.6) than in the Cockpit Physics whole group setting (6.7, σ= 2.8). Without spending time focused on the computers, the control instructors were able to interact more one-on-one with the students and focus on the course content.

The data from the fifteen minute observation protocol also indicates that Cockpit Physics is more student centered than Physics 110 Control. Comparing Cockpit Physics small group to Physics 110 Control group, there are significantly more student initiated interactions in Cockpit Physics (20.1, σ=7.4 vs. 4.5, σ=4.16). Further, significantly more student-student interactions occurred in Cockpit Physics. In fifteen minutes while working at the computers, students interacted with each other an average of 16.6 (σ=8.4) times while no student-student interactions occurred in the control group setting. Students made isolated comments about working with their partners, but peer interaction did not impact student attitudes greatly. For example:

> Student #ZJ45 (male) 3/21/96
> today was pretty good. I learned more from my classmate than from the computer lesson. My partner taught me how to cross vectors which is a skill that will be a lot more helpful over time.

Students made isolated positive comments about learning in the context of flight and Air Force applications. This aspect of the course did not seem to have a great positive or negative impact on the students' attitudes.

On the other hand, the Physics 110 Control students maintained a consistent attitude throughout the course. The student journals contained isolated comments expressing frustration but no significant attitudinal trends. The results of the Purdue Master Attitudes Scale are consistent with the student journal comments in that neither their attitudinal score nor the variance in score showed notable fluctuation. The attitudes of the female students in Physics 110 Control did not change significantly throughout the course either.

The Maryland Physics Expectations Survey was administered as a pre-test to two sections of Cockpit Physics in the fall of 1996 (it first became available for general use in the summer of 1996).

Although these students were not the original population, they were also randomly assigned freshman, and knowing their expectations provided insight into the attitudes reflected in the Cockpit Physics student journals. Three questions indicated student expectations that were unlikely to be met by Cockpit Physics and were likely to predict the frustrations expressed by the students in both their journals and interviews.

Table IV-3
Results of questions related to Cockpit Physics from the Maryland Physics Expectations Survey

Students responded on a Likert scale with 1=Strongly Disagree and 5=Strongly Agree

Question	**Score**
6. I expect to spend a lot of time figuring out and understanding at least some of the derivations given either in class or in the text.	3.1 sd=1.0 n=40
11. A good understanding of physics is necessary for me to achieve my career goals. A good grade in this course is not enough.	3.1 sd=1.1 n=40
19. The most crucial thing in solving a physics problem is finding the right equation to use.	4.0 sd=0.8 n=40
35. Learning physics requires that I substantially rethink, restructure, and reorganize the information that I am given in class and that is in the text	3.2 sd=1.0 n=40

The students gave a neutral response to statement number six: "I expect to spend a lot of time figuring out and understanding at least some of the derivations given either in class or in the text.". In Cockpit Physics the information is not given to the students in the form of lecture, rather the students are expected to discuss the lesson in their cooperative groups and use the computer lesson and course text as references. They are expected to spend much of their study time figuring out the course material. If the students do not agree with this expectation, they will be frustrated by having reduced contact with the teacher and by not receiving knowledge from the teacher.

The students also gave a neutral response to statement number eleven: "A good understanding of physics is necessary for me to achieve my career goals. A good grade in this course is not enough". The students may not see physics as necessary for their career. The context of flight and Air Force applications for Cockpit Physics grew out of a desire to teach physics in a context that matches the cadet's real world experiences and to increase student motivation by having students study their own problem. The design was based on the opinion of the instructors and course developers that physics was essential to the cadet's career. If the students do not share this opinion, then a fundamental premise of the course may have been compromised.

The students agreed with statement number nineteen: "The most crucial thing in solving a physics problem is finding the right equation to use." In Cockpit Physics the students are expected to use the course text and computer lesson as resources for mathematical equations as opposed to having the equations reviewed and reinforced primarily in lecture. The students agree the equations are the most crucial thing. In Cockpit Physics they are not repeatedly given what they think is most crucial.

The students also gave a neutral response to statement number thirty five: "Learning physics requires that I substantially rethink, restructure, and reorganize the information that I am given in class and that is in the text." This response is another example that the students expect the instructor to do the thinking for them and to give them the information that they need. In a typical lecture the instructor does the thinking and presents the thought process as well as the raw material. The computer lessons and hands-on activities in Cockpit Physics are formatted so that the students must structure their own knowledge in applying the concepts to the activities. This mismatch between student expectation and course format could lead to frustration. (This lack of externally supplied structure was also a significant source of frustration for the students in *The Physics InfoMall* CD-ROM based course (Wessman, 1996.).

B. Instructor Attitudes

Both Cockpit Physics instructors and one Physics 110 Control instructor recorded their thoughts about the courses in journals. Because of the teaching and administrative requirements placed on the faculty at the Academy and the additional burden of teaching a new technology-based course for the first time, the length and frequency of the Cockpit Physics instructors' journal entries were disappointing. The most significant trend in the Cockpit Physics instructors' journals was their own frustration with the students' wanting more teacher-student interaction. The instructors felt that they were interacting with the students constantly, and one instructor felt that he was lecturing the entire class period from boards at the side of the classroom. He did not understand why the students did not perceive these interactions as lecture.

> Instructor 110Z1 6 Mar 1996
> -I can't believe it. Some surveys purport that I don't lecture enough or not at all. I'm at a loss to explain this one. My lectures go from board to board throughout the class time.

The results of the observation indicate that although this teacher was lecturing, he was doing so to small groups within the class. Comparing whole group setting to whole group setting, significantly more interactions at the small group level occurred in Cockpit Physics than in Physics 110 Control and more whole group interactions occurred in the control classes. An average of 5.14 (σ=3.1) interactions at the small group level occurred during fifteen minutes in Cockpit Physics and 0.59 (σ= 2.77), in Physics 110 Control. At the whole group level an average of 3.43 (σ= 6.9) interactions took place during fifteen minutes in Cockpit Physics and 17.0 (σ= 9.16), in Physics 110 Control. The Cockpit Physics instructors would usually lecture at the side blackboards of the classroom in response to one group's question. Only that group would listen, the other groups were busy at their computer. The teacher was lecturing and interacting with the students, but he was not able to interact with as many students as a control instructor in the same amount of time.

The instructors also wanted more control over the classroom. This result is similar to that of Kufman (1995) who found that a fear of computer technology is a lack of control. One instructor wrote frequent comments about wanting to give the students more specific guidance. He needed to maintain his authority position in the classroom as the source of knowledge. In particular, he wanted a checklist for solving each type of problem. A checklist can be useful for problem solving but does not require students to think and restructure their knowledge.

> Instructor 110Z2
> lesson #3
> -need to clearly identify the necessary equations and tell them to avoid the equations in the book that are only good for one situation, range equation...
>
> -need to add in the velocity equation on the main text instead of buried in the derivation.
>
> - Also, no instruction on how to do a FBD [Free body diagram]- we should have a checklist procedure for them (a real AF application - a check list so you can't mess it up.) I gave them one, but they did not use it. I should have made a handout and referred to it as I did problems to reinforce the idea.
>
> lesson #11
> -make a checklist for solving energy problems, I did this on the board, but a more formalized handout would work better if they thought they were doing it the pilot way.
>
> lesson #13
> -need to have a check list for momentum problems.

The other instructor was pleased with implementing a requirement that students complete a computer quiz before the end of each lesson. Using the quiz he could control the pace of the class.

> Instructor 110Z1
> 22 Jan 96
> Emphasis on completing the quizzes at the end of the lecture causes the students to proceed with a <u>much</u> improved pace.

Implementing a group computer quiz had the potential to increase cooperation within the group as a result of group rewards, an example of outcome interdependence (O'Donnell, 1996). However, the result was that completion of the quiz, and not the exploration activities, became the focus of the lesson. The instructor reminded the students repeatedly throughout the lesson to complete the quiz before the end of class but rarely reminded the students to complete the exploration activities.

Both Cockpit Physics instructors were overwhelmed with the administrative responsibilities of teaching a new course. One instructor who was also a course developer estimated that it took fifty to sixty hours to develop each lesson. Once the lessons were developed, it took him only half an hour to prepare for class. The other instructor, who was not a course developer and was less familiar with the lessons, was frustrated that he could not just do a quick review to prepare for class.

> Instructor 110Z2 lesson #5
> Same lesson as last semester, not quite-so I was not totally prepared for it. I did a quick 30 min review. For example, the cadets were suppose to drop cups and see no difference in the time of fall. I made the cadets drop them from higher up so there was a difference, which was part of a different exercise. The point was that over small differences there is no difference. But I got the exercises mixed up with cadets doing different exercises....Overall not a good performance on my part. Complacent because I had done this lesson before. Can't do a quick review like a normal class.

One control instructor kept a journal throughout the course. In his journal this instructor wrote many comments about the importance of interacting with his students. Having fun with the students was important, and he considered interacting with them essential to their learning physics. He also added extra activities to the curriculum such as a physics Olympiad, a planetarium show, and a class in the observatory.

> Instructor 110C1
> lesson 1
> Section T3-I was unhappy with my presentation. There seemed to be little chemistry between me and the class and I felt as if I was talking to an empty classroom. Did not cover unit analysis, unit conversion, significant figures, and fundamental forces (mentioned it was their responsibility to read this in the text).
> Section T5-I added a bit of discussion about the syllabus, office hours and unit conversion. Deleted one of my units examples. I think this class went much better, having some student interaction. I also felt more relaxed, perhaps because of the student "feedback" in that they seemed to be paying attention.
>
> lesson 4
> During the lesson I think I went too quickly and was a bit sloppy with my example problem (ballistic motion). Need to organize my board work!
>
> lesson 5
> Section T5- Similar to T3, except I don't think they did as well on the lesson quiz. The performance of this section is considerably lower than T3, although I think I have a better rapport with these guys. Strange.

lesson 7
Section T3- Very good class. I was very happy with the quiz in the beginning. Not much new material, so filled out the time with board work.
Section T5-Ditto except that many groups decided to their "boardwork" as a group at their desks. I couldn't interact with them as well in this configuration....

lesson 8
...the class enjoyed it...

lesson 9
...I had a lot of fun with this lesson...

lesson 11
Class went OK. Lots of extraneous discussion about black holes, general relativity, ect [*sic*].. Several questions about topics yet to be covered. Deferred most, some explained partially but eventually said it was beyond the scope of this course." Excited some but possibly confused others. Fun stuff. I need to infuse these sort of examples into my quizzes and lessons from now on.

However, the control instructor also went to great lengths to organize the class material for his students and provide a detailed review of concepts with which the students demonstrated difficulty. He was disappointed that the students did not put more effort into their homework, but compensated for their lack of effort with his own effort.

Instructor I10C1
lesson 5
Section T3-Review and then Lab Quiz and lesson Quiz took up most of the time. Anticipate poor performance an the Lab Quiz, but the review I'm sure helped the Lesson Quiz. Took an extra 25 minutes to cover the lesson material for the day. I'm afraid it was a long lecture day.

lesson 19
Section T3- For most of the class I conducted a review of what we've learned about Work and Energy, then administered the lesson 18 quiz. I think it went well. I think it's important to explain WHY the energy concept is developed, since all the problems could be solved with Newton's second law (and Euler's method) anyway. I'm not sure if they appreciated it now, but if they become Physics majors, hopefully they'll remember my homily. Ended with energy diagrams.

lesson 24
Section T3- Today was a scheduled Application lesson, but due to my cadet's performance on the last Lab Quiz, I decided a review session would be wise. Made a flow chart covering all the material from block 2 on one of the side board and basically spent most of the first hour reviewing each concept. I think it was time well spent. I tried to hammer in the notion that all the material from this block has its origins in Newton's Second Law.

Hoff indicates that as teachers we undermine student learning by doing the work for them. "Inadvertently, we tend to eliminate the need to listen well (the teacher explains in such detail that students do not need to actively search for information, develop questions, or make predictions----all skills that make students good listeners, readers, and thinkers). Without meaning to, teachers take responsibility for all the work" (Hoff, 1994, p. 46.). Hoff would conclude that the best intentions of the control instructor actually undermined student learning.

C. Student Understanding of Physics

Cockpit Physics and Physics 110 Control students took the same periodic examinations testing matched learning objectives.

Table IV-4
Results on Periodic Course Exams

Group	Exam 1	Exam 2	Exam 3	Final period 10	Final period 5
Cockpit Physics	mean= 579 82.77% n=73 σ=99.1	mean=484.76 69.25% n=74 σ=99.1	mean= 470.03 67.15% n=71 σ= 99.1	mean=1161.75 77.4% n=55 σ=99.1	mean=1118.61 74.6% n=220 σ=97
110 Control	mean=583 83.31% n=316 σ=115	mean=473.17 67.60% n=312 σ=97	mean=450.30 64.33% n=312 σ=97	mean=1179.74 78.6% n=16 σ=99.1	mean=1119.59 74.6% n=99 σ=97

t-tests (α =.05) indicate no difference in exam scores.

The Force Concept Inventory was given as a pre- and post-test.

Table IV-5
Results on the Force Concept Inventory

Group	Pre-test	Post-test
Cockpit Physics	mean= 15.20 52.4 % n=70 σ=5.21	mean= 19.0 65% n=72 σ=5.01
110 Control	mean=15.17 52.3% n=161 σ=4.74	mean=18.0 62% n=105 σ=5.3

No difference in the scores of Cockpit Physics and Physics 110 Control students were found (*t*- test, $\alpha=.05$) for either pre-test or post-test. The similarity of pre-test results helps verify the equivalence of the classes. The post-test results indicate that both groups learned concepts assessed by the Force Concept Inventory.

D. Summary

The data collected during this study indicate that the students in Cockpit Physics and Physics 110 Control learned introductory physics equally well. No significant differences are present in the students' exam or Force Concept Inventory scores. However, a significant difference occurs in student attitudes about learning. These differences were measured with the Purdue Master Attitudes Scale and are reflected in the Cockpit Physics student journal and interview comments. The Cockpit Physics students perceived that the teacher and a teacher's lecture were absent from their class. The observations confirm that the control teachers interacted significantly more one-on-one with the students. Although the Cockpit Physics students were enthusiastic about the hands-on nature of the activities, the lack of contact with the instructor was an overriding source of frustration for second tier and female students in particular.

CHAPTER V: CONCLUSIONS

The purpose of this study is to determine if an interactive student-centered environment provides the social community that second tier students need to learn physics and to develop a more positive attitude toward physics. To address these issues research questions related to student attitudes and academic performance were formulated. Answers to the attitudinal questions were sought with survey instruments, classroom observations, analysis of journals and individual interviews. Student learning of physics was assessed through class examinations and an inventory widely used in the physics teaching community. Together these data provide a view of two very different teaching methods.

A. Student Attitudes and the Interactive Nature of Cockpit Physics

The first research question addresses the relationship between the interactive and student-centered nature of the classrooms and student attitudes toward learning physics. Cockpit Physics does provide a social context to learning. The students work in cooperative groups and interact significantly more at the student-student level in Cockpit Physics than in the control classes. Cockpit Physics is also student-centered; more students initiated interactions in Cockpit Physics than in the control classes. The students did appreciate the contact with other members of their groups, and, in isolated cases, mentioned learning from other group members. However, the smaller amount of individual teacher-to-student interaction received by the Cockpit Physics students was an overriding problem and source of frustration for some students. For second tier students the negative impact of the lack of contact with the teacher outweighed the positive impact of greater peer interaction. Second tier students in Cockpit Physics remained focused on the teacher as the source of knowledge and wanted to return to a small class lecture. This result is not consistent with Tobias' expectations that the introduction of more cooperative modes of learning would result in more second tier students pursuing a future in physics (Tobias, 1990).

Cockpit Physics female students in particular struggled with the course and the reduced interaction with the instructor. The Purdue Master Attitudes Scale and student journals indicate that

Cockpit Physics did not provide a more conducive learning environment than the control classes for female students. This result is consistent with previous studies on women in physics. The female Cockpit Physics students as Tobias' female second tier stand-ins did not perceive support in the physics classroom. This result is also consistent with the 1993 Climate Study conducted by the American Physics Society and the American Association Physics Teachers which concludes that the academic climate in most physics departments has a more negative effect on the female students than on the male students.

Student attitudes toward the hands-on nature of Cockpit Physics were positive throughout the semester. This aspect of the course kept the students' attention and in some cases helped the students to see the benefit of the context of flight and Air Force applications. However, the context of flight and Air Force applications itself was not a source of great attitudinal gains. The following student quotation is illustrative of many students' positive comments about the hands-on activities, and is an example of one student's positive attitude about the course context.

> "Our class was able to get a practical (and actual working) view of how physics applies in the Air Force. This practical experience was calculating a trajectory of a dummy bomb using certain given variables. Upon making the calculation and seeing our "ordinance" hit its target, I was able to better picture the usefulness of physics. Of course computers do most of the calculations with regards to guiding today's bombs, but knowing the principles that provided the input for these computers seems to be a necessary piece of knowledge. If nothing else, the bombing experiment made you feel good after you worked on a problem, and then saw your results being applied to an actual circumstance."

The students enjoyed doing laboratory activities and using the multi-media aspects of the computer programs. However, for students with second tier characteristics the benefits of the hand-on activities were not significant enough to compensate for decreased contact with the instructor.

B. Student Understanding of Physics

The second research question addresses student understanding of course learning objectives. No statistically significant differences between groups were found in the scores of periodic examinations testing matched learning objectives, and no difference was found in the results of the Force Concept Inventory. Students in the Cockpit Physics environment did not learn more or less physics than their colleagues in the traditional course. Despite their frustration and having to adapt to a new learning method, the Cockpit Physics students did learn physics as well as the other students, as measured by classroom examinations.

C. Instructor Attitudes and Teacher Training

The third research question addresses instructor attitudes. The Cockpit Physics teachers encountered a myriad of new responsibilities: teaching using cooperative groups, the introduction of the computer as an integrated tool in the classroom, and the development of new curriculum materials to incorporate the context of flight and Air Force applications. Unfortunately, no formal training was conducted for the teachers in either group learning or technology-based learning. This study confirms Hurst's prediction, "If teachers are to use technology effectively in their classrooms, we must meet their need for adequate inservice training programs (Hurst, 1994).

For example, both Cockpit Physics instructors were highly proficient with computers, but personal expertise does not necessarily equate to expertise in the use of computers with students in the classroom. The instructors had a tendency to do the students' computer work for them. If the students asked how to do something, the instructors would often take the computer mouse and do what needed to be done. The potential benefit of the hands-on activities was reduced because the instructor was doing the activity.

The instructors also tried to answer every question rather than focus the students within their group and coach their learning.

> Instructor 110Z2
> lesson #5
> -I would like the answers to the questions in the text someplace. They could think about it, then see if they are right, instead of waiting to ask me. Not enough of me to go around to each group for this number of questions.

Cooperative learning is not designed for the teachers to answer all of the questions nor for all of the answers to be available to the students. This study confirms O'Donnell's predictions (1995) that without an understanding of how the uses of cooperative learning influence academic achievement, there is the risk of subverting that achievement.

The most significant trend in the control instructor's journal was his constant emphasis on interaction with his students and having fun. The instructor's efforts to interact with the students are reflected in the results of observation that indicate significantly more individual student-teacher interaction in Physics 110 Control. Although the Cockpit Physics instructors were also enthusiastic, they were able to interact less one-on-one with the students. The most positive finding of this study is that in terms of teacher-student interaction the small class lecture at the Air Force Academy is already a good learning environment.

D. Cockpit Physics and Studio Physics

The study of Studio Physics at Rensselaer Polytechnic Institute did not find similar trends with regards to student-teacher interaction, but did find similar positive results with regards to the hands-on nature of the lessons. Among those students who said they would prefer Studio Physics over a traditional lecture the most common reasons were (Cooper, 1994, pp.60.):

-the studio format provides the opportunity for more direct interaction of students with instructors, teaching assistants, and other students. Cockpit Physics did not show similar results. In Cockpit Physics the students received less one-on-one interaction from the teacher than in the control classes.

-questions can be asked as they arise, and answered immediately, with the possibility for demonstrations, simulations, or lab investigations readily available as needed. Cockpit Physics did not show similar results. The student journal comments indicate that the teacher was not available in the classroom. The teachers also were frustrated that they were not able to answer all of the student questions.

-integration of activities provides the opportunity to apply concepts immediately and in a variety of contexts. Similar responses were not given by the Cockpit Physics students.

-the variety of modes of interaction provides for students' different learning styles. No formal study based on learning styles was conducted for Studio Physics or for Cockpit Physics.

-responsibility for learning is shifted from the instructor to the student: it is impossible to remain passive. Cockpit Physics students were also actively involved in the hands-on activities. However, the responsibility for learning was not shifted from the instructor to the student. Second tier students in Cockpit Physics remained focused on the instructor as a source of knowledge throughout the semester.

No significant cognitive gains in problem solving skills or on the Force Concept Inventory were found in Studio Physics. No significant cognitive gains on course examinations or on the Force Concept Inventory were found in Cockpit Physics. Both Cockpit Physics and Physics 110 Control scores on the Force Concept Inventory were almost identical to scores of the Studio Physics students at Rensselaer.

Studio Physics at Rensselaer and Cockpit Physics at the Air Force Academy differ greatly in the traditional lecture class which each replaced. At Rensselaer the standard physics lecture had several hundred students. Recitation and lab classes were much smaller but the lecture was the primary instructional forum. The Studio Physics class size is sixty students with one instructor, a graduate research assistant, and two undergraduate assistants. The student-teacher ratio changed from greater than three-hundred to one, to approximately fifteen to one (Wilson, 1994). In Cockpit Physics the student-teacher ratio stayed the same as in a traditional control lecture, approximately twenty-three to one.

In Cockpit Physics the students went from small traditional class to small student-centered class and showed attitudinal losses. In Studio Physics the students went from large traditional class to small student-centered class and showed attitudinal gains. This study indicates that for affecting student attitudes the Studio Physics approach may not be significantly superior to small traditional classes, while the Rensselaer study indicates that it may be superior to the large lecture-lab-recitation format.

E. Implications for Physics Teaching

Though the attitudinal results of this study may seem discouraging, the study has merit as a comparison between two very closely matched groups. The differences between the Cockpit Physics students and the Physics 110 Control students were minimal. Both groups of students were randomly assigned freshman cadets who had gone through an extensive screening process for admission to the Academy. Academic performance, involvement in extracurricular activities, and physical fitness are criteria for admission. Once at the Academy, freshman live in a highly structured and controlled environment where outside influence on attitudes and opinions is limited. Though this environment is not ideal for personal growth, it provides a homogenous population unlikely to be found at most colleges.

The instructors also came from very similar backgrounds and experiences. All of the instructors were Air Force officers who differed in military rank by only one pay grade. They were all teaching physics at the Academy as rotating instructors. Though their regular jobs in the Air Force were different, they all had the same basic academic and professional training. Three of the instructors held Master's degrees in Physics, one held a Ph.D. in astronomy but indicated that his Doctoral work in astronomy did not give him an advantage teaching introductory physics. All of the instructors had taught regular Physics 110 in the lecture setting previously. The teachers in this study were also an unusually homogeneous group.

Both the Cockpit Physics and Physics 110 Control classes had less than twenty five students. Both were conducted in well equipped classrooms. A multitude of experimental equipment, demonstration materials, and administrative support was available to both groups.

One distinct difference between the groups was the use of student-centered activities. Active hands-on learning is what students enjoy. Throughout the semester the Cockpit Physics students made positive comments about the hands-on nature of the course. In developing and implementing new physics curriculum or in updating a current curriculum, hand-on activities should be incorporated wherever possible.

Another distinct difference between the groups was the use of cooperative learning groups with the computer as the primary instructional forum. Distinguishing between the influence of cooperative learning and the influence of technology in this case is difficult because the cooperative learning was taking place as the students worked through computer lessons. This combined aspect of the course resulted in negative attitudes because of the lack of contact with the instructor. Individual interaction with the teacher is important and cannot be replaced by peer interaction or interaction with a computer.

The introduction of technology or cooperative learning alone do not result in more learning or improved attitudes. The implementation of technology in cooperative groups requires a complete refocus of the classroom. Only a complete change of instructional approach implemented after formal training is likely to result in attitudinal or cognitive gains.

The homogeneity of the student and instructor population and the clear distinctions between Cockpit Physics and Physics 110 Control insure the internal validity of this study but severely limit the external validity. At most universities the multiple variables of diverse academic backgrounds, age, and exposure to outside influences of both the students and the instructors must be considered. The students at the Air Force Academy are a uniquely focused and motivated population. Although the context of Cockpit Physics did not prove to be a significant factor in this study, the context of flight and Air Force applications is unlikely to motivate a more diverse student population.

F. Recommendations for Further Studies

Recommended studies to address student attitudes

The main components of Cockpit Physics are student-centered cooperative learning, the computer as the primary classroom resource, and the context of flight and Air Force applications. Implementing Cockpit Physics changed three aspects of the Physics 110 core curriculum at once. I recommend further studies which isolate each component of Cockpit Physics to attempt to determine which aspect of the course contributed to the attitudinal losses due to reduced interaction with the instructor. Did the Cockpit Physics instructors interact less one-on one with the students as a result of the cooperatives groups, or as a result of the use of computers as the primary classroom resource? These issues however can not be addressed without a reasonable level of teacher preparation.

The female Cockpit Physics students' negative attitude warrants further study. Though not addressed by data, a speculative reason for the female students' negative attitude about Cockpit Physics lies in the work of Belenky (1986) and colleagues. Female students need to identify with authority figures to move past the epistemological stage of received knowledge. An inability to relate to both the instructors and the course context is a possible explanation. One Cockpit Physics instructor was a combat pilot, the other a combat navigator, and the context of learning for Cockpit Physics is flight and Air Force applications. Currently in the Air Force, no female role models are in combat flight positions, and there are unlikely to be any in the near future. In the fall of 1996, two sections of Cockpit Physics were taught by a civilian female instructor. The instructor indicated that her female students made positive comments about the course. However no formal study was conducted, and the format of the course had been changed as well as the gender and military status of the instructor. A formal study of the studio format in a small class setting which addresses the issue of the instructor as a role model could yield important information about female student attitudes toward physics.

Recommended studies to address cognitive performance

Although the Cockpit Physics students did not learn more physics than the control students, they did not learn less physics. One objective of teaching physics in a context is to increase the likelihood of transfer to other physics topics. Follow-on studies of student performance are warranted to see if the Cockpit Physics students retain knowledge better or transfer knowledge better in their follow-on physics courses.

No significant difference was found in student scores on periodic course examinations or on the Force Concept Inventory. However an analysis of the data has not yet been done to determine if the students learned the same thing. A study which looks at the individual questions on the examinations and the Force Concept Inventory would address not only how much physics the students in each group learned, but also what physics they learned.

G: Conclusions

In conclusion, Cockpit Physics provided more peer interaction and a more hands-on environment for learning. Cockpit Physics provided less one-on-one student teacher interaction than the control classes. This lack of interaction with the teacher was a significant source of frustration for the students. Students with second tier characteristics were more frustrated than students with first tier characteristics. The second tier students in Cockpit Physics had to struggle with their fear of physics, a new teaching method, and with using computers in a new way; they now had three obstacles to learning physics.

This study confirms earlier work by Kaufman about the fears of computerized learning. Kaufman et al. says:

> "There are interpersonal needs in the teaching-learning environment which computers are totally incapable of handling. It is safe to assume that not even fifth generation computers will be able to fill those needs. People need people" (Kaufman, et al. 1989, p.465.).

A Cockpit Physics student says:

> Student # ZJ15 (male) 1/20/96
> ...The teacher student interaction cannot be replaced by a computer. It is in the human nature to long for human contact and interaction, especially in learning new information. Computers are an effective tool, but this class is just another outcome of the insensitivity of the computer age. The concept of the class is good, but you still need that class time to be able to talk with the teacher and learn from his experiences. Only with such additions, will the Physics class learning experience be taken to its greatest heights.

The Academy Department of Physics slowed the swing of the Slavin's educational pendulum (Slavin, 1989). Based the results of this study and their own observations, the Department of Physics elected not to develop the Cockpit Physics materials further. Instead, the Cockpit Physics course materials are being adapted for use from the cadet dormitory for individual study. The study of Cockpit Physics did not show significant attitudinal or cognitive gains to warrant teaching the course again. The Studio Physics format in lieu of a large lecture shows promise for improving student attitudes and performance in introductory physics but may not be superior to an interactive small classroom.

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Appendix I-A: Cockpit Physics Syllabus

COCKPIT PHYSICS WELCOME LETTER
Spring 1996

Cockpit Physics is an experimental approach to teaching first year physics at the Academy. We in the Physics Department feel that to take physics into the 21st century, we must place Air Force relevant topics at the forefront. Our approach will be one of displaying an Air Force problem, weapon system, or design philosophy and then using physics to explain and clarify what is going on and why. In addition to taking a more topic driven approach, Cockpit Physics will use more advanced educational technologies like computer workstations and computer based labs to facilitate learning. So in the end, Cockpit Physics will be topic driven and technologically abundant, but will still contain very difficult and rigorous physics material.

KEYS TO SUCCESS

1. **Stay on top of your reading and homework assignments!** As with any course, grades earned in Cockpit Physics are typically a reflection of the amount of time spent going over the material. Stay on top of the assignments and read the assigned material **BEFORE** coming to class. If you get behind, you will have trouble understanding the current material because the topics will build upon one another. Use your opportunities to access Cockpit Physics material over the "Net" in your room to keep up with the pace of this course if you need to.

2. Second, take responsibility for **your** understanding and performance in this course. It is easy to fall into the trap of asking an instructor or fellow student for help **before** you really attempt the reading and/or homework problems. Remember that "problem solving" abilities are learned during that phase in which you are not exactly sure how to approach the problem but you attempt a solution anyway.

3. Finally, if you find that, despite your efforts, you are having trouble, seek extra instruction (EI)! Don't spend endless hours spinning your wheels over a particular problem. While it is important to give a good effort on each problem, there comes a point when additional time spent is probably not going to get you anywhere. Before this happens, please get help! Past experience has shown that students who seek help from other students and EI from a Physics instructors quite often recover from their difficulties and go on to do well in the course. On the other hand, those who do not get help from other students or instructors are more likely to have serious problems.

Be sure to read and then comply with the material presented in the administrative notes which follow this letter. If you have any questions about the notes, ask your instructor for further clarification. Your instructors will be working hard to make this course interesting, challenging, useful, and even fun. Work hard with us, and we will all benefit. Good luck!

Course Director, Cockpit Physics

COCKPIT PHYSICS ADMINISTRATIVE NOTES
Spring 1996

Textbook: The course textbook is **Principles of Physics** by Serway. This is a new textbook, designed, in part, with the Air Force Academy in mind (see the introductory notes in the text)! You are required to purchase and personally possess a copy of this book for the duration of Cockpit Physics. This textbook will serve as the frame work for concepts which will be woven into complex physics problems which face the Air Force. If you feel the temptation to ignore this book and concentrate only on the computer problems and labs given in class you will certainly miss the physics contained within them.

Reading Assignments: We expect you to read the assigned material prior to class!

Homework: Homework consists of questions and problems assigned in the syllabus and other exercises assigned by your instructor. For these assignments, you may work with the following persons, in addition to an instructor in this course: **anyone**. For these assignments, you may use the following materials produced by other cadets: **anything**. Your instructor will provide further guidance regarding his or her homework policy. The department does not specify that homework assignments for Cockpit Physics will be graded; therefore, documentation is not required for these assignments. While it is acceptable to work with other students on the homework, you will not perform well on the exams if other students become too large a "crutch". Put in the individual effort necessary to learn the course material and you will deepen your understanding of it.

Computer Workstation: Of any given lesson, one of the two hours of classroom instruction will be spent on a computer workstation. You will work in groups of two while you explore various Air Force related problems. All questions asked in the lesson will be answered on a sheet of paper (**The Hurdle Quiz**) and turned in at the end of class for your instructor to grade.

Course Grading: Your course grade will be based upon the following point breakdown:

	Points	% Total
3 Graded Reviews (700 points each)	2100	37%
1 Final Examination	1500	26%
6 "Debriefs"	600	11%
Electronic Quizzes	1000	18%
Instructor Prerogative (IP)	400	7%
Assessment Test(50 pts x 2)	100	2%
TOTAL	5700	100%

Late or missed work: If you choose not to turn in an assignment on the day it is due, your score for that assignment will be zero until you turn it in. If you know you will miss a class on the day an assignment is due, make **PRIOR** arrangements with your instructor regarding the assignment. Late work will lose 15% of the possible points per day of lateness. This includes weekend days and holidays.

Instructor Prerogative Points: Instructor prerogative (IP) points will be assigned to you at various times during class while you are working on the lesson, implementing a lab, or participating in class. Grading may be based on creativity, inquisitiveness, or other qualities that your instructor deems necessary.

Debriefs: There are six graded "Debriefs" in the course. A debrief requires you to work on material back in your room and turn it in at the beginning of the next scheduled class period. Your instructor will advise you of any required "pre-brief" questions or problems to be completed prior to turning in the "debrief". If you miss a period in which a "debrief" in assigned, your instructor may permit you to receive credit if you contribute substantially to the write-up. Again, your instructor may provide additional guidance. For these "debriefs", you may work with the following persons, in addition to an instructor in this course: **anyone in your two man lab group.** For these "debriefs", you may use **no** materials produced by other cadets. Because the "debrief" material represents an important component of Cockpit Physics, you **will** encounter questions and/or problems about the "debrief" write-up on the graded reviews and final examination.

Graded Reviews and Final Examination: The three graded reviews will each be given during a common GR period (lessons M13, M25, and M35 , at 0700 hr.). They will consist of multiple choice, short answer, and workout questions, problems and estimation problems. The final examination is comprehensive and will also consist of multiple choice, short answer, and workout questions, problems and estimation problems.

Equation sheets: There will be **no** course wide instructor-prepared equation sheets for your use throughout the semester. There will also be **no** course wide equation sheets prepared for your use during the GRs and final exam. You will be permitted to prepare and bring to each GR and the final exam your own summary sheet containing information you feel is helpful to you. A summary sheet template will be provided for you that will allow you to write information in a 5"x7" area. All information you want to bring to the exam with you must fit in this region (for the three GRs). The final exam equation sheet size will be determined at a later date. You will be required to turn in your summary sheet with each GR and the final exam. Summary sheets turned in with GRs will be returned to you with your graded GR.

If you are unable to attend a scheduled examination, it is your responsibility to contact your instructor (ext. 3510) as soon as possible to arrange a makeup examination.

CQ Absences: You are not permitted to miss Cockpit Physics classes due to CQ Duty if you have a deficient grade in Cockpit Physics at Prog. (Lesson 21) or if you are on Academic Probation.

Extra Instruction (EI): You are expected to read all applicable material and attempt all assigned homework prior to seeking EI. Your instructor will provide you additional guidance pertaining to his or her EI policy. If your instructor is not available for EI, there will be two other Cockpit Physics instructors, each of whom could provide you with EI. Just come to the Physics department, and someone will almost surely be able to help you.

Accessing Lessons in Your Room: You may preview or review all lessons from you computer in your room at any time. The file to start with is located on the world wide web:

http://www.usafa.af.mil/dfp/lessons/cp_home.htm

Ask your instructor for help on how to correctly configure your InterNet Browser to view all files such as: .exe, .avi, .xls, etc.

English as a Second Language (ESL) Students: If desired by the student, an ESL student will receive double time to complete all exams and quizzes except the final exam. The final exam will be designed to take two hours. All students, including ESL students, will have four hours to complete the final exam.

In conclusion: The content in Cockpit Physics is both fascinating, challenging and designed to take physics instruction into the 21st century. It has direct applications to your future academic courses and your Air Force career. Our intent is to make this class an exploration of the laws and principles that govern the universe as we know it and apply them so as to understand relevant Air Force situations and problems. Experience has shown that those who stay enthusiastic toward the class will be quite successful in Cockpit Physics. Stay ahead, work hard, and you may begin to appreciate and understand the incredible things about our world and universe!

Course Director, Cockpit Physics

Director of Core Programs

COCKPIT PHYSICS COURSE OVERVIEW
INTRODUCTORY PHYSICS
Spring 1996

BLOCK I: "THE BASICS"

1	FLIGHT PLANNING: Assessment Test: Introduction, Vectors, S.I. units and the Fundamental Interactions of Nature
2	VIRTUAL $\vec{v}$ and $\vec{a}$: *Debrief #1:* "The Sonic Ranger" (Position, Velocity, and Acceleration)
3	MUNITIONS DELIVERY I: 1 D Motion: The Kinematic Equations
4	MUNITIONS DELIVERY II: 2 D Motion: Projectile Motion
5	MUNITIONS DELIVERY III: Newton's Laws and Various Forces
6	EJECTION: Terminal Velocity, Resistive Forces, Euler's Method, Bail Out, *Debrief #2:* "Bail Out, Bail Out"(An Ejection Sequence)
7	PULLING G's I: Centripetal Acceleration, and the Centrifuge.
8	PULLING G's II: Curvilinear Motion, GR #1 Review
M-13	**Graded Review #1**

BLOCK II: "FLY, FIGHT, & WIN"

10	PHYSICS OF FLIGHT I: Work and Energy
11	PHYSICS OF FLIGHT II: Conservation of Mechanical Energy
12	PHYSICS OF FLIGHT III: *Debrief #3*: "An Uphill Battle", Conservation of Mechanical Energy
13	KINEMATIC WEAPONS I: Linear Momentum, 1-D & 2-D Collisions, Elastic Collisions
14	KINEMATIC WEAPONS II: Momentum Conservation, 1-D & 2-D Collisions, Elastic Collisions
15	MISSILE AND ROCKET TECHNOLOGY I: Momentum Conservation, Propulsion.
16	MISSILE AND ROCKET TECHNOLOGY II: *Debrief #4*: "Rocket Launch"
17	STABILITY: Stability, GR #2 Review
M-25	**Graded Review #2**

BLOCK III: "AIR AND SPACE"

19	HUEY, PAVE LOW, PAVE HAWK I: Rotational Kinematics, Angular Momentum and Conservation of Angular Momentum
20	HUEY, PAVE LOW, PAVE HAWK II: Conservation of Angular Momentum, Torque
21	HUEY, PAVE LOW, PAVE HAWK III: Moment of Inertia
22	G.P.S. I: Orbital Motion, Kepler's Laws
23	G.P.S. II: Dynamics of Satellite Orbits
24	G.P.S. III: Applications to Momentum and Energy, *Debrief #5 "Killer Satellite"*
25	G.P.S. IV: Field Trip to Falcon Airfield, GR #3 Review
M-35	**Graded Review #3**

BLOCK IV: "POWER OF THE ATOM"

27	SATELLITES TO ATOMS: Bohr Model of the Atom
28	RELATIVITY: The Beginnings of Particle Physics, Relativistic Energy and Momentum
29	PARTICLE PROPULSION: Thrust and Thrust Efficiency
30	BRIGHTER THAN A THOUSAND SUNS I: Radioactive Decay
31	BRIGHTER THAN A THOUSAND SUNS II: Binding Energy of the Nucleus, Debrief #6 "Radiation"
32	BRIGHTER THAN A THOUSAND SUNS III: Fission, Fusion Energy, and "Limitless Energy Assessment Test.

FINAL EXAMINATION (Time to be Determined)

COCKPIT PHYSICS COURSE SYLLABUS
SPRING 1996

BLOCK I: "THE BASICS"

Lesson #1

Flight Planning: Introduction, Vectors, S.I. Units and the Fundamental Interactions of Nature

Purpose: Welcome to **Cockpit Physics.** In this lesson, we introduce a novel approach to teaching/learning physics which we hope you will enjoy and benefit from. The SI system of units will be introduced along with a review of vectors. In addition, the Fundamental Forces of nature will also be presented.

Reading: Chapter 1
Questions: Chapter 1 - 5, 8, 18, 25
Problems: Chapter 1 - 17, 24, 31, 34
Handout: Experimental Physics Guide
Asses. Test: Approx. 25 minutes taken during class.
Objectives:

1.1 Know and be able to use the SI base units and the SI unit prefixes.
1.2 Know the types and relative strengths of the fundamental forces which act on particles.
1.3 Be able to define the terms "vector" and "scalar" and give physical examples of each.
1.4 Be able to express a vector in terms of its components and the Cartesian unit vectors.
1.5 Be able to calculate the magnitude and direction of a vector.
1.6 Be able to add and subtract vectors graphically and algebraically.
1.7 Be able to apply dimensional analysis to check the consistency of a given equation.

Lesson #2

Virtual Velocity and Acceleration: Position, Velocity, and Acceleration

Purpose: This lesson focuses on how to describe the motion of an object, by defining and exploring the concepts of position, velocity, and acceleration. It's important to spend the entire lesson exploring these relationships since they are fundamental to an understanding of motion. After this lesson, you should be able to describe the motion of an object through space and time and understand the relationships between position, velocity, and acceleration in one dimension. This "debrief" will include a procedure we will revisit many times during the semester, **error analysis.**

Reading: Chapter 2 - Sections 1-3
Experimental Physics Guide
Questions: Chapter 2 - 1, 13, 14, 17
Problems: Chapter 1 - 58;
Chapter 2 - 1, 4, 6, 10
Assignment: Debrief #1: "The Sonic Ranger" (Position, Velocity, and Acceleration):

Objectives:

2.1 Know and understand the relationship between acceleration, velocity, and position of an object moving in one dimension, both for averages over finite time intervals and for instantaneous quantities.
2.2 Given a graph of position vs. time, be able to plot velocity and acceleration vs. time and qualitatively describe the motion of the object.
2.3 Be able to differentiate and integrate simple functions analytically in order to determine the motion of an object.
2.4 Know the meaning of precision, accuracy, reading error, and experimental range.
2.5 Be able to calculate percent differences and properly use significant figures.
2.6 Be able to calculate the standard deviation of a set of data.
2.7 Know the meaning of error bars and be able to place them on a graph.
2.8 Know the mechanics of graphing.

Lesson #3

Munitions Delivery I: 1-Dimensional Motion and the Kinematic Equations

Purpose: This lesson continues the focus on one dimensional motion in which **acceleration is constant.**

Reading: Chapter 2 - Sections 5, 6
Questions: Chapter 2 - 7, 10
Problems: Chapter 2 - 14, 15, 18, 23
Turn In: Debrief #1: "The Sonic Ranger" (Position, Velocity, and Acceleration):
Objectives:

3.1 Understand that motion with constant acceleration is a special case..
3. 2 Be able to list the assumptions under which the kinematics equations for motion with constant acceleration are derived.
3. 3 Know the kinematics equations for constant acceleration
3. 4 Be able to use kinematics equations to solve problems of one-dimensional motion..
3. 5 Understand that all freely falling bodies experience the same acceleration.
3.6 Be able to determine the acceleration due to gravity at USAFA

Lesson #4

Munitions Delivery II: 2-Dimensional Motion, Projectile Motion

Purpose: In this lesson we now consider motion in two dimensions. The independence of motion along each dimension is emphasized. You'll find that there are some interesting Air Force applications of projectile motion!

Reading: Chapter 3 - Sections 1-3
Questions: Chapter 2 - 8, 16 Chapter 3 - 4, 16, 17
Problems: Chapter 2 - 33, 46 Chapter 3 - 2, 11
Objectives:

4.1 Know and understand position, velocity, and acceleration, defined as <u>two-dimensional</u> vectors.
4.2 Recognize two-dimensional projectile motion as simultaneous motion in two directions.

4.3 For two-dimensional projectile motion. be able to identify the acceleration in each direction and formulate the appropriate kinematics equations for each direction, given initial conditions.
4.4 Be able to solve problems of projectile motion with constant acceleration.

Lesson #5

Munitions Delivery III: Newton's Laws and Various Forces

Purpose: In this lesson, we see that accelerated motion is the consequence of applied forces. Various force types are introduced along with drag and its application to the projectile motion problem.

Reading:	Chapter 4 - Sections 1-8	
Questions:	Chapter 3 - 23, 27	Chapter 4 - 1, 2, 3,4, 9, 22
Problems:	Chapter 3 - 31, 32	Chapter 4 - 1, 2, 12, 16, 21
Objectives:		

5.1 Know and understand the content of Newton's First and Second Laws.
5.2 Know and understand the concepts of inertia and inertial mass.
5.3 Know and understand what is meant by the term "inertial reference frame."
5.4 Know the units of mass and understand mass as a fundamental property of matter.
5.5 Recognize the term "weight" as the force of gravity on an object near the surface of a planet.
5.8 Be able to construct free-body diagrams to identify the net force on each object under consideration.
5.9 Be able to sum the forces acting on a body.
5.10 Be able to use Newton's First and Second Laws to solve problems of force and acceleration.
5.11 Know and understand Newton's Third Law.
5.12 Be able to identify action and reaction force pairs according to Newton's Third Law.
5.13 Understand that the action and reaction forces act on different objects.
5.14 Know the conditions for static equilibrium of point particles, and be able to solve two-dimensional equilibrium problems.
5.15 Be able to use Newton's Three Laws to solve a wide variety of dynamics problems
5.16 Review the types and relative strengths of the fundamental forces which act on particles

Lesson #6

Ejection: Terminal Velocity, the Resistive Force of Drag, Euler's Method

Purpose: So for we've limited ourselves to study of constant acceleration situations. As you can see form the previous lessons our assumptions of "frictionless surfaces" and "no air resistance" are often not consistent with our everyday experiences. Fortunately, computers now make it possible to tackle more complex problem at the introductory level. In this lesson you will model motion numerically by applying the Euler method solving equations.

Reading:	Chapter 5 - Sections 4, 5
Questions:	Chapter 5 - 8, 13, 14, 17, 20, 21, 24

Problems: Chapter 5 - 20, 27, 29, 34, 40(a), 41(a), 42(a)
Assignment: Debrief #2: "Ejection" (Euler's Method for a Bailout Sequence):
Objectives:

6.1 Know and understand the Euler method for numerical solution of the equations of motion for problems with non-constant acceleration.
6.1 Understand air drag as a resistive force that depends on velocity.
6.2 Know and understand how terminal velocity arises as a result of a balance of forces (a dynamic equilibrium condition).
6.3 Understand that drag forces are generally nonlinear and resistant to analytic solutions.
6.4 Be able to formulate the Euler method to determine the motion of an object in the presence of velocity dependent forces.

Lesson #7

Pulling G's I: Centripetal Acceleration and the Centrifuge

Purpose: In this lesson, we generalize Newton's Second Law to include centripetal acceleration.

Reading: Chapter 3 - Sections 4, 5
Questions: Chapter 3 - 8, 14, 18, 21
Problems: Chapter 3 - 17, 27, 30, 35
Turn In: Debrief #2: "Ejection" (Euler's Method for a Bailout Sequence):
Objectives:

7.1 Know and understand what is meant by Uniform Circular Motion.
7.2 Recognize that an object in circular motion experiences an acceleration, called "centripetal acceleration."
7.3 Be able to calculate the centripetal acceleration of an object in Uniform Circular Motion.
7.4 Be able to solve kinematics problems involving Uniform Circular Motion.
7.5 Know and understand how to analyze general curvilinear motion in terms of its radial and tangential accelerations.

Lesson #8

Pulling G's II: Curvilinear Motion, , GR #1 Review

Purpose: In this lesson is to look at various Air-to-Air Missile profiles that could conceivably be launched against you in your aircraft. You will continue to deepen your understanding of the motion of an object acted upon by gravity and also complete your understanding of what it means to pull g's.

Reading: Chapter 5 - Sections 2, 3
Questions: Chapter 4 - 8, 10, 14, 18 Chapter 5 - 7, 10, 11, 18
Problems: Chapter 4 - 28, 30, 38, 51 Chapter 5 - 16, 19
Objectives:

8.1 Know the definition of centripetal force and acceleration.
8.2 Understand that "centripetal force" is **not** a new kind of force, but is just the name given to a force which causes an object to undergo centripetal acceleration.
8.3 Be able to use Newton's Second Law to solve a wide variety of dynamics problems.

8.4 Understand that acceleration occurs due to changes in the direction and/or magnitude of the velocity vector.
8.5 Be able to calculate the number of "g's" experienced by aircrews when aircraft undergo various turns and loops.

Lesson 9:
GRADED REVIEW #1
0700 M-13 in Lectinars (8 Feb 96)

BLOCK II: "FLY, FIGHT, & WIN"

Lesson #10

Physics of Flight I: Work and Energy

Purpose: In this lesson, we begin our study of Energy and Conservation of Energy. You probably already know what "energy" is and in this lesson we'll begin to discuss "energy" as it is relevant to physics. The concept of work is introduced to help describe the transfer of energy from one object to another. In this lesson, you will learn that the application of a net force produces a change in a particle's kinetic energy.

Reading: Chapter 7 - Sections 1-4 (skip section on "Kinetic Friction" on pp. 176-177 and example 7.8)
Questions: Chapter 7 - 1, 6, 7, 14
Problems: Chapter 7 - 2, 5, 28 Chapter 9 - 60, 67
Objectives:

10.1 Know and understand the definition of work.
10.2 Know the SI units for work and energy.
10.3 Be able to calculate the work done by a force, including gravity and a spring.
10.4 Know and understand the definition of kinetic energy.
10.5 Be able to calculate the kinetic energy of an object of given mass and speed
10.6 Know and understand and be able to apply the work-energy theorem.

Lesson #11

Physics of Flight II: Conservation of Mechanical Energy

Purpose: In this lesson, we introduce the concepts of conservative forces and potential energy. To conclude the lesson, we briefly begin to put these concepts together in the principle of Conservation of Mechanical Energy for conservative systems.

Reading: Chapter 8 - Sections 1-4
Questions: Chapter 7 - 8, 16, 17 Chapter 8 - 8, 16
Problems: Chapter 7 - 19, 26, 27 Chapter 8 - 2
Objectives:

11.1 Know and understand the definition of mechanical energy.

11.2 Know and understand the definition of conservative and non-conservative forces.
11.3 Know and understand the definition of potential energy
11.4 Realize that a potential energy function can only be associated with a conservative force.
11.5 Be able to calculate the potential energy given a conservative force..

Lesson #12

Physics of Flight III: Conservation of Mechanical Energy

Purpose: The purpose of this lesson is to tie together the concepts of energy and conservation of energy into an exercise that will test your problem solving abilities.

Reading: Chapter 8 - Sections 5-8
Questions: Chapter 8 - 4, 7
Problems: Chapter 8 - 10, 12
Assignment: Debrief #3: "An Uphill Battle"
Objectives:

12.1 Be able to solve dynamics problems using conservation of energy.
11.6 Be able to apply the principle of conservation of mechanical energy.

Lesson #13

Kinematic Weapons I: Linear Momentum, 1-D & 2-D Collisions, Elastic Collisions

Purpose: Having learned to predict the motion of particles under the influence of various interactions via equations of motion and conservation laws, we now turn our attention to a new vector quantity called momentum. In this lesson, we will examine momentum and apply it to 1-D and 2-D collisions. The term "elastic" collision is introduced.

Reading: Chapter 4 - Section 4,5,7
Chapter 9 - Sections 1, 3
Questions: Chapter 9 - 4, 13, 25
Problems: Chapter 9 - 7, 9, 11, 69
Turn In: Debrief #3: "An Uphill Battle"
Objectives:

13.1 Know and understand Newton's Third Law (we are revisiting this!).
13.2 Know and understand the definition of linear momentum for a single particle.
13.3 Understand Newton's Second Law in the form $\vec{F} = d\vec{p} / dt$.
13.4 Be able to identify action and reaction force pairs according to Newton's Third Law for a system of two particles.
13.5 Be able to distinguish between external and internal forces and to show that if the net external force is zero, Newton's Second Law gives conservation of momentum.
13.6 Know and understand that conservation of linear momentum is a consequence of Newton's Third Law for an isolated system of particles.
13.7 Be able to solve certain problems in one and two dimensions by applying momentum conservation.

13.8 Know and understand the definition and differences between an elastic and inelastic collision.

Lesson #14

Kinematic Weapons II: Momentum Conservation, 1-D & 2-D Collisions, Inelastic Collisions

Purpose: As expected, there is also another conservation law associated with momentum just like the one for energy. In this lesson, we will see how Newton's Third Law can lead naturally to the Conservation of Momentum for an isolated system. 1-D and 2-D collisions will continue to be explored. The term "inelastic" collision is introduced.

Reading: Chapter 9 - Section 5-7 (ignore Equation 9.26 and Example 9.9)
Questions: Chapter 9 - 5, 16, 18
Problems: Chapter 9 - 5, 10, 30, 44(a)
Objectives:

Review Lesson 13's Objectives!

Lesson #15

Missile and Rocket Technology I: Momentum Conservation, Propulsion

Purpose: Now let's take our knowledge of momentum and apply it to the space shuttle and a launch sequence. You should quickly develop new insight into what propulsion is and how to examine it in a more general sense.

Reading: Chapter 9 - Section 8
Questions: Chapter 8 - 2, 12 Chapter 9 - 2, 6
Problems: Chapter 8 - 43, 44, 65 Chapter 9 - 25, 26, 43
Objectives:

15.1 Understand that rocket propulsion is a "reverse collision".
15.2 Understand rocket propulsion in terms of Newton's Third Law and Conservation of Momentum.

Lesson #16

Missile and Rocket Technology II: Momentum Conservation, Propulsion

Purpose: This lesson will increase the emphasis on propulsion technology through the application of momentum conservation.

Reading: Chapter 9 - Section 8 (Again!)
Questions: Chapter 9 - 14
Problems: Chapter 9 - 45(a), 58, 59
Assignment: Debrief #4: Debrief #4 *"Rocket Launch"*
Objectives:

16.1 Know and understand the basic expressions for rocket propulsion and thrust.

16.2 Be able to solve problems of rocket propulsion and acceleration in one dimension.
16.3 Be able to determine position, velocity, mass and acceleration of a rocket as a function of time.

Lesson #17

Stability: Stability, GR #2 Review

Purpose: We will continue to apply the principle of Conservation of Energy. Furthermore, since stability is an important consideration in contemporary applications, you will also learn to read energy diagrams and recognize stable and unstable situations by inspecting potential energy functions and plots.

Reading: Chapter 8 - Section 9
Questions: Chapter 8 - 13
Problems: Chapter 7 - 51 Chapter 8 - 34, 45, 48
Turn In: Debrief #4: *"Rocket Launch"*
Objectives:

17.1 Be able to calculate the conservative force related to a given potential.
17.2 Understand the concept of equilibrium and be able to determine whether an equilibrium position is stable, unstable, or neutral.
17.3 Be able to use energy concepts to understand and interpret an energy diagram.
17.4 Be able to use an energy diagram to calculate the force at any point and, given the total energy, determine the kinetic energy at that point.

Lesson 18:
GRADED REVIEW #2
0700 M-25 in Lectinars (14 Mar 96)

BLOCK III: "AIR AND SPACE"

Lesson #19

Huey, Pave Low, Pave Hawk I: Rotational Kinematics, Angular Momentum and Conservation of Angular Momentum

Purpose: This lesson reopens our investigation into rotational motion that was started in the "Pulling G's" lessons. We now apply our previous knowledge of kinematic equations, momentum and conservation of momentum to arrive at the new quantities of rotational kinematic equations, angular momentum and conservation of angular momentum.

Reading: Chapter 11 - Sections 1-3

Questions: Chapter 10 - 14 Chapter 11 - 1, 4
Problems: Chapter 10 - 40, 43 Chapter 11 - 3, 6, 9, 12

Objectives:

19.1 Be able to determine the angular speed of a spinning object.
19.2 Be able to determine the angular acceleration of a spinning object.
19.3 Be able to solve angular kinematics problems.
19.4 Be able to relate angular quantities to their linear counterparts.
19.5 Know and understand what is meant by the term "angular momentum".

Lesson #20

Huey, Pave Low, Pave Hawk II: Conservation of Angular Momentum, Torque

Purpose: Why does a pilot apply rudder to stay on the runway while applying power for the takeoff? Why did that helicopter spin out of control when its tail rotor failed? In lesson, we introduce the concept of torque and study the relationship between angular momentum and torque.

Reading: Chapter 11 - Sections 7,8
Questions: Chapter 11 - 8, 9, 18, 19
Problems: Chapter 11 - 20, 27, 33, 34
Objectives:

20.1 Be able to calculate the angular momentum of a particle about a given point.
20.2 Know the relationship between angular momentum and torque.
20.3 Be able to solve simple problems in rotational dynamics of single particles.
20.4 Know and understand the principle of conservation of angular momentum for single particles.
20.5 Be able to apply the principle of conservation of angular momentum to solve rotational
problems involving a few particles.
20.6 Understand qualitatively how the principle of conservation of angular momentum explains many commonplace situations involving rotating objects.
20.7 Know and understand what is meant by the term "torque".
20.8 Be able to calculate the torque exerted by a force about a given point.

Lesson #21

Huey, Pave Low, Pave Hawk III: Momentum of Inertia

Purpose: Past lessons have introduce the concept of mass and hopefully gave you a deeper understand of its meaning. This lesson introduces a more difficult idea called momentum of inertia. In addition, rotational kinetic energy is introduced.

Reading: Chapter 11 - Sections 4-6
Questions: Chapter 11 - 3, 5, 7
Problems: Chapter 11 - 14, 21, 23, 25
Objectives:

21.1 Understand and be able to give a qualitative explanation of the term "moment of inertia."
21.2 Be able to calculate the moment of inertia for a point mass system..
21.3 Be able to calculate the rotational kinetic energy of an object.

Lesson #22

Global Positioning System (G.P.S.) I: Orbital Motion, Kepler's Laws

Purpose: This is the first of four lessons that take us fully into space. This bold "new" frontier is at the forefront of Air Force goals and policies. We begin our exploration of space by studying the fundamental laws of planetary motion. Newton's Second Law will enable us to analyze planetary and satellite motion while Kepler's Law's will lead us back to conservation of angular momentum. The Air Force's GPS will be our spring board for these topics.

Reading: Chapter 12 - Sections 1,2, 3
Questions: Chapter 12 - 1, 7, 11, 12
Problems: Chapter 12 - 2, 8
Objectives:

22.1 Know and review the concepts of centripetal acceleration and centripetal force.
22.2 Know and review Universal Gravitation as one of the fundamental forces.
22.3 Recognize how we can determine the mass of the Earth, using "the Cavendish experiment."

Lesson #23

Global Positioning Satellite (G.P.S.) II: Dynamics of Satellite Orbits

Purpose: Now we can look closely at some interesting satellite issues, including geostationary satellites and line of sight limitations. The global positioning system (GPS) of satellites has revolutionized war fighting by enabling the use of autonomous smart weapons delivery. This in turn has vastly changed our doctrine on how we carry out armed conflict..

Reading: Handout (Orbits: Pages 31 - 41. Stop before reading "Orbital Maneuvering")
Questions: Chapter 12 - 4, 18
Problems: Chapter 12 - 17, 20, 24
Orbit Problem Set I
Objectives:

23.1 Be able to show how Kepler's third law (for a circular orbit) can be derived using Newton's second law and the law of gravitation
23.2 Be able to calculate the period and altitude of geostationary satellites.
23.3 Know and understand how Kepler's three laws of planetary motion are applications of Newton's second law and conservation of angular momentum.
23.4 Be able to apply Newton's second law and conservation of angular momentum to analyze problems involving the orbit of an object about a star or planet.
23.5 Be able to compare different kinds of satellite orbits, and understand why certain types of satellites require certain orbits.
23.6 Understand what is meant by the *Satellite Orbit Paradox.*

Lesson #24

Global Positioning Satellite (G.P.S.) III: Applications to Momentum and Energy

Purpose: With what speed would astronauts who land on Mars need to leave Mars in order to make it back to Earth? How much energy would be required to change the altitude of a satellite by a given amount? In this lesson, we concentrate on answering such questions. We now broaden our study of planetary and satellite motion to include energy considerations. Again, our goal is to learn how to apply the principles of conservation of energy and conservation of angular momentum.

Reading: Chapter 12 Section 4
Review Example 6.1
Questions: Chapter 12 - 8, 15
Problems: Chapter 12 - 11, 12, 18, 42
Assignment: Debrief #5: *"Killer Satellite"*
Objectives:

24.1 Be able to derive orbital velocity from Newton's second law and the law of gravitation.
24.2 Be able to determine the energy and angular momentum requirements to transfer from one circular orbit to another.
24.3 Be able to calculate the escape velocity of an object from the surface of a planet and from satellite orbits..
24.4 Be able to derive escape velocity from the total energy equation.
24.5 Understand the difference between escape velocity and orbital velocity.
24.6 Understand what is meant by the *Satellite Orbit Paradox.*

Lesson #25

Global Positioning Satellite (G.P.S.) IV: GR #3 Review

Purpose: In this lesson, we'll get to see the Air Force's Space Command in action.

Reading: None
Questions: None
Problems: Chapter 6 - 15, 24
Turn In: Debrief #5: *"Killer Satellite"*
Objectives:

25.1 Witness the Air Force's Space Command in action.

Lesson 26:
GRADED REVIEW #3
0700 M-35 in Lectinars (18 Apr 96)

BLOCK IV: "POWER OF THE ATOM"

Lesson #27

Satellites to Atoms: Bohr Model of the Atom

Purpose: The concepts we used for planetary and satellite motion are also used in the Bohr model of the atom! After this lesson, you should be able to see how logical it was for Bohr to develop this model of the atom from his knowledge of classical physics. However, we must also remember that the failure of classical mechanics to correctly describe the atom spurred the development of quantum theory and a new quantum mechanics.

Reading: Chapter 8 - Section 10
Chapter 11 - Section 9
Chapter 12 - Section 5

Questions: Chapter 12 - 20, 23

Problems: Chapter 12 - 27, 28, 46

Objectives:

27.1 Understand the concept of "Quantization".

27.2 Know that the Bohr model of the atom, while accurately describing a number of observed phenomena, is not the complete model of the atom as we understand the atom today.

27.3 Understand that the failure of classical mechanics to correctly describe the atom spurred the development of quantum theory and a new quantum mechanics.

27.4 Be able to calculate wavelengths, frequencies and energies for electron transitions in the Bohr atom.

27.5 Be able to explain Bohr's Correspondence Principle and relate it to relativity.

Lesson #28

Relativity: The Beginnings of Particle Physics, Relativistic Energy and Momentum

Purpose: This lesson introduces a block in which we begin to consider 20th century physics! Have you ever been in a car, stopped at a traffic light with a car next to you, and been unsure whether you or the other car has begun to move? We discuss this type of motion, which is described by Galilean relativity. This should serve to enhance your appreciation of inertial reference frames and expand the applications of Newton's Laws. Then, we'll move from classical relativity to Einstein's special theory of relativity. Having introduced a large portion of mechanics from a Newtonian perspective in the last two blocks, we now pause to reconsider mechanics in light of 20th century research. We will introduce Einstein's theory of special relativity and continue by generalizing the concepts of energy and momentum. The "gamma factor" is stressed.

Reading: Chapter 3 - Section 6
Chapter 10 - Sections 1-7

Questions: Chapter 3 - 11, 19 Chapter 10 - 1, 6, 10, 11

Problems: Chapter 3 - 37, 39 Chapter 10 - 1, 2, 6

Objectives:

28.1 Know the Galilean coordinate and velocity transformations and be able to solve one- and two- dimensional problems in reference frames moving at constant velocity.
28.2 Be able to discuss the failure of Galilean relativity for high particle speeds.
28.3 Know the two postulates of the special theory of relativity.
28.4 Understand the principle of correspondence between Galilean and Special Relativity as a guideline for evaluating new theoretical models and explaining observations.
28.5 Understand that the simultaneity of events is relative to an observer's frame of reference.
28.6 Be able to make simple time dilation and length contraction calculations.
28.7 Know the relativistic definition of linear momentum and be able to calculate relativistic momentum.
28.8 Be able to calculate the relativistic factor "gamma."
28.9 Be able to calculate kinetic energy and total energy of particles moving at relativistic speeds.
28.10 Be able to show that the non-relativistic results are obtained in the limit of low speeds.

Lesson #29

Particle Propulsion: Thrust and Thrust Efficiency

Purpose: A C-130 turboprop blade provides thrust for an airplane. An ion propulsion drive does the same for some advanced satellites. Can you see the physics connection between the two and when one is appropriate to use and not the other? This lesson is meant to tie together topics from previous lessons and show you how they can be applied even in the sub-atomic world of the very small.

Reading: Handout Material: "TBD"
Questions: In class Quizzes
Problems: In class Quizzes
Objectives:

29.1 Understand Newton's Second Law in the form $\bar{F} = d\bar{p} / dt$.(revisited)
29.2 Know and understand the basic expressions for rocket propulsion and thrust. (revisited)
29.3 Be able to solve problems of rocket propulsion and acceleration in one dimension. (revisited)

Lesson #30

"Brighter Than a Thousand Suns" I: Radioactive Decay

Purpose: The process of radioactivity illustrates the equivalence of mass and energy. When a substance spontaneously decays, some of its mass is converted into energy! Where does this energy go? We now look at the process of radioactivity, the types of radiation which occur, and how we are able to shield ourselves and our instrumentation from its dangerous effects. We also look at radioactive decay in terms of half life and explore the significance of a long half life.

Reading: Chapter 31 - Sections 3-5
Questions: Chapter 31 - 3, 4, 7, 8

Problems:	Chapter 31 - 16, 18, 28, 29
Objectives:	
	30.1 Know the three processes by which radioactive nuclei decay and the type of radiation given off by each process.
	30.2 Understand that radioactive decay follows an exponential function.
	30.3 Know the meaning of decay constant and decay rate.
	30.4 Understand the meaning of half-life of a radioactive substance.
	30.5 Know the curie as the unit of radioactivity.
	30.6 Be able to solve problems using the exponential decay law.
	30.7 Understand the basic principles used in carbon dating.

Lesson #31

"Brighter Than a Thousand Suns" II: Binding Energy of the Nucleus

Purpose: Nearly everyone has heard or seen Einstein's famous equation, $E = mc^2$. During this lesson, we focus on that concept, the equivalence of mass and energy. Since most applications are taken from nuclear physics, some fundamental terminology is also introduced. We also look into the forces that keep the nucleus from breaking apart.

Reading:	Chapter 31 Sections 1 (stop at Equation 31.2), 2	
Questions:	Chapter 10 - 10, 17	Chapter 31 - 1
Problems:	Chapter 10 - 24, 29, 32	Chapter 31 - 14
Objectives:		
	31.1 Understand the equivalence of mass and energy.	
	31.2 Know how to use the appropriate nomenclature in describing the static properties of nuclei.	
	31.3 Be able to calculate the binding energy of nuclei, given a table of physical data.	
	31.11 Be able to determine the rest energy of a particle of known mass using both SI units and electron volts.	

Lesson #32

"Brighter Than a Thousand Suns" III: Fission, Fusion, and "Limitless Energy"

Purpose: After this lesson, you should understand the fundamental concepts of fission energy generation and the underlying hopes for fusion energy generation. Although our focus is mass-energy equivalence, we believe it's important here to take some time to address the safety and environmental issues associated with nuclear power generation, and to explore some of the physics of nuclear weapons. Reactor technology is also discussed.

Reading:	Chapter 10 - Section 8
Questions:	Chapter 31 - 6, 9, 13
Problems:	Chapter 31 - 23, 56
	Chapter 10 - 37

Objectives:

32.1 Understand the basis for energy release in fission and fusion reactions.
32.2 Be able to analyze an equation representing a typical fission reaction and describe the sequence of events which occurs during the process.
32.3 Be able to explain how a pressurized-water fission reactor works and describe some attendant safety and environmental issues in fission reactor operation.
32.4 Be able to analyze energy release in fusion reactions.
32.5 Be able to compare nuclear weapons and high explosives.

COMPREHENSIVE FINAL EXAMINATION (Time and Location TBD)

Appendix I-B: Physics 110 Control Syllabus

PHYSICS 110 WELCOME LETTER
SPRING 1996

Welcome to Physics 110! In this first course in Physics here at the Air Force Academy, we'll cover a number of important scientific concepts and principles which will allow you to better describe, model and understand the world we live in. Many of the concepts have relevance to important problems and issues you'll encounter throughout your Air Force career. In addition, some of the material we cover will prove helpful as you go on to other technical courses here at the Academy.

You may be wondering what you should do in order to **do well** in Physics 110:
First and most important, **stay ahead!** In Physics, it's even more important to stay current than it is in some other subjects, because physics topics often build on one another. If you get behind, you'll have trouble understanding the current material because you haven't spent adequate time mastering the previous material. So please, stay ahead! That means reading the assigned material **before** coming to class, doing the homework questions and problems assigned for that day's class, participating and paying attention in class, and turning in all assignments on time.

Second, make an effort to wrestle your way through your trouble spots *yourself*. Often, a homework problem or lab question can seem easy when the instructor does it for you, and because it then seems easy, you may be tempted to assume you could do a similar problem on your own. Until you actually ***do these problems by yourself***, it's likely that you'll not truly understand them. Try problems on your own first! Then, seek help to answer questions you have or to learn what mistakes you may have made.

Third, if you find that, despite your efforts, you're having trouble, **seek extra instruction (EI)!** Don't sit back and wait for it all to settle into place in your mind, or decide that you can handle the difficulty on your own at a later time. History has shown that students who seek EI from an instructor quite often recover from their difficulties and go on to do well in the course. On the other hand, those who are having difficulty do not seek the help of an instructor are more likely to have serious problems. The Physics 110 instructors are here to help you learn physics. Ask for our help when you need it.

Be sure to read and then comply with the material presented in the administrative notes which follow this letter. If you have any questions about the notes, ask your instructor for further clarification.

Your instructors will be working hard to make this course interesting, challenging, useful and even fun for you. Work hard with us, and we'll all benefit. Good luck!

Course Director, Physics 110

PHYSICS 110 ADMINISTRATIVE NOTES
SPRING 1996

Who's In Charge: You are! However, as with any military organization, we have a chain of command. Your chain starts with your instructor. Next are the Course Director, Captain Summers (office 2A44E, Ext 2240) and the Assistant Course Director, Captain [Name] (office 2A10A, Ext 4619). Feel free to contact either director after first working with your instructor. The course directors report to the Director of Core Programs, Major [Name] (office 2A42E, Ext 3055), who in turn reports to the Deputy Head of Academics, Lieutenant Colonel White (office 2A42B, Ext 2091), who in turn reports to the Physics Department Head, Colonel Enger (office 2A4, Ext 3510). **You can always contact or leave a message for any physics department member during normal duty hours by calling Ext 3510.**

Syllabus: Your instructor will give you an overview of the syllabus on Lesson 1. Lesson assignments are designed so that you read the material and do the homework **BEFORE** coming to class.

Textbook: The course textbook, *Principles of Physics* by Serway, was designed, in part, specifically with the Air Force Academy in mind (See the introductory notes in the text.). You're required to purchase and personally possess a copy of this book for the duration of Physics 110. (Note: This will also be the textbook for Physics 215.)

Course Grading: Your course grade will be based upon three graded reviews, one final exam, seven graded laboratories and quizzes, and instructor prerogative (IP) points.

The point breakdown for the course is as follows:

#	ITEM GRADED	POINTS EACH	TOTAL	%
3	Graded Reviews	700	2100	41.7
1	Final	1500	1500	29.7
7	Laboratories and Lab Quizzes	100 20	840	16.7
2	Instructor Prerogative (IP) Points	300	600	11.9
			5040	100.0

Late or missed work: If you choose not to turn in an assignment on the day it's due, your score for that assignment will be zero until you turn it in. If you know you'll miss a class on the day an assignment is due, make *prior* arrangements with your instructor regarding the assignment. If no prior arrangements are made, **late work will lose 15% of the possible points per day of lateness. This includes weekend days and holidays.**

English as a Second Language (ESL) Students: If desired by the student, an ESL student will receive double time to complete all exams and quizzes except the final exam. The final exam will be designed to last two hours. All students, including ESL students, will have four hours to complete the final exam. Please make arrangements with your instructor PRIOR to the exam date.

READING ASSIGNMENTS AND HOMEWORK

The accompanying syllabus outlines the reading assignments as well as the objectives for each lesson. You're expected to have read the assignment **before** coming to class, allowing you to get the most out of class time. Several lessons are scheduled to be **double periods**, and you should plan on enjoying class for two full hours on those days.

In addition to the readings, most lessons also have homework problems assigned from those readings. Not only will these problems help you prepare for quizzes and graded reviews (GRs), problem solving is essential to understanding the physics. **When accomplishing these problems we suggest you write down the critical equations or concepts you used. These notes will prove useful when creating your summary sheets for the GRs and Final.** We encourage you to work with anyone in order to solve these problems. The bottom line is that you simply will not develop problem solving skills without practicing! **For homework assignments you may work with the following individuals, in addition to an instructor in the course: anyone. For homework assignments, you may use the following materials produced by other cadets: anything.** Document all sources of help—people and/or materials.

Why do we sometimes allow you to work with others when doing homework assignments? The intent of joint effort assignments is to help you learn the course material and to deepen your understanding of the material. However, please don't use "joint effort" as a crutch, simply counting on classmates to give you the answers. It's fine to compare answers to help locate and correct a trivial error or two. It's also acceptable to get help understanding how to do a problem you had trouble with. But, it's not appropriate to show up early for class without your homework, planning to get the homework done before class with your classmates' help. In general, you're abusing the intent of our homework policy if you find yourself putting minimal time into homework by leaning on classmates who have already done the work.

LABORATORIES

There are seven labs in this course. Laboratories can be very enjoyable and rewarding experiences if you properly prepared for them. Make sure you have read the procedures beforehand so you don't waste valuable time when the lab starts. Many of the labs will have a computer worksheets to complete as a part of the lab report. **For laboratory assignments you may work with the following individuals, in addition to an instructor in the course: anyone.** You may seek assistance from **anyone** for computer (i.e., Excel, Mathematica, etc.) questions that are specific to the capability of the computer program and that don't involve the physics being studied. **For laboratory assignments, you may use the following materials produced by other cadets, in addition to your lab group: nothing.** Document all sources of help—people and/or materials. A fifteen minute, twenty point lab quiz will be given at the beginning of the next lesson following a lab.

Because the laboratories represent an important component of Physics 110, you can expect questions and/or problems about the labs to be included on the graded reviews and final examination.

Thinking Problems: There are seven thinking problems due during the course of Physics 110. These will supplement your homework and better prepare you for exam questions involving critical thinking and estimation skills. "Critical thinking" involves the ability to solve problems that are not simple "plug and chug" equations. These problems are available course-wide and, if used, are graded according to your instructor's directions. Take them seriously. They're designed for **individual and group thought and exploration.** For thinking problem assignments you may work **with the following individuals, in addition to an instructor in the course: anyone. For thinking problems, you may**

use the following materials produced by other cadets: anything. Document all sources of help—people and/or materials.

Application Lessons: These lessons are more activity based than the data acquisition techniques of laboratories. You'll be asked to review video clips of fighters, get a true feel for rocket motion, and find out what it really takes to get satellites into orbit. These applications are given course-wide and are graded according to your instructor's directions. Application activities will be accomplished in teams. **For these activities, you may work with the following persons, in addition to an instructor in this course: anyone.** Your team's performance on these activities will be assessed through worksheets and/or "exit interviews" with your instructor upon your completion of the activity. **For application lessons, you may use the following materials produced by other cadets: nothing.** Document all sources of help—people and/or materials.

Instructor Prerogative (IP) Points: Your instructor will tell you his or her policy on these points.

Graded Reviews and Final Examination: The three graded reviews will each be given during a common GR period (Lessons M13, M25, and M35). They may consist of multiple choice, short answer, essay, estimation, and workout questions and problems. The final examination is comprehensive. Typically one third of the material for the final examination will come from Block IV.

If you're unable to attend a scheduled examination, contact your instructor or the physics department (Ext 3510) as soon as possible to arrange a make-up examination.

Equation Sheets: There'll be **no** course-wide instructor-prepared equation sheets for your use throughout the semester. There'll also be **no** course-wide equation sheets prepared for your use during the GRs or the final. You'll be permitted to prepare and bring to each GR your own summary sheet containing information you believe is helpful to you. The summary information you bring to each GR must fit within a 5" by 7" area on one side of a piece of paper or filecard. Although it's not mandatory that you use it, a summary sheet template will be provided. You'll be required to turn in your summary sheet with each GR. Your summary sheets will be returned to you with your graded GR.

CQ Absences: You're not permitted to miss Physics 110 classes due to CQ Duty if you have a deficient grade in Physics 110 at prog (Lesson 21) or if you're currently on Academic Probation.

Extra Instruction (EI): You're expected to read all applicable material and attempt all assigned homework prior to seeking EI. Your instructor will provide you additional guidance pertaining to his or her EI policy. If your instructor is not available for EI, there'll be several Physics 110 instructors this semester (8), each of whom could provide you with EI. Just come to the physics department, and someone will almost surely be able to help you.

In conclusion, the content in Physics 110 is both fascinating and challenging. It has direct applications to your future academic courses and your Air Force career. Stay ahead, work hard, and you'll learn to appreciate and understand amazing things about our world and universe!

Course Director, Physics 110
Director of Core Programs

PHYSICS 110 COURSE OVERVIEW
A PARTICLES APPROACH TO INTRODUCTORY PHYSICS
SPRING 1996

BLOCK I: INTERACTIONS OF NATURE AND MOTION OF PARTICLES

	1	Introduction, the Fundamental Interactions of Nature and the Math of Physics
	2	* Velocity and Acceleration; ***Lab 1***: The Beginnings of Experimental Technique
	3	One-Dimensional Kinematics and Free Fall
	4	* Two-Dimensional Motion - Projectiles; ***Lab 2:*** Graphing Free Fall
⇒	5	Two-Dimensional Motion - Circular Acceleration
	6	Force and Acceleration: Newton's First and Second Laws
	7	Newton's Third Law, Using Free-body Diagrams
	8	* Newton's Laws: Centripetal Force/Circular Motion; ***Application 1***: The Physics of Flight
	9	Introduction to Numerical Modeling (Euler's Method)
	10	* Physics as a Process; ***Lab 3***: The Effects of Drag using Euler's Method
⇒	11	Forces in Nature
	12	* Fields in Nature and Review
	M-13	Graded Review #1

BLOCK II: ENERGY AND LINEAR MOMENTUM

	14	Introduction to Energy
	15	Work and Energy
	16	Conservation of Mechanical Energy
	17	* Applications of Energy Conservation; ***Lab 4:*** Energy Conservation and Conversion
⇒	18	The $1/r^2$ Forces: The Potential Energy of Gravitational and Electrical Forces
	19	Advanced Energy Concepts: Stability
	20	Conservation of Linear Momentum: One-dimensional Collisions
	21	Energy-Momentum Applications: Collisions
	22	* Two-Dimensional Collisions; ***Lab 5:*** Two-dimensional Air Puck Collisions
⇒	23	Rocket Propulsion
	24	* Applications of Momentum Conservation; ***Application 2:*** Computer Modeling of Rocket Propulsion
	M-25	Graded Review #2

BLOCK III: ANGULAR MOMENTUM, ORBITAL MOTION AND THE ATMOSPHERE

	26	Rotational Kinematics
	27	Moment of Inertia, Energy and Torque
	28	Angular Momentum and Conservation of Angular Momentum
⇒	29	Planetary and Satellite Motion: Kepler's Laws
	30	Energy and Angular Momentum in Orbital Motion
	31	* Dynamics of Satellite Orbits; ***Application 3:*** Orbit Modeling
	32	Kinetic Theory of Gases
⇒	33	The Atmosphere
	34	* ***Lab 6:*** Atmospheric Modeling and Orbital Decay
	M-35	Graded Review #3

BLOCK IV: RELATIVISTIC MOMENTUM AND ENERGY; MODERN PHYSICS

	36	* Introduction to Einstein's Principle of Relativity
	37	Relativistic Momentum and Energy
	38	Applications of Relativity: Fission and Fusion Energy
	39	Applications of Relativity: Binding Energy

⇒ 40 Military Applications and Introduction to Radiation
41 * Radioactivity; ***Lab*** *7:* Radioactive Decay
42 The Beginnings of Particle Physics

<u>FINAL EXAMINATION (Time to be Determined)</u>

⇒ Thinking Problem Due This Lesson

* Double Period This Lesson

PHYSICS 110 COURSE SYLLABUS
A PARTICLES APPROACH TO INTRODUCTORY PHYSICS
SPRING 1996

BLOCK I: INTERACTIONS OF NATURE AND MOTION OF PARTICLES

Lesson 1: WELCOME!

Introduction, the Fundamental Interactions of Nature and the Math of Physics

Purpose: Welcome to **A Particles Approach to Introductory Physics**, a curriculum originally developed at the United States Air Force Academy. In this lesson, we introduce the process of physics and briefly explore our understanding of the basic interactions that govern the universe. We also introduce the language of physics, emphasizing space and time, and the SI system of units. A brief review of vectors is also included in the reading.

Reading: Chapter 1
Chapter 6 - Section 1 (excluding examples)

Questions: Chapter 1 - 12, 16, 21 **Problems:** Chapter 1 - 9, 16, 35, 42

Objectives:
1.1 Know the SI base units and the SI unit prefixes.
1.2 Be able to use SI base units and SI unit prefixes in numerical computations.
1.3 Know the types and relative strengths of the fundamental forces which act on particles.
1.4 Be able to define the terms "vector" and "scalar" and give physical examples of each.
1.5 Be able to express a vector in terms of its components and the Cartesian unit vectors.
1.6 Be able to calculate the magnitude and direction of a vector.
1.7 Be able to add and subtract vectors graphically and algebraically.
1.8 Be able to apply dimensional analysis to check the consistency of a given equation.

Lesson 2: DOUBLE PERIOD

Velocity and Acceleration
***Lab 1*: The Beginnings of Experimental Technique**

Purpose: This lesson focuses on how to describe the motion of an object, by defining and exploring the concepts of position, velocity, and acceleration. It's important to spend the entire lesson exploring these relationships since they are fundamental to an understanding of motion. After this lesson, you should be able to describe the motion of an object through space and time and understand the relationships between position, velocity, and acceleration in one dimension. During the second hour, you'll begin to explore proper experimental methods for performing laboratory exercises in this course.

Readings: Chapter 2 - Sections 1-4
Lab Handout

Questions: Chapter 2 - 2, 6, 17 **Problems:** Chapter 1 - 67
Chapter 2 - 3, 9, 13

Objectives:
2.1 Know and understand the relationship between acceleration, velocity, and position of an object moving in one dimension, both for averages over finite time intervals and for instantaneous quantities.
2.2 Given a graph of position, velocity, or acceleration vs. time, be able to determine the other two plots and qualitatively describe the motion of the object.
2.3 Be able to differentiate and integrate simple functions analytically in order to determine the motion of an object.
2.4 Know the meaning of precision, accuracy, reading error, and experimental range.
2.5 Be able to calculate percent error and differences and properly use significant figures.
2.6 Be able to calculate the standard deviation of a set of data.

Lesson 3:

One-dimensional Motion and The Kinematics Equations

Purpose: Having introduced the quantities we need to be able to describe the motion of a particle, we now formally begin our study of motion and the interactions which cause it, limiting ourselves in this lesson to **constant acceleration** in one dimension.

Reading: Chapter 2 - Sections 5, 6

Questions: Chapter 2 - 7, 8, 16 **Problems:** Chapter 2 - 12, 15, 21, 23

Objectives:
3.1 Understand that motion with constant acceleration is a special case.
3.2 Be able to list the assumptions under which the kinematics equations for motion with constant acceleration are derived.
3.3 Know the kinematics equations for constant acceleration.
3.4 Be able to use kinematics equations to solve problems of one-dimensional motion.
3.5 Understand that all freely falling bodies experience the same acceleration.

Lesson 4: DOUBLE PERIOD

Two-dimensional Motion - Projectiles
Lab 2: **Graphing Free Fall**

Purpose: To this point in the course we've limited our discussion to motion in one dimension. Motion, however, is often not one dimensional! In this lesson we now consider motion in two dimensions. The independence of motion along each dimension is emphasized. You'll find there are some interesting Air Force applications of projectile motion! The laboratory will introduce the techniques of graphing and error propagation. These are techniques used to quantify your experimental measurements.

Readings: Chapter 3 - Sections 1-3
Lab Handout

Questions: Chapter 3 - 4, 16, 17 **Problems:** Chapter 2 - 33, 46
Chapter 3 - 2, 10

Objectives: 4.1 Know and understand position, velocity, and acceleration, defined as <u>two-dimensional</u> vectors.

4.2 Recognize two-dimensional projectile motion as simultaneous motion in two directions.

4.3 For two-dimensional projectile motion, be able to identify the acceleration in each direction and formulate the appropriate kinematic equations for each direction, given initial conditions.

4.4 Be able to solve problems of projectile motion with constant acceleration.

4.5 Be able to perform simple error calculations in a laboratory environment. (Lab)

4.6 Know the meaning of error bars and be able to place them on a graph. (Lab)

4.7 Know the mechanics of graphing. (Lab)

4.8 Be able to determine the acceleration due to gravity at USAFA. (Lab)

Lesson 5: **THINKING PROBLEM 1 DUE**

Two Dimensional Motion-Circular Acceleration

Purpose: Because curvilinear motion will occur so frequently in future applications, we've given this topic a lesson of its own, building upon what was learned about projectile motion. In this lesson, we emphasize the unique aspects of uniform circular motion. You should remember, however, that uniform circular motion is a special case of curvilinear motion.

Reading: Chapter 3 - Sections 4, 5

Questions: Chapter 3 - 8, 14, 21 **Problems:** Chapter 3 - 17, 27, 30, 35

Objectives:

5.1 Know and understand what is meant by Uniform Circular Motion.

5.2 Recognize that an object in circular motion experiences an acceleration, called "centripetal acceleration."

5.3 Be able to calculate the centripetal acceleration of an object in Uniform Circular Motion.

5.4 Be able to solve kinematics problems involving Uniform Circular Motion.

5.5 Know and understand how to analyze general curvilinear motion in terms of its radial and tangential accelerations.

Lesson 6:

Force and Acceleration: Newton's First and Second Laws

Purpose: In this lesson we see that accelerated motion is the consequence of applied forces. Only forces can cause acceleration.

Reading: Chapter 4 - Sections 1-6

Questions: Chapter 3 - 25, 27
Chapter 4 - 2, 3

Problems: Chapter 3 - 31, 32
Chapter 4 - 2, 12

Objectives:

6.1 Know and understand the content of Newton's First and Second Laws.
6.2 Know and understand the concepts of inertia and inertial mass.
6.3 Know and understand what is meant by the term "inertial reference frame."
6.4 Know the units of mass and understand mass as a property of matter.
6.5 Recognize the term "weight" as the force of gravity on an object near the surface of a planet.

Lesson 7:

Newton's Third Law: Using Free-body Diagrams

Purpose: This lesson is designed to help you deepen your understanding of the motion of an object acted upon by gravity and other forces. You're probably already familiar with the saying which begins, "For every action..." This is a popular statement of Newton's third law, which we'll investigate in this lesson. We also develop free-body diagrams and a method of formal analysis to aid in solving problems involving force and acceleration.

Reading: Chapter 4 - Sections 7, 8

Questions: Chapter 4 - 4, 9, 25

Problems: Chapter 4 - 16, 21, 31, 48

Objectives:

7.1 Be able to construct free-body diagrams to identify the net force on each object under consideration.
7.2 Be able to sum the forces acting on a body.
7.3 Be able to use Newton's first and second laws to solve problems of force and acceleration.
7.4 Know and understand Newton's third law.
7.5 Be able to identify action and reaction force pairs according to Newton's Third Law.
7.6 Know the conditions for static equilibrium of point particles, and be able to solve two-dimensional equilibrium problems.
7.7 Be able to use Newton's three laws to solve a wide variety of dynamics problems.

Lesson 8: DOUBLE PERIOD

Newton's Laws: Centripetal Force and Circular Motion
Application 1: **The Physics of Flight**

Purpose: In this lesson, we generalize Newton's second law to include centripetal acceleration. As in Lesson 7, in this lesson, you'll again deepen your understanding of the motion of an object acted upon by gravity. Today we'll also use the Physics of Flight video disks to deepen our understanding of what it means to pull "g's."

Readings: Chapter 5 - Sections 2, 3
Activity Handout

Questions: Chapter 4 - 10, 18
Chapter 5 - 10, 11, 18

Problems: Chapter 4 - 28, 30, 51
Chapter 5 - 17, 23

Objectives:

- **8.1** Know the definition of centripetal force and acceleration.
- **8.2** Understand that "centripetal force" is **not** a new kind of force, but is just the name given to a force which causes an object to undergo centripetal acceleration.
- **8.3** Be able to use Newton's second law to solve a wide variety of dynamics problems.
- **8.4** Be able to calculate the number of "g's" experienced by aircrews when aircraft undergo various turns and loops.

Lesson 9

Introduction to Numerical Modeling: Euler's Method

Purpose: So far, we've limited our study to constant acceleration situations. However, a large class of real problems cannot be accurately modeled as "constant acceleration problems." Furthermore, our assumptions of "frictionless surfaces" and "no air resistance" are often not consistent with our everyday experiences. Fortunately, today's calculators and personal computers now make it possible to treat these more complex problems at the introductory level. In this lesson you'll learn how to use these modern computing tools to solve more complex (and more common) problems. Here, we introduce drag as a velocity dependent force and identify terminal velocity in terms of a balance of forces. We model motion numerically, introducing the Euler method for solving equations. We want you to understand physics as a process of modeling natural phenomena.

Reading: Chapter 5 - Sections 4, 5

Questions: Chapter 5 - 13, 14, 17, 21

Problems: Chapter 5 - 20, 27, 34, 40(a)

Objectives:

- **9.1** Know and understand the Euler method for numerical solution of the equations of motion.
- **9.2** Be able to use Euler's method to solve problems with NON-constant acceleration.

Lesson 10: DOUBLE PERIOD

Physics as a Process: Modeling Drag
***Lab 3*: The Effects of Drag Using Euler's Method**

Purpose: Having introduced the basics of Euler's method in the previous lesson, we now apply these techniques to several interesting problems.

Reading: Lab Handout

Questions: Chapter 5 - 20, 26, 30 **Problems:** Chapter 5 - 41(a), 42(a) & (b), 43(a)

Objectives:
10.1 Understand air drag as a resistive force that depends on velocity.
10.2 Know and understand how terminal velocity arises as a result of a balance of forces (a dynamic equilibrium condition).
10.3 Understand that drag forces are generally nonlinear and resistant to analytic solutions.
10.4 Be able to formulate the Euler method to determine the motion of an object in the presence of velocity dependent forces.

Lesson 11: **THINKING**
PROBLEM 2 DUE

Forces of Nature

Purpose: Here we introduce the four fundamental forces of nature. We find a great mathematical parallel between the gravitational and electric force. The goal of this lesson is for you to understand the important physical concept is force, not gravity or electricity. Here, we study gravity and the electric force as two similar examples of forces. Thus, we now introduce the electric force, a concept you'll encounter again later in this course and in Physics 215.

Reading: Chapter 6 - Section 1 [Review]

Questions: Chapter 6 - 2, 5, 10, 12 **Problems:** Chapter 6 - 1, 5, 10

Objectives:
11.1 Be able to use Newton's Universal Law of Gravitation to solve gravitational force problems involving point masses.
11.2 Know and understand Coulomb's Law.
11.3 Recognize and understand the mathematical similarity between Coulomb's Law and the Universal Law of Gravitation.
11.4 Be able to calculate the electrical force between two point charges separated by a known distance.
11.5 Be able to compare the magnitude of the gravitational and electrical forces between electrons and protons.
11.6 Be able to explain the fundamental forces of nature.

Lesson 12:

Fields in Nature and Review

Purpose: In this lesson, we introduce the field concept, which is widely used in describing gravitational, electromagnetic and nuclear interactions. Also, we'll review some ideas in preparation for your first Physics 110 graded review.

Reading: Chapter 6 - Sections 2-4

Questions: Chapter 6 - 7, 9, 11 **Problems:** Chapter 6 - 14, 19, 25

Objectives:
12.1 Know what's meant by the term "field" and be able to describe and quantitatively determine an example, such as a gravitational field.
12.3 Describe quantitatively the motion of charged particles in a uniform electric field.

Lesson 13: <u>8 FEBRUARY 1996</u>
GRADED REVIEW #1
0700 M-13 in Various Classrooms: SEE YOUR INSTRUCTOR!

BLOCK II: ENERGY AND LINEAR MOMENTUM

Lesson 14:

Introduction to Energy

Purpose: This lesson begins a new phase in the course. We'll begin our study of energy after we define the concept of work. The concept of work is introduced to help describe the transfer of energy from one object to another. The work concept will prove fundamental to our discussions about energy and several other topics covered later in the course.

Reading: Chapter 7 - Sections 1-3

Questions: Chapter 7 - 1, 14 **Problems:** Chapter 7 - 1, 5, 8, 18

Objectives:
14.1 Know and understand the definition of work.
14.2 Know the SI units for work and energy.
14.3 Be able to calculate the work done by a force, including gravity and a spring.

Lesson 15:

Work and Energy

Purpose: Having learned to predict the motion of particles under the influence of various forces, we now turn our attention to the fundamental conservation laws which govern these interactions. In this lesson, we begin our study of a great conservation principle, that of conservation of energy. You probably already have an idea of what "energy" is, and in this lesson we'll begin to discuss "energy" as it is relevant to physics. The concept of work introduced last lesson helps to describe the transfer of energy from one object to another. In this lesson, you'll learn that the application of a net force over some displacement can produce a change in a particle's kinetic energy.

Readings: Chapter 7 - Section 4 (skip section on "Kinetic Friction" on pp. 176-177 and example 7.8)
Chapter 8 - Section 1

Questions: Chapter 7 - 6, 7
Chapter 8 - 8

Problems: Chapter 7 - 26, 27
Chapter 8 - 1, 2

Objectives:

15.1 Know and understand the definition of kinetic energy.
15.2 Be able to calculate the kinetic energy of an object of given mass and speed.
15.3 Know and understand the work-energy theorem.
15.4 Be able to apply the work-energy theorem.
15.5 Know and understand the definition of potential energy.
15.6 Be able to calculate the gravitational potential energy of an object near the Earth's surface.

Lesson 16:

Conservation of Mechanical Energy

Purpose: In this lesson, we introduce the concepts of conservative forces and mechanical energy. To conclude the lesson, we briefly begin to put these concepts together in the principle of Conservation of Mechanical Energy for conservative systems. In Lab 4, we'll work with a system which demonstrates Conservation of Mechanical Energy.

Reading: Chapter 8 - Sections 2-4

Questions: Chapter 7 - 16
Chapter 8 - 16

Problems: Chapter 7 - 28
Chapter 8 - 7

Objectives:

16.1 Know and understand the definition of mechanical energy.
16.2 Know and understand the definition of conservative and non conservative forces.
16.3 Know and understand the principle of conservation of mechanical energy.
16.4 Be able to calculate the potential energy given a conservative force.
16.5 Be able to apply the principle of conservation of mechanical energy.
16.6 Given an energy diagram, be able to identify potential energy and total energy.
16.7 Be able to calculate the kinetic energy by looking at an energy diagram.

Lesson 17: DOUBLE PERIOD

Applications of Energy Conservation
***Lab 4*: Energy Conservation and Conversion**

Purpose: From what height must a loop-the-loop car begin its journey down the track to ensure that it'll stay on the track, even when it's upside down at the top of the loop? How strong a spring would you need on a plunger used to launch a water balloon through a 6th floor open window? This lesson will help you answer these questions and many others like them! We now apply the principle of Conservation of Energy to a variety of situations. After this lesson, you should understand that conservation of energy is a powerful tool for solving dynamics problems.

Readings: Chapter 7 - Section 5
Chapter 8 - Sections 5, 6
Lab Handout

Questions: Chapter 7 - 18
Chapter 8 - 7, 17

Problems: Chapter 7 - 41, 43
Chapter 8 - 10, 14

Objectives:
17.1 Know and understand the definition of power and be able to calculate it.
17.2 Know the SI units of power.
17.3 Know the principle of conservation of total energy.
17.4 Be able to solve dynamics problems using conservation of energy when both conservative and non-conservative forces are present.
17.5 Be able to draw energy diagrams involving various springs and masses and discuss relevant features of the diagrams such as turning points, equipotential lines, initial conditions, and effects of changing total energy available to the system.

Lesson 18: **THINKING**
PROBLEM 3 DUE

$1/r^2$ Forces: The Potential Energy of Gravitational and Electrical Forces

Purpose: To set the stage for planetary and satellite motion we'll study next block, we need to revisit gravitational potential energy. In the general expression for gravity, the force varies inversely with the square of the distance between two objects ($1/r^2$). After this lesson you should understand how our constant value of "g" for the surface of the earth is calculated from Newton's Universal Law of Gravitation. We can also learn much about the electric force between two charged particles by analogy with gravitation. Once again, you should note the mathematical similarities between the Coulomb force and the gravitational force. You should also note the similarities between gravitational and electrical potential energies.

Reading: Chapter 8 - Sections 7, 8

Questions: Chapter 8- 11, 20, 21, 30, 37

Problems: Chapter 8 - 19(a-c),

Objectives:

18.1 Be able to calculate the value of the gravitational acceleration on the surface of a planet of radius R and mass M.
18.2 Be able to derive gravitational potential energy from Newton's Universal Law of Gravitation.
18.3 Be able to calculate the gravitational potential energy of a mass in a central gravitational field.
18.4 Be able to calculate the gravitational potential energy of a system of two or more point masses.
18.5 Be able to derive electrical potential energy from Coulomb's Law.
18.6 Be able to calculate the electrical potential energy of a system of two point particles.
18.7 Be able to use the principle of conservation of energy with the gravitational and electrical potential energies to solve problems.

Lesson 19:

Advanced Energy Concepts: Stability

Purpose: This lesson should help you enrich your understanding of the Conservation of Energy as a basic principle of physics. We'll continue to apply the principle of Conservation of Energy. Furthermore, since stability is an important consideration in contemporary applications, you'll also learn to read energy diagrams and recognize stable and unstable situations by inspecting potential energy functions and plots.

Reading: Chapter 8 - Section 9

Questions: Chapter 8 - 13

Problems: Chapter 7 - 51
Chapter 8 - 34, 43, 45, 48

Objectives:

19.1 Be able to calculate the conservative force related to a given potential.
19.2 Understand the concept of equilibrium and be able to determine from an energy diagram whether an equilibrium position is stable, unstable or neutral.
19.3 Be able to use energy concepts to understand and interpret an energy diagram.
19.4 Be able to use an energy diagram to calculate the force at any point and, given the total energy, determine the kinetic energy at that point.

Lesson 20:

Conservation of Linear Momentum: One-dimensional Collisions

Purpose: In this lesson, we introduce the another great conservation law we'll encounter in Physics 110. We use Newton's third law to identify the action-reaction forces present when two particles interact. This leads naturally to the Law of Conservation of Linear Momentum for an isolated system.

Readings: Chapter 4 - Section 7 [Review]
Chapter 9 - Sections 1, 3

Questions: Chapter 9 - 1, 4, 13 **Problems:** Chapter 9 - 3, 8, 11, 72

Objectives:

20.1 Know and understand Newton's third law (We're revisiting this!).

20.2 Know and understand the definition of linear momentum for a single particle.

20.3 Understand Newton's second law in the form $\vec{F} = d\vec{p} / dt$.

20.4 Be able to identify action and reaction force pairs according to Newton's third law for a system of two particles.

20.5 Be able to distinguish between external and internal forces and to show that if the net external force is zero, Newton's second law gives conservation of momentum.

20.6 Know and understand that conservation of linear momentum is a consequence of Newton's third law for an isolated system of particles.

20.7 Be able to solve certain problems in one dimension by applying momentum conservation.

Lesson 21:

Energy-Momentum Applications: Collisions

Purpose: What happens when two cars collide? What does it take to make the great billiard shots you may have seen on TV? Can we describe and model such collisions? We continue our study of Conservation of Momentum and Energy by applying them in situations where both conservation principles must be considered. The terms "elastic" and "inelastic" collisions are also introduced.

Reading: Chapter 9 - Sections 4, 5

Questions: Chapter 9 - 2, 6, 8 **Problems:** Chapter 9 - 12, 22, 26, 35, 36

Objectives:

21.1 Be able to apply conservation of energy and momentum principles to solve problems involving collisions.

21.2 Know and understand the differences between elastic and inelastic collisions.

21.3 Be able to solve problems involving elastic and inelastic collisions in one and two dimensions.

Lesson 22: DOUBLE PERIOD

Two-dimensional Collisions
***Lab 5*: Two-dimensional Air Puck Collisions**

Purpose: To further our understanding of two-dimensional collisions, we'll conduct a lab involving air puck collisions. We'll quantitatively examine collisions in two dimensions and demonstrate the conservation of momentum in component form.

Reading: Lab Handout

Questions: Chapter 9 - 5, 16, 18 **Problems:** Chapter 9 - 30, 44

Objectives: 22.1 Be able to solve collision problems in two dimensions by applying conservation of linear momentum independently for each dimension.
22.2 Quantitatively investigate linear momentum conservation in the lab.
22.3 Be able to calculate kinetic energy changes that may occur due to a collision.

Lesson 23: **THINKING**
PROBLEM 4 DUE

Rocket Propulsion

Purpose: We apply what we've learned about momentum conservation by tackling an intriguing and very practical application of this conservation principle—rocket propulsion. We'll see that rocket propulsion does not occur because the exhaust is pushing against something, but rather is a manifestation of the conservation of momentum. We then find that rocket propulsion is still effective in outer space, where there is nothing to push against.

Reading: Chapter 9 - Section 8

Questions: Chapter 9 - 14 **Problems:** Chapter 9 - 45, 46, 58, 59

Objectives: 23.1 Know and understand the basic expressions for rocket propulsion and thrust.
23.2 Be able to solve problems of rocket propulsion and acceleration in one dimension.

Lesson 24: DOUBLE PERIOD

Applications of Momentum Conservation
Application 2: **Computer Modeling of Rocket Propulsion**

Purpose: We conclude our study of momentum conservation with a rocket propulsion application. Our goal will be to discover the limiting factors of single-stage-to-orbit rocket propelled platforms.

Reading: Activity Handout

Questions: Chapter 9 - 17 **Problems:** Chapter 9 - 60, 62

Objectives: 24.1 Be able to determine position, velocity, mass and acceleration of a rocket as a function of time.

Lesson 25: **14 MARCH 1996**
GRADED REVIEW #2
0700 M-25 in Various Classrooms: SEE YOUR INSTRUCTOR!

BLOCK III: ANGULAR MOMENTUM, ORBITAL MOTION AND THE ATMOSPHERE

Lesson 26:

Rotational Kinematics

Purpose: Here we lay the groundwork for all aspects of rotational motion. Over this and the next few lessons we'll answer questions on many aspects of what it takes to start spinning, what you can do to change the way you spin, and, ultimately, look at how the planets rotate around each other the way they do.

Reading: Chapter 11 - Sections 1-3

Questions: Chapter 11 - 1, 4 **Problems:** Chapter 11 - 3, 6, 9, 12

Objectives:
26.1 Be able to determine the angular speed of a spinning object.
26.2 Be able to determine the angular acceleration of a spinning object.
26.3 Be able to solve angular kinematics problems.
26.4 Be able to relate angular quantities to their linear counterparts.

Lesson 27:

Moment of Inertia, Energy and Torque

Purpose: We'll use these concepts of rotational motion to describe orbital motion, a concept with numerous contemporary applications. In this lesson, we introduce the concept of torque and study the relationship between angular momentum and torque for single particles.

Reading: Chapter 11 - Sections 4-6

Questions: Chapter 11 - 3, 5, 7 **Problems:** Chapter 11 - 14, 21, 23, 25

Objectives:
27.1 Understand and be able to give a qualitative explanation of the term "moment of inertia."
27.2 Be able to calculate the rotational kinetic energy of an object.
27.3 Know and understand what is meant by the term "torque."
27.4 Be able to calculate the torque exerted by a force about a given point.

Lesson 28:

Angular Momentum and Conservation of Angular Momentum

Purpose: How does a dropped cat nearly always land on its feet? Why does an ice skater spin faster as she brings her arms in for her final scratch spin? This lesson is devoted to the principle which helps us to answer these questions—the principle of conservation of angular momentum. As with linear momentum and energy, our principle focus is on the fundamental conservation laws.

Reading: Chapter 11 - Sections 7, 8

Questions: Chapter 11 - 8, 9, 18, 19 **Problems:** Chapter 11 - 20, 27, 33, 34

Objectives:

28.1 Know and understand what's meant by the term "angular momentum."
28.2 Be able to calculate the angular momentum of a particle about a given point.
28.3 Know the relationship between angular momentum and torque.
28.4 Be able to solve simple problems in rotational dynamics of single particles.
28.5 Know and understand the principle of conservation of angular momentum for single particles.
28.6 Be able to apply the principle of conservation of angular momentum to solve rotational problems involving a few particles.
28.7 Understand qualitatively how the principle of conservation of angular momentum explains many commonplace situations involving rotating objects.

Lesson 29: **THINKING**
PROBLEM 5 DUE

Planetary and Satellite Motion: Kepler's Laws

Purpose: Today we'll review Newton's Universal Law of Gravity. We'll find we can use this law to derive the basic orbital motion of the planets. This is the first of two lessons on gravitational applications of angular momentum. In this lesson we study the fundamental laws of planetary motion. We use Kepler's Laws to show how conservation of angular momentum and Newton's second law enable us to analyze planetary and satellite motion. Our goal in this lesson is to learn how to use conservation of energy and Newton's second law to characterize planetary and satellite motion.

Readings: Chapter 6 - Section 1 [Review]
Chapter 12 - Sections 1-3

Questions: Chapter 6 - 5 (repeat)
Chapter 12 - 1

Problems: Chapter 6 - 14
Chapter 12 - 2

Objectives:

29.1 Be able to perform gravitational force calculations for three bodies.
29.2 Be able to find the gravitational acceleration "g" on the surface of different planets.
29.3 Realize the "g" does NOT disappear in low earth orbit.

29.4 Know and understand how Kepler's three laws of planetary motion are applications of Newton's second law and conservation of angular momentum.
29.5 Be able to apply Newton's second law and conservation of angular momentum to solve problems involving the orbit of an object about a star or planet.
29.6 Be able to show how Kepler's third law can be derived using Newton's second law and the law of gravitation.

Lesson 30:

Energy and Angular Momentum in Orbital Motion

Purpose: With what speed would astronauts who land on Mars need to leave Mars in order to make it back to Earth? How much energy would be required to change the altitude of a satellite by a given amount? In this lesson, we concentrate on answering such questions. We now broaden our study of planetary and satellite motion to include how to apply the principles of conservation of energy and conservation of angular momentum.

Readings: Chapter 12 Section 4
Review Example 6.1

Questions: Chapter 12 - 8

Problems: Chapter 12 - 11, 12, 18

Objectives:
30.1 Be able to calculate the escape velocity of an object from the surface of a planet and from satellite orbits.
30.2 Be able to determine the energy and angular momentum requirements to transfer from one circular orbit to another.
30.3 Be able to derive escape velocity from the total energy equation.
30.4 Be able to derive orbital velocity from Newton's second law and the law of gravitation.
30.5 Understand the difference between escape velocity and orbital velocity.
30.6 Given a radial energy diagram, be able to describe the shape of an orbit for various total orbital energies.
30.7 Understand what a black hole is and be able to calculate the radius of its associated event horizon.

Lesson 31: DOUBLE PERIOD

Dynamics of Satellite Orbits
Application 3: **Orbit Modeling**

Purpose: Now we can look closely at some interesting satellite issues, including geostationary satellites and line of sight limitations. The global positioning system (GPS) of satellites has revolutionized war fighting by enabling the use of autonomous smart weapons delivery. This in turn has vastly changed our doctrine on how we carry out armed conflict. Also, perhaps the most difficult aspect of the Apollo mission wasn't the technology of building the rockets. but rather the ability to perform the calculations required in getting to the moon and back, safely. A tremendous number of orbital maneuvers had to be performed. Today we'll talk about those maneuvers and learn how to use them to get to get a simple cargo transport from Earth to Mars, in one of the most economical ways—the Hohmann transfer.

Reading: Handout, "Dynamics of Satellite Orbits"
Activity Handout

Questions: Chapter 12 - 4, 18 **Problems:** Chapter 12 - 17, 20, 23, 24

Objectives:
31.1 Be able to calculate the period and altitude of geosynchronous satellites.
31.2 Understand what's meant by the *Satellite Orbit Paradox.*
31.3 Be able to compare different kinds of satellite orbits, and understand why certain types of satellites require certain orbits.
31.4 Understand the purpose of apogee kick.
31.5 Understand and know how a Hohmann transfer is performed.
31.6 Be able to perform basic calculations to use a Hohmann transfer to change from one circular orbit to another.
31.7 Be able to describe the differences between traveling from Earth to the inner planets and traveling from Earth to the outer planets.

Lesson 32:

Temperature and the Kinetic Theory of Gases

Purpose: Until now, we've dealt with no more than two or three particles at a time. In this lesson we consider multiparticle systems and note that we can describe gases in this way. We'll learn how temperature and pressure arise from the kinetic theory of gases. We'll also learn the molecules in a gas do not all have the same speed, but can be described by a distribution of speeds.

Reading: Chapter 13 - Sections 1, 3, 5, 6

Questions: Chapter 13 - 10, 21 **Problems:** Chapter 13 - 5, 26, 33

Objectives:
32.1 Know the definition of pressure as it relates to the force exerted by a gas.
32.2 Understand how a thermometer works and be able to convert temperatures between the Celsius, Kelvin, and Fahrenheit scales.
32.3 Know the equation of state for an ideal gas (Ideal Gas Law).
32.4 Be able to solve problems using the ideal gas equation of state.
32.5 Know and understand the relationship between pressure and molecular kinetic energy in a gas.
32.6 Know the definition of temperature based on a gas's average molecular kinetic energy.
32.7 Be able to solve problems using the **kinetic theory** of pressure and temperature.

Lesson 33: **THINKING PROBLEM 6 DUE**

The Atmosphere

Purpose: The atmosphere is very important to us!. In this lesson, we'll explore the parameters that affect the distribution of molecules that make up our atmosphere. We'll learn the density of the atmosphere decreases exponentially as a function of height, as we've all experienced as we have gone from sea level to a place like Colorado. This density decrease is temperature dependent, and we'll later see this can have a profound effect on the orbits of Air Force satellites

Reading: Handout, "The Atmosphere"

Problems: Chapter 13 - 43; Handout Problems

Objectives:

33.1 Be able to describe how the molecules in our atmosphere are distributed and to explain why all molecules aren't found at the earth's surface.

33.2 Be able to solve problems with the Law of Atmospheres.

33.3 Know that the average potential energy of a molecule at temperature T in a uniform gravitational field is k_BT; be able to describe the significance of this fact.

33.4 Understand that mixing processes in the lower 100 km of the atmosphere produce a uniform distribution of atmospheric gases in this region.

Lesson 34: DOUBLE PERIOD

***Lab 6*: Atmospheric Modeling and Orbital Decay**

Purpose: Did you know that atmospheric heating from such things as a solar flare can cause a satellite's orbit to decay prematurely? This is exactly what happened to Skylab back in the 1970's! Lab 6 will allow you to use computer tools to examine the atmosphere and its effect on orbits in a quantitative way.

Reading: Lab Handout

Problems: Handout Problems

Objectives:

34.1 Understand the concepts of atmospheric number density and mass density.

34.2 Provided a spreadsheet template, be able to produce an atmospheric density profile given a temperature profile.

34.3 Given an atmospheric temperature profile, be able to determine the atmospheric mass density as a function of altitude.

34.4 Understand that temperature variations can have profound effects on the atmospheric density.

Lesson 35: 18 APRIL 1996

GRADED REVIEW #3

0700 M-35 in Various Classrooms: SEE YOUR INSTRUCTOR!

BLOCK IV: RELATIVISTIC MOMENTUM AND ENERGY; MODERN PHYSICS

Lesson 36: DOUBLE PERIOD

Introduction to Einstein's Principle of Special Relativity

Purpose: This lesson introduces a block in which we begin to consider 20th century physics! Have you ever been in a car, stopped at a traffic light with a car next to you, and been unsure whether you or the other car has begun to move? We discuss this type of motion, which is described by Galilean relativity. This should serve to enhance your appreciation of inertial reference frames and expand the applications of Newton's Laws. Then, we'll move from Galilean relativity to Einstein's special theory of relativity. Having introduced a large portion of mechanics from a Newtonian perspective in the previous blocks, we now pause to reconsider mechanics in light of 20th century research. We'll introduce Einstein's theory of special relativity, showing the connection to Newtonian mechanics and illustrating how new theories and observations are tested. We'll also discover that Einstein's theory of Special Relativity leads to some very interesting results!

Reading: Chapter 3 - Section 6
Chapter 10 - Sections 1-3

Questions: Chapter 3 - 11, 19
Chapter 10 - 1, 11

Problems: Chapter 3 - 39, 40
Chapter 10 - 1, 2

Objectives:

36.1 Know the Galilean coordinate and velocity transformations and be able to solve one- and two- dimensional problems in reference frames moving at constant velocity.
36.2 Be able to discuss the failure of Galilean relativity for high particle speeds.
36.3 Know the two postulates of the special theory of relativity.
36.4 Understand the principle of correspondence between Galilean and Special Relativity as a guideline for evaluating new theoretical models and explaining observations.

Lesson 37:

Relativistic Momentum and Energy

Purpose: We continue our study of special relativity by generalizing the concepts of energy and momentum. We find the expressions for relativistic momentum and energy are always correct, but are approximated by the classical expressions at low speeds compared to the speed of light. We also introduce the "gamma factor" in this lesson.

Reading: Chapter 10 - Sections 6, 7

Questions: Chapter 10 - 10, 13, 16

Problems: Chapter 10 - 23, 27, 29

Objectives:

37.1 Know the relativistic definition of linear momentum and be able to calculate relativistic momentum.
37.2 Be able to calculate the relativistic factor "gamma."
37.3 Be able to calculate kinetic energy and total energy of particles moving at relativistic speeds.
37.4 Be able to show that the non-relativistic results are obtained in the limit of low speeds.
37.5 Be able to determine the rest energy of a particle of known mass using both SI units and electron volts.

Lesson 38:

Applications of Relativity: Fission and Fusion Energy

Purpose: We begin our applications of Special Relativity by considering fission and fusion. After this lesson, you should understand the fundamental concepts of fission energy generation and the underlying hopes for fusion energy generation. Reactor technology and the difficulties associated with controlled fusion will also be discussed.

Reading: Chapter 10 - Section 8

Questions: Chapter 10 - 14 **Problems:** Chapter 10 - 30, 33, 37, 38

Objectives:

38.1 Understand the basis for energy release in fission and fusion reactions.
38.2 Be able to analyze an equation representing a typical fission reaction and describe the sequence of events which occurs during the process.
38.3 Be able to analyze energy release in fusion reactions.
38.4 Understand the technological challenges involved in controlled fusion.

Lesson 39:

Applications of Relativity: Binding Energy

Purpose: During this lesson, we focus on the equivalence of mass and energy. Since most applications are taken from nuclear physics, some fundamental terminology is introduced. We'll also look into the forces that keep the nucleus from breaking apart.

Reading: Chapter 31 - Sections 1 (through Equation 31.2), 2

Questions: Chapter 31 - 1, 4 **Problems:** Chapter 31 - 12, 14, 16

Objectives:

39.1 Understand the equivalence of mass and energy.
39.2 Know how to use the appropriate nomenclature in describing the static properties of nuclei.
39.3 Be able to calculate the binding energy of nuclei, given a table of physical data.

Lesson 40: **THINKING PROBLEM 7 DUE**

Military Applications and Introduction to Radiation

Purpose: Let's consider some military applications of special relativity. Also, we need to set the groundwork for our radiation lab in the next lesson. We'll soon discover there are several ways unstable nuclei can spontaneously emit radiation known as radioactivity. The process of radioactivity illustrates the equivalence of mass and energy. When a substance spontaneously decays, some of its mass is converted into energy! Where does this energy go? We now look at the various radioactive decay processes, and the exponential decrease of radioactive nuclei as a function of time. In addition, we'll see how radioactive elements can be used in the dating of certain substances, such as the use of Carbon-14 dating.

Readings: Handout, "The Physics of Nuclear Explosives"
Chapter 31 Sections 3-5

Questions: Chapter 31 - 3, 6, 8 **Problems:** Chapter 31 - 23, 36, 56

Objectives:
40.1 Be able to compare nuclear weapons and high explosives.
40.2 Know the three processes by which radioactive nuclei decay and the type of radiation given off by each process.
40.3 Understand that radioactive decay follows an exponential function.
40.4 Know the meaning of decay constant and decay rate.
40.5 Understand the meaning of half-life of a radioactive substance.
40.6 Know the curie as the unit of radioactivity.
40.7 Be able to solve problems using the exponential decay law.
40.8 Understand the basic principles used in carbon dating.

Lesson 41: DOUBLE PERIOD

Radioactivity
***Lab 7*: Radioactive Decay**

Purpose: Lab 7 reinforces the concepts relating to radioactivity as we determine the half-life of radioactive barium.

Reading: Lab Handout

Questions: Chapter 31 - 7, 17 **Problems:** Chapter 31 - 18, 22, 28

Objective: **41.1** Be able to determine the exponential decay, decay rate, and half-life of a given sample.

Lesson 42:

The Beginnings of Particle Physics

Purpose: Our last lesson concludes our series of applications of Special Relativity. You've probably read or heard about discoveries of new particles, the canceled Superconducting Super Collider project, and other particle physics topics in the news. In this lesson, we'll study implications of the mass-energy relationship in the realm of elementary particles. We'll also introduce antiparticles and processes by which particles and antiparticles are created and destroyed. As we study this material, we'll once again be using the principles of conservation of momentum and energy.

Readings: Chapter 32 - Sections 3, 4 (through Equation 32.1)
Handout, "The Beginnings of Particle Physics"

Problems: Handout Problems

Objectives:

42.1 Know what a photon is.

42.2 Be able to calculate the energy of a photon given its frequency, or visa versa.

42.3 Know and understand the properties of antiparticles such as the positrons and antiprotons.

42.4 Be able to determine the energy needed to produce particle-antiparticle pairs.

42.5 Be able to analyze energy and momentum in the annihilation of an electron and a positron, resulting in two photons.

42.6 Be able to apply the principles of conservation of charge, conservation of momentum, and conservation of mass-energy in determining whether reactions can occur or not.

Last, But Not Least!
COMPREHENSIVE FINAL EXAMINATION

Appendix III-A: The Purdue Master Attitudes Scale

Electronic mail sent to Cockpit Physics and Physics 110 Control Students

Good day,

You have been selected to complete an attitudinal survey about some courses that you may be taking this semester. Your participation in this survey is voluntary though very important to academic research that I am conducting this semester. Your participation in no way affects your grade in the referenced subject areas, and your instructors are not aware of your participation in this survey. Only I will see your individual responses. Please complete the attached survey as soon as you receive it (before the first day of class).

1. View the survey by choosing the Attach logo on your email menu and select run. The survey is titled atti.doc.

2. Complete the attached survey save it with a new name.

3. Reply to my message attaching your saved file.

Note: the data about which physics section you are enrolled in, and your age, are very important so please don't leave these sections blank.

I will be meeting you in your physics class soon to give you more information about the study. Thank-you for your time. If you have questions about this survey you may contact me through email, grunerh@dfp, by phone at #472-3129, or in my office, room 6F13 Fairchild Hall.

Mrs. Heidi Mauk Gruner

A SCALE FOR MEASURING ATTITUDE TOWARD ANY SCHOOL SUBJECT

Test Collection
Carl Campbell Brigham Library
Educational Testing Service

Ella B. Silance

Edited by
H. H. Remmers

Form B

Please fill in the blanks below. (You may leave the space for your name blank if you wish.)

Name____

Male   Female   (underline or encircle one)   Today's date___________

Age today _______   USAFA Class___________

What physics section are you enrolled in this semester? Be sure to note if it is physics 110 or physics 110Z. ______________________

What occupation would you best like to follow?____________________

Directions:

Following is a list of statements about school subjects. Place a plus sign (+) before each statement with which you agree with reference to the subject or subjects listed at the left of the statements. Your score will in no way affect your grade in any course.

Subject Math	Physics	Computer Science	
_____	_____	_____	1. I am "crazy" about this subject.
_____	_____	_____	2. The very existence of humanity depends on this subject.
_____	_____	_____	3. If I had my way, I would compel everybody to study this subject.
_____	_____	_____	4. This subject is one of the most useful subjects I know.
_____	_____	_____	5. I believe this subject is the basic one for all college courses.
_____	_____	_____	6. This is one subject that all young Americans should know.
_____	_____	_____	7. This subject fascinates me.
_____	_____	_____	8. The merits of this subject far outweigh the defects.
_____	_____	_____	9. This subject gives students the ability to interpret situations they will meet in life.
_____	_____	_____	10. This subject will help students socially as well as intellectually.
_____	_____	_____	11. This subject makes me efficient in school work.
_____	_____	_____	12. There are more chances for development of high ideals in this subject.
_____	_____	_____	13. This subject is interesting.
_____	_____	_____	14. This subject teaches methodical reasoning.
_____	_____	_____	15. This subject serves the needs of a large number of students.

_____	_____	_____	16. All methods used in this subject have been thoroughly tested in the classroom by experienced teachers.
_____	_____	_____	17. This subject has its merits and fills its purpose quite well.
_____	_____	_____	18. Every year more students are taking this subject.
_____	_____	_____	19. This subject aims mainly at power or execution or application.
_____	_____	_____	20. This subject is not based on untried theories.
_____	_____	_____	21. I think this subject is amusing.
_____	_____	_____	22. This subject has its drawbacks, but I like it.
_____	_____	_____	23. This subject might be worth while if it were taught right.
_____	_____	_____	24. This subject doesn't worry me in the least.
_____	_____	_____	25. My likes and dislikes for this subject balance one another.
_____	_____	_____	26. This subject is all right, but I would not take any more of it.
_____	_____	_____	27. No student should be concerned with the way this subject is taught.
_____	_____	_____	28. To me this subject is more or less boring.
_____	_____	_____	29. No definite results are evident in this subject.
_____	_____	_____	30. This subject does not motivate the student to do better work.
_____	_____	_____	31. This subject has numerous limitations and defects.
_____	_____	_____	32. This subject interferes with developing.
_____	_____	_____	33. This subject is dull.
_____	_____	_____	34. This subject seems to be a necessary evil.
_____	_____	_____	35. This subject does not hold my interest at all.
_____	_____	_____	36. The average student gets nothing worth having out of this subject.
_____	_____	_____	37. All of the material in this subject is very uninteresting.
_____	_____	_____	38. This subject can benefit me.
_____	_____	_____	39. This subject has no place in the modern world.
_____	_____	_____	40. Nobody likes this subject.
_____	_____	_____	41. This subject is more like a plague than a study.
_____	_____	_____	42. This subject is all bunk.
_____	_____	_____	43. No sane person would take this subject.
_____	_____	_____	44. Words can't express my antagonism toward this subject.
_____	_____	_____	45. This is the worst subject taught in school.

Scoring table form B

The median scale value of the statements marked with a plus is the attitude score. If an odd number of statements is thus endorsed, the scale value of the middle item of those endorsed gives the score. For example, if nine statements are endorsed of which the fifth one is item 10, the score for the student is 8.9, the scale value of item 10. If an even number of items is endorsed, the student's score is the scale value half-way between the two middle items. Example: If ten items are endorsed of which items 13 and 8 are the fifth and sixth in order, the pupil's score will be the scale value of item 13, 8.5, plus the scale value for item 8, 9.1, divided by 2. (8.5 + 9.1)/2 = 8.8.

#	score
1	10.3
2	10.3
3	9.8
4	9.7
5	9.6
6	9.4
7	9.2
8	9.1
9	9.0
10	8.9
11	8.8
12	8.7
13	8.5
14	8.4
15	8.3
16	8.1
17	7.9
18	7.7
19	7.6
20	7.3
21	6.7
22	6.5
23	6.0
24	5.9
25	5.5
26	4.7
27	3.6
28	3.5
29	3.4
30	3.3
31	3.1
32	2.9
33	2.8
34	2.6
35	2.5
36	2.4
37	2.2
38	2.1
39	1.6
40	1.5
41	1.3
42	1.0
43	.8
44	.7
45	.6

Appendix: III-B
Student Journal Keepers
Instructions for Volunteers

Spring 1996

Thank you for volunteering to be a journal keeper for Physics 110Z or Physics 110 Control. I think you will find keeping a journal an educational as well a fun experience. The information that you will provide about the course is extremely important.

Keeping a journal is not complicated, you simply need to document your experiences in physics class, and your feelings about the course. Tell me about your experiences in class or lab, about the homework and exams, about your study group, or anything else you want to write about.

You can keep your journal daily if you choose, but I would like you to make at least one entry a week. You should plan to spend about 15 minutes per lesson on your journal, though you may want to write more. Please date each entry and send me your journal every two weeks. You can get the journal to me in one of three ways:

1. Email it to me each time that you write.

2. Keep an ongoing electronic journal and email it (or bring a hard copy) to me every two weeks.

3. Keep a handwritten journal and bring a photo copy to me every two weeks. I have notebooks that I can give you for this purpose.

Let me assure you again that your participation with me is anonymous. Your instructor does not know who is keeping a journal.

I recognize that you have many constraints on your time and I appreciate your willingness to spend time to help me with this study. At the end of the semester I will be glad to contact your Air Officer Commander and inform him or her of your willingness to participate, and, I will request extra privileges for you as a small token of my appreciation. I will ask your permission individually before I do this however.

Occasionally I will send you a question or two to stimulate thought about the course. Please answer the questions in the next journal entry that you make.

Here is a question to get you started:

You were given the opportunity to choose your own working group for Cockpit Physics and Physics 110 Control lab. How did you choose who you worked with?

Thanks again! Please contact me if you have any questions.

Heidi Gruner
room 6F13A
grunerh@DFP

Faculty Journal Keepers
Instructions for Volunteers
Spring 1996

Thank you for volunteering to be a faculty journal keeper for Physics 110Z or Physics 110 Control. I think you will find keeping a journal an educational as well a fun experience. The information that you will provide about the course is extremely important.

Keeping a journal is not complicated, you simply need to document your experiences teaching physics class, and your feelings about the course that you are teaching. Tell me about your experiences with the students, equipment, and course materials. I am interested in what you have to say about class preparation, labs, or anything else you want to write about.

You can keep your journal daily if you choose, but I would like you to make at least one entry a week. You should plan to spend about 15 minutes per lesson on your journal though you may want to write more. Please date each entry and send your journal to me once every two weeks. You can get the journal to me in one of three ways:

1. Email it to me each time that you write.

2. Keep an ongoing electronic journal and email (or bring a hard copy) to me every two weeks.

3. Keep a handwritten journal and bring a photo copy to me every two weeks. I have notebooks that I can give you for this purpose.

Let me assure you again that your participation with me is anonymous. Although your supervisor many know that I have asked you to keep a journal, he or she has no access to the journal, and I will not use identifying characteristics of any type if I quote you anonymously in my reports and findings.

I recognize that you have many constraints on your time and I appreciate your willingness to spend time to help me with this study.

Occasionally I will send you a question or two to stimulate thought about the course. Please answer the questions in the next journal entry that you make.

Here is a question to get you started:

You have experience working with physics students in many different settings, the lecture classroom, doing laboratory or application activities, and using the computer in Cockpit Physics class. In which environment do you think the students learn the most? Why?

Thanks again! Please contact me if you have any questions.

Heidi Gruner
room 6F13A
grunerh@DFP

Appendix III-C: Sample letter to Air Officer Commanding

DEPARTMENT OF THE AIR FORCE
THE DEPARTMENT OF PHYSICS
USAF ACADEMY, COLORADO

1 April 1997

HQ USAFA/DFP
2354 Fairchild Drive, Suite 2A6
USAF Academy CO 80840-6200

Air Officer Commander
CWDS #
USAF Academy, CO 80840

Dear Major X

The Department of Physics, USAFA, has commissioned me as a graduate student in the field of Curriculum and Instruction, to study Physics 110Z, a prototype restructuring of the core physics course. In this capacity it is my pleasure to inform you that Cadet X volunteered his/her time this semester to participate in the study of Physics 110Z. Cadet X volunteered to keep a student journal on his/her experiences in physics (or volunteered to be interviewed for the study). I recognize that cadet time is valuable, and I appreciate Cadet X's willingness to contribute to this academic initiative. I hope that you will take this into account when awarding privileges for cadets who make extra contributions to the Academy mission. In similar studies, at civilian schools, student volunteers are compensated monetarily.

I am obligated to inform you that Cadet X's participation is anonymous and unknown to his/her instructor. I specifically received permission from Cadet X to inform you of his/her participation, but, I cannot reveal to you the content of his/her journal (interview).

Please contact me if you have questions about the nature of this study. I can be reached at x3129 or by Email at grunerh@DFP. Thank you for your consideration.

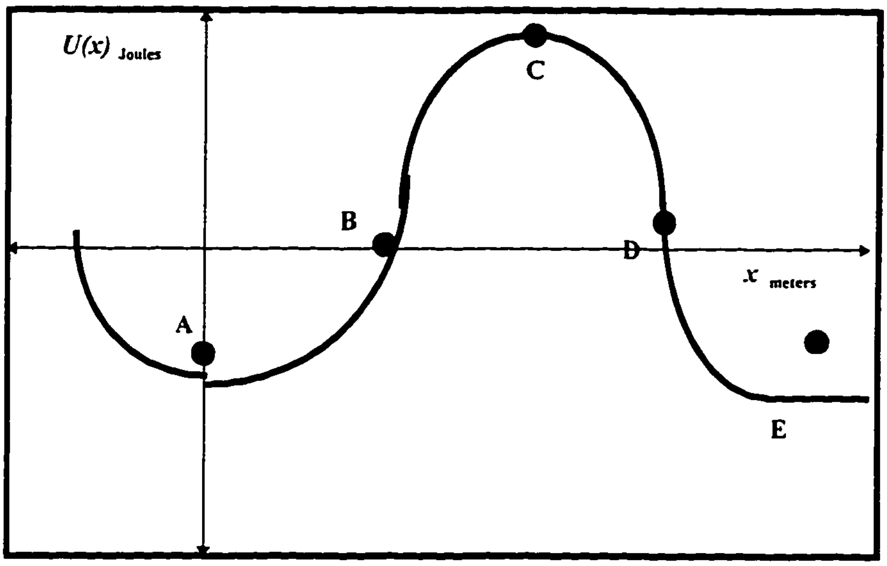
Sincerely,

Heidi Mauk Gruner
Adjunct Instructor
Department of Physics

cc:
Cadet X

Appendix III-D: Student Interview Protocol
Exam #_____ Question #______
Cadet name________________ Section____________
Assigned Cadet #________
Date__________ Start time__________ Stop time_________
"Please refer to your exam and look at short answer question number 2. I would like you to solve the problem for me out loud. Tell me the physics that you are using in your solution. Think about when you took the exam. Was there some aspect of the course that you refereed to when solving this problem?"

Sample Graded Review Problem for student interviews
SA-2. (50) Consider the potential energy curve , *U(x)* versus *x*, as shown below. You DO NOT need to show any calculations to answer the following questions.



(a) (10) The force, F(x), is positive at the point(s) _____________ .

(b) (10) The force, F(x), is zero at the point(s) _____________ .

(c) (10) Point(s) _____________ is (are) in stable equilibrium.

(d) (10) Point(s) _____________ is (are) in unstable equilibrium.

(e) (10) Point(s) _____________ is (are) in neutral equilibrium.

Appendix III-E: The Maryland Physics Expectations Survey

Name____ **Student Number**______________

Univ./College__USAFA________ **Course/Section**______________ **Instructor**__________________

Date________________

Introductory Physics MPEX Survey: Pre-course

This is a survey about what you expect to happen in the coming physics class. We have developed this survey to try to help us understand where we might run into trouble in this course. The results will help us design materials to help other students get over these problems more effectively. This survey is voluntary. The results will have no impact on your grade in this course. We do, however, appreciate your cooperation and filling the survey out will contribute to making this a better course. NOTE: This survey is being given at many universities and colleges. Please fill out the information above so we can identify both the school and the course you are attending.

To help us understand your background, please answer the following questions:

1. What is your age? __________

2. Are you male (M) or female (F) ? __________

3. Have you taken a physics course before this one

in high school _________ or in college?________

If so:

Did you feel it was a good course? __________ ___

Do you feel you did well in that course? __________ ___

When did you take it? (what year?) __________ ___

Are you repeating this course ___

4. What was the last math course you completed in high school?__________

5. What was the last math course you completed in college? ________

When did you take it? (year) __________

6. What is your major or intended major? ____________________________

7. The number of hours per week I will spend reading, studying, and doing homework for this course (not counting time in labs, writing lab reports, and reviewing for exams) is about: __________.

8. The number of hours I will spend preparing for an exam is about: _________.

9. I will work with others ______% of the time I spend on physics outside of class (excluding labs).

For the list of skills below, rate yourself using the following scale:

1 = Excellent 2 = Good 3 = Average 4 = Weak 5 = Poor N = Can'tsay

Understanding physics text materials	_______	Taking tests	_______
Understanding physics lectures	_______	Laboratory skills	_______
Understanding experiments and demonstrations	_______	Algebra	_______
Solving homework problems on your own	_______	Trigonometry	_______
Expressing yourself clearly in writing	_______	Calculus	_______
Convincing others of your point of view	_______	Vectors	_______

The remainder of the survey should take about 15 minutes to fill out. There are 35 statements which may or may not describe your beliefs about the course. You are asked to rate each statement by circling a number between 1 and 5 where the numbers mean the following:

1 strongly disagree
2 disagree
3 neutral
4 agree
5 strongly agree.

Read the survey items carefully. Answer the questions by circling the number that best expresses your feeling. Don't over-elaborate the meaning of each statement. The statements are meant to be taken as straightforward and simple. If you do not understand a statement, leave it blank. If you understand, but have no strong opinion one way or the other, circle the 3. If an item combines two statements and you disagree with either one, choose 1 or 2.

Space is left after each statement for you to explain your choice and give an example if appropriate.

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

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

3. I plan to go over my class notes carefully in preparation for exams in this course. 1 2 3 4 5

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

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

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

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

8. In this course, I do <u>not</u> expect to understand equations in an intuitive sense; they must just be taken as givens. 1 2 3 4 5

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

10.	Physical laws have little relation to what I experience in the real world.	1 2 3 4 5
11.	A good understanding of physics is necessary for me to achieve my career goals. A good grade in this course is not enough.	1 2 3 4 5
12.	Knowledge in physics consists of many pieces of information that apply primarily to a specific situation.	1 2 3 4 5
13.	My grade in this course will be primarily determined by how familiar I am with the material. Insight or creativity will have little to do with it.	1 2 3 4 5
14.	Learning physics is a matter of acquiring new knowledge that is specifically located in the laws, principles, and equations given in the textbook and in class.	1 2 3 4 5
15.	In doing a physics problem, if my calculation gives a result that differs significantly from what I expect, I'd have to trust the calculation.	1 2 3 4 5
16.	The derivations and proofs of equations in class or in the text have little to do with solving problems or with the skills I need to succeed in this course.	1 2 3 4 5
17.	Only very few specially qualified people are capable of really understanding physics.	1 2 3 4 5
18.	To understand physics, I expect to sometimes think about my personal experiences and relate them to the topic being analyzed.	1 2 3 4 5

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

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

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

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

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

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

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

26. When I solve most exam or homework problems, I explicitly think about the concepts that underlie the problems. 1 2 3 4 5

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

28. Spending a lot of time (half an hour or more) working on a problem is a waste of time. If I don't make progress quickly, I am better off asking someone who knows more (a classmate, a TA, or a Prof.) what to do. 1 2 3 4 5

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

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

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

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

33. I expect that what I learn in this course will agree with my gut feelings about how the physical world works. 1 2 3 4 5

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

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

Appendix III-F:Classroom Observations
Section:
Environment:
Date:
Notes:

minute	teacher initiated	student initiated		whole group	small group	individual T to S	individual S to T	individual S to S		context		process		msc	
										Q	C	Q	C	Q	C
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

Reference: Swan, K. & Mitrani., (1993). The changing nature of teaching and learning in computer-based classrooms. Journal of Research on Computing in Education, 26 (1), 40- 54.

Force Concept Inventory Part One

Please enter your student ID

Check the one best answer to the questions below.
You can make corrections if you change your mind.
When you are done click on the SUBMIT button at the bottom of this page.

1. Two metal balls are the same SIZE, but one weights twice as much as the other. The balls are dropped from the top of a two story building at the same time. The time it takes the balls to reach the ground below will be:

- ☐about half as long for the heavier ball.
- ☐about half as long for the lighter ball.
- ☐about the same time for both balls.
- ☐considerably less for the heavier ball, but not necessarily half as long.
- ☐considerably less for the lighter ball, but not necessarily half as long.

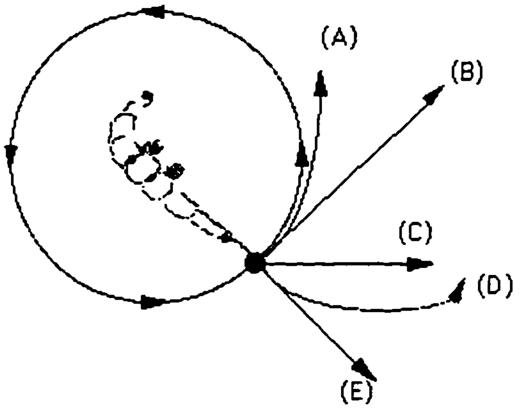
2. Imagine a head-on collision between a large truck and a small compact car. During the collision,

- ☐the truck exerts a greater amount of force on the car than the car exerts on the truck.
- ☐the car exerts a greater amount of force on the truck than the truck exerts on the car.
- ☐neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
- ☐the truck exerts a force on the car, but the car doesn't exert a force on the truck.
- ☐the truck exerts the same amount of force on the car, as the car exerts on the truck.

3. Two steel balls, one of which weighs twice as much as the as the other, roll off a horizontal table with the same speeds. In this situation;

- ☐both balls impact the floor at approximately the same horizontal distance from the base of the table.
- ☐the heavier ball impacts the floor at about half the horizontal distance from the base of the table than does the lighter.
- ☐the lighter ball impacts the floor at about half the horizontal distance from the base of the table than does the heavier.
- ☐the heavier ball hits considerably closer to the base of the table than the lighter, but not necessarily half the horizontal distance.
- ☐the lighter ball hits considerably closer to the base of the table than the heavier, but not necessarily half the horizontal distance.

4. A heavy ball is attached to a string and swung in a circular path in a horizontal plane as illustrated in the diagram on the right. At the point indicated in the diagram, the string suddenly breaks at the ball. If these events were observed from directly above, indicate the path of the ball after the string breaks.**

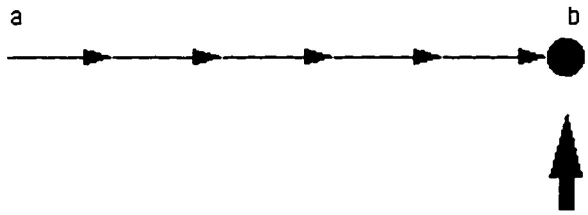


- ☐A
- ☐B
- ☐C
- ☐D
- ☐E

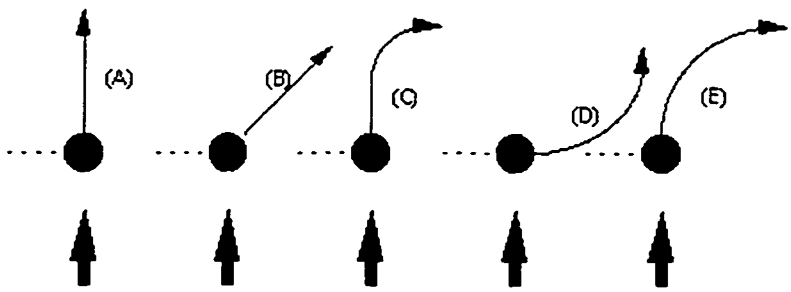
5. A boy throws a steel ball straight up. Disregarding any effects of air resistance, the force(s) acting on the ball until it returns to the ground is(are):

- ☐its weight vertically downward along with a steadily decreasing upward force.
- ☐a steadily decreasing upward force from the moment it leaves the hand until it reaches its highest point beyond which there is a steadily increasing downward force of gravity as the object gets closer to the earth.
- ☐a constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point, after which there is only the constant downward force of gravity.
- ☐a constant downward force of gravity only.
- ☐none of the above, the ball falls back down to the earth simply because that is its natural action.

Use the statement and diagram below to answer the next four questions: The diagram depicts a hockey puck sliding, with constant velocity, from point "a" to point "b" along a frictionless horizontal surface. When the puck reaches point "b", it receives an instantaneous horizontal "kick" in the direction of the heavy print arrow.



6. Along which of the paths will the hockey puck move after receiving the "kick"?



- ☐A
- ☐B
- ☐C
- ☐D
- ☐E

7. The speed of the puck just after it receives the "kick"?

- ☐Equal to the speed "Vo" it had before it received the "kick".
- ☐Equal to the speed "V" it acquires from the "kick", and independent of the speed "Vo".
- ☐Equal to the arithmetic sum of the speeds "Vo" and "V".
- ☐Smaller than either of speeds "Vo" or "V".
- ☐Greater than either of the speeds "Vo" or "V", but smaller than the arithmetic sum of these two speeds.

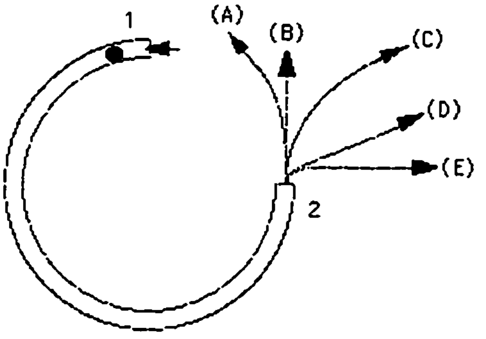
8. Along the frictionless path you have chosen, how does the speed of the puck vary after receiving the "kick"?

- ☐No change.
- ☐Continuously increasing.
- ☐Continuously decreasing.
- ☐Increasing for a while, and decreasing thereafter.
- ☐Decreasing for a while, and increasing thereafter.

9.The main forces acting, after the "kick", on the puck along the path you have chosen are:

- ☐the downward force due to gravity and the effect of air pressure.
- ☐the downward force of gravity and the horizontal force of momentum in the direction of motion.
- ☐the downward force of gravity, the upward force exerted by the table, and a horizontal force acting on the puck in the direction of motion.
- ☐the downward force of gravity and an upward force exerted on the puck by the table.
- ☐gravity does not exert a force on the puck, it falls because of the intrinsic tendency of the object to fall to its natural place.

10.The accompanying diagram depicts a semicircular channel that has been securely attached, in a horizontal plane, to a table top. A ball enters the channel at "1" and exits at "2". Which of the path representations would most nearly correspond to the path of the ball as it exits the channel at "2" and rolls across the table top?



- ☐A
- ☐B
- ☐C
- ☐D
- ☐E

11. Two students, a student "a" who has a mass of 95 kg and a student "b" who has a mass of 77 kg sit in identical office chairs facing each other. Student "a" places his bare feet on student "b"'s knees, as shown below. Student "a' then suddenly pushes outward with his feet, causing both chairs to move.

In this situation,

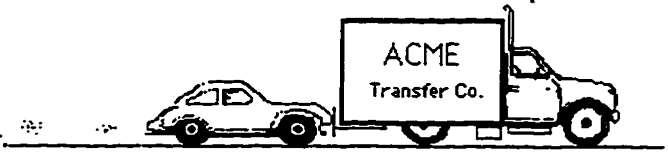
- ☐neither student exerts a force on the other.
- ☐student "a" exerts a force on "b", but "b" doesn't exert any force on "a".
- ☐each student exert a force on the other but "b" exerts the larger force.
- ☐each student exert a force on the other but "a" exerts the larger force.
- ☐each student exerts the same force on the other.

12. A book is at rest on a table top. Which of the following force(s) is(are) acting on the book?
1. A downward force due to gravity.
2. The upward force by the table.
3. A net downward force due to air pressure.
4. A net upward force due to air pressure.

- ☐1 only
- ☐1 and 2
- ☐1,2, and 3

- ☐1,2, and 4
- ☐none of these, since the book is at rest there are no forces acting on it.

Refer to the following statement and diagram while answering the next two questions.
A large truck breaks down out on the road and receives a push back into town by a small compact car.



13. While the car, still pushing on the truck, is speeding up to get up to cruising speed,

- ☐the amount of force of the car pushing against the truck is equal to that of the truck pushing back against the car.
- ☐the amount of force of the car pushing against the truck is less than that of the truck pushing back against the car.
- ☐the amount of force of the car pushing against the truck is greater than that of the truck pushing back against the car.
- ☐the car's engine is running so it applies a force as it pushes against the truck, but the truck's engine is not running so it can't push back against the car, the truck is pushed simply because it is in the way of the car.
- ☐neither the car nor the truck exert any force on the other, the truck is pushed forward simply because it is in the way of the car.

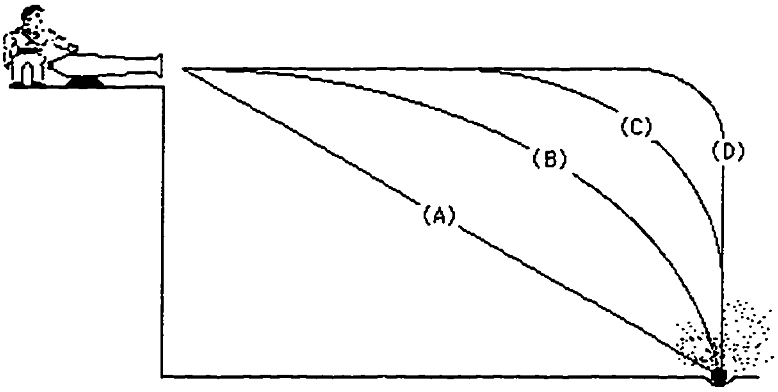
14. After the person in the car, while pushing the truck, reaches cruising speed at which he/she wishes to continue to travel at constant speed;

- ☐the amount of force of the car pushing against the truck is equal to that of the truck pushing back against the car.
- ☐the amount of force of the car pushing against the truck is less than that of the truck pushing back against the car.
- ☐the amount of force of the car pushing against the truck is greater than that of the truck pushing back against the car.
- ☐the car's engine is running so it applies a force as it pushes against the truck, but the truck's engine is not running so it can't push back against the car, the truck is pushed simply because it is in the way of the car.
- ☐neither the car nor the truck exert any force on the other, the truck is pushed forward simply because it is in the way of the car.

15. When a rubber ball dropped from rest bounces off the floor, its direction of motion is reversed because;

- ☐energy of the ball is conserved.
- ☐momentum of the ball is conserved.
- ☐the floor exerts a force on the ball that stops its fall and then drives it upward.
- ☐the floor is in the way and the ball has to keep moving.
- ☐none of the above.

16. Which of the paths in the diagram to the right best represents the path of the cannon ball?



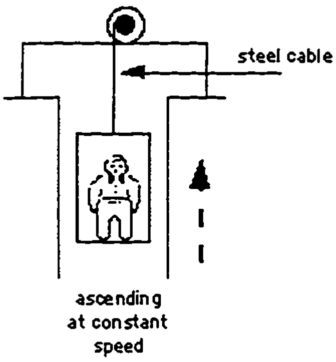
- ☐A
- ☐B
- ☐C
- ☐E
- ☐F

17. A stone falling from the roof of a single story building to the surface of the earth;

- ☐reaches its maximum speed quite soon after release and then falls at constant speed thereafter.
- ☐speeds up as it falls, primarily because the closer the stone get to the earth, the stronger the gravitational attraction.
- ☐speeds up because of the constant gravitational force acting on it.
- ☐falls because of the intrinsic tendency of all objects to fall toward the earth.
- ☐falls because of a combination of the force of gravity and the air pressure pushing it downward.

When responding to the following question, assume that any frictional forces due to air resistance are so small that they can be ignored

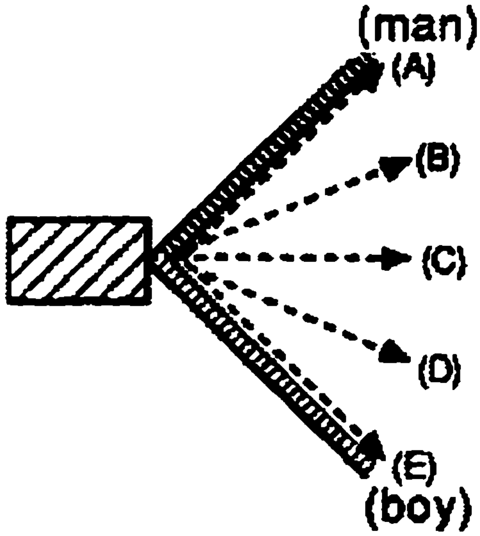
18. An elevator, as illustrated, is being lifted up an elevator shaft by a steel cable. When the elevator is moving up the shaft at constant velocity;



- ☐the upward force on the elevator by the cable is greater than the downward force of gravity.
- ☐the amount of upward force on the elevator by the cable is equal to that of the downward force of gravity.

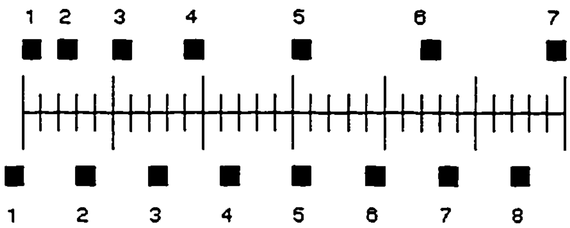
- ☐the upward force on the elevator by the cable is less than the downward force of gravity.
- ☐it goes up because the cable is being shortened, not because of the force being exerted on the elevator by the cable.
- ☐the upward force on the elevator by the cable is greater than the downward force due to the combined effects of air pressure and the force of gravity.

19. Two people, a large man and a boy, are pulling as hard as they can on two ropes attached to a crate as illustrated in the diagram on the right¥. Which of the indicated path (A-E) would most likely correspond to the path of the crate as they pull it along?



- ☐A
- ☐B
- ☐C
- ☐D
- ☐E

4. The positions of two blocks at successive 0.20 second time intervals are represented by numbered squares in the diagram below. The blocks are moving toward the right.

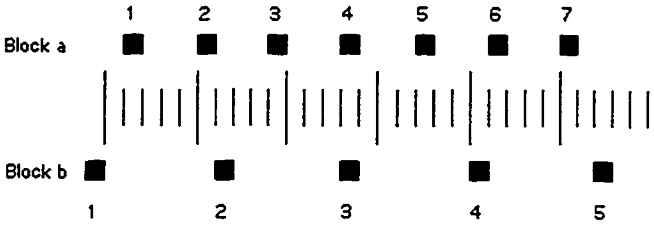


20. Do the blocks ever have the same speed?

- ☐No.
- ☐Yes, at instant 2.
- ☐Yes, at instant 5.
- ☐Yes, at instant 2 and 5.

- ☐Yes, at some time during interval 3 to 4.

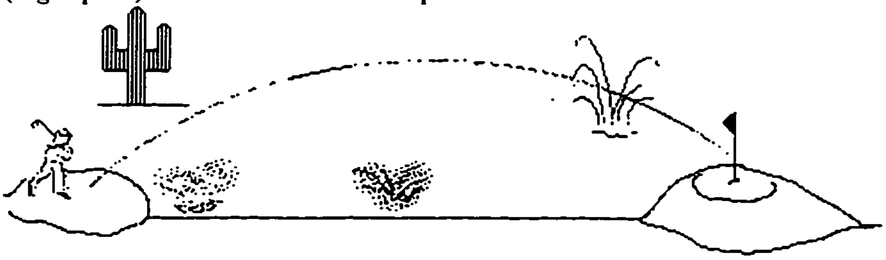
The positions of two blocks at successive equal time intervals are represented by numbered squares in the diagram below. The blocks are moving toward the right.



21. The accelerations of the blocks are related as follows:

- ☐acceleration of "a" > acceleration of "b"
- ☐acceleration of "a" = acceleration of "b" > 0
- ☐acceleration of "b" > acceleration of "a"
- ☐acceleration of "a" = acceleration of "b" = 0
- ☐not enough information to answer.

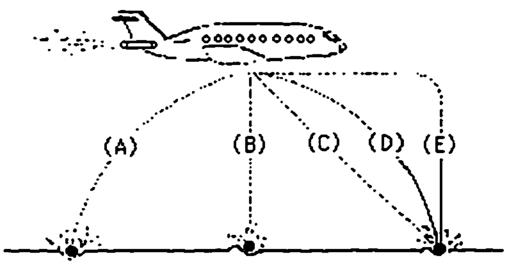
22. A golf ball driven down a fairway is observed to travel through the air with a trajectory (flight path) similar to that in the depiction below.



Which of the following force(s) is(are) acting on the golf ball during its entire flight?
1. the force of gravity
2. the force of the "hit"
3. the force of air resistance

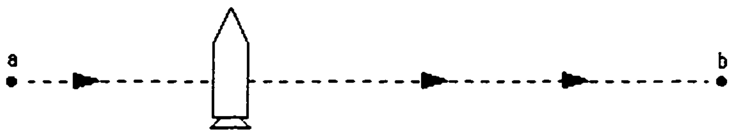
- ☐1 only
- ☐1 and 2
- ☐1,2, and 3
- ☐1 and 3
- ☐2 and 3

23. A bowling ball accidentally falls out of the cargo bay of an airliner as it flies along in a horizontal direction. As seen from the ground, which path would the bowling ball most closely follow after leaving the airplane?

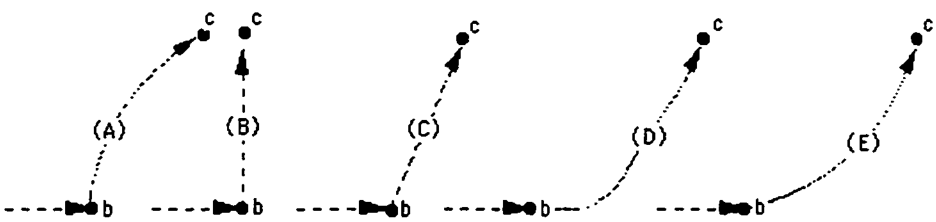


- ☐A
- ☐B
- ☐C
- ☐D
- ☐E

When answering the next four questions, refer to the following statement and diagram. A rocket, drifting sideways in outer space from position "a" to position "b" is subject to no outside forces. At "b", the rocket's engine starts to produce a constant thrust at right angles to the line "ab". The engine turns off again as the rocket reaches some point "c".



24. Which path below best represents the path of the rocket between "b" and "c"?

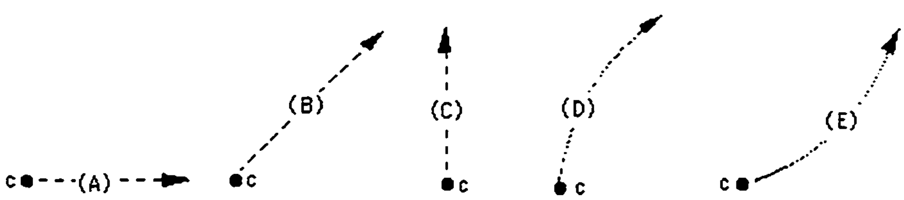


- ☐A
- ☐B
- ☐C
- ☐D
- ☐E

25. As the rocket moves from "b" to "c", its speed is

- ☐constant.
- ☐continuously increasing.
- ☐continuously decreasing.
- ☐increasing for a while and constant thereafter.
- ☐constant for a while and decreasing thereafter.

26. At "c" the rocket's engine is turned off. Which of the paths below will the rocket follow beyond "c"?



- ☐A
- ☐B
- ☐C
- ☐D

- ☐E

27. Beyond "c", the speed of the rocket is ;

- ☐constant.
- ☐continuously increasing.
- ☐continuously decreasing.
- ☐increasing for a while and constant thereafter.
- ☐constant for a while and decreasing thereafter.

28. A large box is being pushed across the floor at a constant speed of 4.0 m/s. What can you conclude about the forces acting on the box?

- ☐If the force applied to the box is doubled, the constant speed of the box will increase to 8.0 m/s.
- ☐The amount of force applied to move the box at a constant speed must be more than its weight.
- ☐The amount of force applied to move the box at a constant speed must be equal to the amount of the frictional force that resists its motion.
- ☐The amount of force applied to move the box at a constant speed must be more to the amount of the frictional force that resists its motion.
- ☐There is a force being applied to the box to make it move but the external forces such as friction are not "real" forces they just resist motion.

29. If the force being applied to the box in the preceding problem is suddenly discontinued, the box will;

- ☐stop immediately.
- ☐continue at a constant speed for a very short period of time and then slow to a stop.
- ☐immediately start slowing to stop.
- ☐continue a constant velocity.
- ☐increase its speed for a very short period of time, then start slowing to a stop.

Appendix III-H
Student Letter of Informed Consent
Spring Semester
Cockpit Physics Study

To Physics 110Z Students and selected 110 Control Students,

You are asked to participate in the study of Cockpit Physics at the United States Air Force Academy during AY 95-96. The focus of this study is the affective and cognitive impact of Cockpit Physics on the students. My role is that of an external observer collecting information directly from the students and faculty, through the use of surveys, classroom observations, interviews, and journals. I am conducting this study for the Department of Physics, USAFA, and for my personal dissertation research at Kansas State University. The results of this study will help to determine if Cockpit Physics has the potential to be used course wide. This study is being conducted with the full support of the Department of Physics and the Office of the Dean, USAFA.

I will observe your class periodically but will make every attempt not to disrupt the natural flow of the class. I will be disseminating surveys to you at various times during the semester, and will be conducting interviews with some of you. These surveys and interviews will be conducted outside of scheduled class time, and will require no more than 3 hours of your time this semester. You are asked to keep a journal about your experiences in physics class. Specific instructions about journal keeping have been given to you separately. It is reasonable to plan to spend 15 minutes per lesson on your journal.

This study will last through the spring semester of 1996, but follow up studies may be conducted after that time. Records about this study will be kept indefinitely for my personal use. Your communication with me about this study, to include your journal entries, is confidential. I request your permission to quote you anonymously in reports and publications about this study. Your name or other identifying features will not be linked with the results of this study.

You will be provided a copy of this letter with your signature.

Sincerely,

Heidi Mauk Gruner

My participation in this study is purely voluntary. I understand that my refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled and that I may discontinue participation at any time without penalty or loss of benefits to which I am entitled.

If I have questions about the rationale or method of the study, I understand that I may contact Heidi Mauk Gruner, room 6F13, #472-3129, grunerh@DFP.

If I have questions about the rights of subjects in this study or about the manner in which the study is conducted, I may contact Jerome Frieman, Chair, Committee on Research Involving Human Subjects, 103 Fairchild Hall, Kansas State University, Manhattan, KS 66506, at (913) 532-6195.

I volunteer to be a journal keeper. yes_____ no_____

Printed Name ______________________ CS______ Date _____________

Section______________

Signature __________________________

Instructor Letter of Informed Consent
Spring Semester 1996
Cockpit Physics Study

To the instructors of Cockpit Physics and selected Physics 110 Control sections.

You are asked to participate in the study of Cockpit Physics at the United States Air Force Academy during AY 95-96. The focus of this study is the affective and cognitive impact of Cockpit Physics on the students. My role is that of an external observer collecting information directly from the students and faculty, through the use of surveys, classroom observations, interviews, and journals. I am conducting this study for the Department of Physics, USAFA, and for my personal dissertation research at Kansas State University. The results of this study will help to determine if Cockpit Physics has the potential to be used course wide. This study is being conducted with the full support of the Department of Physics and the Office of the Dean, USAFA.

I will observe your class periodically but will make every attempt not to disrupt the natural flow of the class. I will be disseminating surveys to your students at various times during the semester, and will be conducting interviews with some of your students. These surveys and interviews will be conducted outside of scheduled class time, and will require no time or participation on your part. Student volunteers are keeping journals. It is essential that the students who participate with me in this study remain anonymous to you.

You are asked to keep a journal about your experiences teaching physics this semester. Specific instructions about journal keeping will be given to you separately, but it is reasonable to plan to spend 15 minutes per lesson on your journal. I may ask to interview you at a later date. This study will last through the spring semester of 1996, but follow up studies may be conducted after that time. Records about this study will be kept indefinitely for my personal use. Your communication with me about this study, to include your journal entries, is confidential. I request your permission to quote you anonymously in reports and publications about this study. Your name or other identifying features will not be linked with the results of this study.

You will be provided a copy of this letter with your signature.

Sincerely,

Heidi Mauk Gruner

My participation in this study is purely voluntary. I understand that my refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled and that I may discontinue participation at any time without penalty or loss of benefits to which I am entitled.

If I have questions about the rationale or method of the study, I understand that I may contact Heidi Mauk Gruner, room 6F13, #472-3129, grunerh@DFP.

If I have questions about the rights of subjects in this study or about the manner in which the study is conducted, I may contact Jerome Frieman, Chair, Committee on Research Involving Human Subjects, 103 Fairchild Hall, Kansas State University, Manhattan, KS 66506, at (913) 532-6195.

Printed Name ______________________ **Date** _____________

Signature __________________________

Appendix IV-A: Journal Keeper Data

Cockpit Physics

Student #	**M/F**	**section**	**Notes/Entry dates**
ZJ26 IZ3	F	M1A	lsn 1, lsn 2, lsn3
ZJ42	F	T1A	1/11,2/6, 4/28,
ZJ28	M	M1A	1/8, 1/17
ZJ18 IZ1	M	T3A	1/11, 2/13,
ZJ43	M	T1A	2/5,
ZJ30	M	M1A	1/24,
ZJ44 IZ16	F	T1A	lsn1-9,
ZJ3 IZ11	M	M3A	1/30, 2/19, 3/2, 4/10
ZJ19	M	T3A	1/24, 2/12,
ZJ45	M	T1A	1/24, 1/30, 2/7, 2/11, 2/6, 2/19, 2/29, 3/5, 3/7, 3/21, 3/31, 4/1, 4/3, 4/12, 4/30, 5/3,
ZJ4	F	M3A	1/31, 5/5
ZJ32	M	M1A	2/8, 3/31
ZJ5 IZ13	M	M3A	1/22,
ZJ33 IZ4	M	M1A	2/8,
ZJ20 IZ8	M	T3A	1/16, 1/20, 1/23, 1/30, 2/8, 3/5, 3/7, 4/1,
ZJ48	M	T1A	1/11, 1/18, 1/24, 2/13, 3/4,
ZJ23	M	T3A	1/21, 2/13
ZJ7	M	M3A	1/24, 2/11,
ZJ35	M	M1A	1/17, 1/27, 2/8, 2/23, 3/15,
ZJ9 IZ10	M	M3A	2/8, 2/23, 3/18, 3/29, 4/18,
ZJ36	M	M1A	1/25, 4/17
ZJ50 IZ19	M	T1A	1/24,
ZJ37	M	M1A	1/20, 2/13, 4/19
ZJ38	M	M1A	1/25, 2/8
ZJ39	M	M1A	1/8, 2/8, 4/16
ZJ15 IZ2	M	T3A	1/20, 2/9, 3/31, 4/23

Journal Keeper Data

Physics 110Control

Student #	**M/F**	**section**	**Notes/Entry dates**
CJ2 IC7	M	M3B	1/24,
CJ17	M	T5C	1/10, 1/16
CJ11	M	T3A	1/16, 1/18, 1/31, 4/14, 4/22, 4/30
CJ4	F	M3B	lsns1-10, lsns11-15,
CJ27 IC13	M	M6B	1/12, 1/23, 1/30, 2/10, 3/3, 4/6
CJ20	F	T5C	3/13, 3/16, 3/21
CJ21 IC9	M	T5C	wants to try, 3/14
CJ22	M	T5C	1/25, 2/4, 2/8, 2/29, 3/7, 3/21, 4/7, 4/10, 4/18, 4/24, 5/1
CJ9	M	M3B	1/6, 1/24, lsn8-13, 2/8, 2/26, 3/22, 4/7, 5/6
CJ34	M	M6B	1/9, 2/10,

Appendix IV-B: Interviews
Exam #1 question: Estimation Problem 1

Physics 110 Control

Student	Volunteer or selected?	date and time of interview	recorded on tape #	Section	score on estimation problem 1.	Score on GR#1
IC7 CJ2	volunteer	2/21/96 1:30 PM	3 side 1	M3B	110/120	515/700 C+
IC6	volunteer	2/21/96 1:00 PM	3 side1	M3B	5/120 makeup GR	459/700 D make up GR
IC5 **F**	volunteer	2/20/96 10:30AM	2 side 1	M3B	120/120	585/700 B
IC12	volunteer	2/27/96 11:00 AM	4 side 1	M3B	120/120	588/700 B exam average
IC8 IC18 for GR2 **F**	volunteer	2/22/96 11:30 AM	3 side2	M3B	70/120	360/700 D
IC4	volunteer	2/13/96 2:00PM	1 side 2	M6B	120/120	615/700 B+
IC9 CJ21	selected	2/22/96 3:00 PM	3 side 2	T5C	90/120	655/700 A
IC3	volunteer	2/13/96 1:300PM	1 side 2	M6B	120/120	565/700 B
IC1 **F**	volunteer	2/12/96 5:00PM	1 side 1	M6B	120/120	590/700 B
IC11	selected	2/26/96 2:30 PM	4 side1	T5C	doesn't remember and lost exam	89% B+
IC2	volunteer	2/12/96 1:00PM	1 side 1	M6B	120/120	615/700 B+
IC10	selected	2/22/96 3:30 PM	4 side1	T5C	120/120	680/700 A

Interviews Exam #1 question: Estimation Problem 1

Cockpit Physics

Student #	Volunteer or selected?	date and time of interview	recorded on tape #	Section	score on estimation problem 1.	Score on GR#1
IZ3 ZJ-26 F	volunteer	2/20/96 11:00	2, side 2	M1A	120/120	635/700 A
IZ5	volunteer	2/20/96 3:00PM	2, side 2	M1A	120/120	700/700
IZ6	volunteer	2/20/96 4:30PM	3, side 1	M1A	90/120	620/700 B+
IZ1ZJ-18	volunteer	2/13/96 3:00 PM	1, side 2 2, side 1	T3A	120/120	660/700 A
IZ4 ZJ-33	volunteer	2/20/96 2:30PM	2, side 2	M1A	120/120	630/700 A
IZ8- ZJ-20	volunteer	2/29/96	4 side2	T3A	120/120	698/70 A
IZ9	selected	2/29/96 4:30 PM	4 side 2	T3A	120/120	620/70 B
IZ2 ZJ-15	volunteer	2/14/96 11:00AM	2, side 1	T3A	115/120	640/700 A
IZ7 F	selected	2/27/96 11:30 AM	4 side 1	T3A	120/120	585/700 B

Interviews Exam #2 question: Workout Problem 1

Physics 110 Control

Student #	Volunteer or selected?	date and time of interview	recorded on tape #	Section	score on work out problem #1	Score on GR#2
IC14	volunteer	4/10/96 11:30	6 side 1	M6B	90/150	385/700 D
IC15	volunteer	4/11/96 9:00 AM	6 side 2	M6 B	120/150	535/700 A
IC18	volunteer	4/15/96 1:30 PM	8 side 2	M3	115/150	575/700 A
IC18 IC8 from GR1	volunteer	4/15/96 11:00 AM	8 side1	M3	120/150	445/700
CJ27 IC13	volunteer	4/9/96 9:00 AM	5 side 1	M6B	140/150	570/700
IC19	volunteer, needs to only stay a few minutes	4/15/96 2:00 PM	8 side 2	M3	85/150	240/700
IC16	volunteer	4/11/96 11:00 AM	6 and 7 side 2 and 1	M6B	80/150	320/700 F
IC17	volunteer	4/11/96 2:00 PM	7 side1	M3 (came from honors a couple of lessons ago)	30/150	360/700

Interviews Exam #2 question: Workout Problem 1

Cockpit Physics

Student #	Volunteer or selected?	date and time of interview	recorded on tape #	Section	score on workout problem 1	Score on GR#2
IZ18 F	volunteer	4/16/96 9:30 AM	9 side1	T3	15/150	290/700 F
IZ14	volunteer	4/11/96 11:30 AM	7 side 1	M3	130/150	643/700 A
ZJ44 IZ16 F	volunteer	4/15/96 1:00 PM	8 side1,2	T1	90/150	355/700 F
ZJ3 IZ11	volunteer	4/10/96 8:00 AM	5 side 1, 2	M3	25/150	450/700 C
IZ12 F	volunteer	4/10/96 8:30 AM	5 side 2	M3	20/150 put in units on problem	350/700 F
ZJ5 IZ13	volunteer	4/10/96 9:00 AM	6 side1	M3	25/150	416/700 D +
IZ20	volunteer	4/16/96 1:45 PM	9,10 side 2,1	T1	55/150	370/700
ZJ9 IZ10	volunteer	4/9/96 10:00 AM	5 side1	M3		
ZJ50 IZ19	volunteer	4/16/96 11:30 AM	9 side1	T1	85/150	540/700
IZ17	volunteer	4/15/96 2:30 PM	8,9 side 2, side1	T1	75/150	505/7000 B
IZ13	volunteer	4/11/96 8:30 AM	6 side 1	M3	30/150 got points for units	445/700 C
IZ15	volunteer	4/15/96 10:00 AM	8 side 1	T1	140/150	610/700 A

Interviews Exam #3 question: Short Answer # 1

Physics 110 Control

Student #	Volunteer or selected?	date and time of interview	recorded on tape #	Section	score on short answer problem #1	Score on GR#3
IC21	selected	30 April 96 9:00 AM	10 side 1	M6	0/30	510/700
IC22	selected	30 April 96 2:00 PM	tape10 side 1,2	M6	30/30	525/700
IC23	selected	30 April 96 2:30 PM	tape 10 side 2	T5	0/30	420/700
IC24 **F**	selected	1 May 96 10:00 AM	tape 11 side 1	M6	30/30	470/700 C+
IC25	selected	1 May 96 11:30 AM	tape 11 side 2	M6	30/30	480/700 C++
IC26 **F**	selected	2 May 96 8:30 AM	tape 11 side 2	T5	30/30	475/700 C+
IC27	selected	6 May 96	tape 13 side 1	T3	0/30	480/700
IC28 **F**	selected	6 May 96	tape 13 side2	T5	30/30	440/700
IC29	selected	6 May 96	tape 13 side 2	T3	0/30	525/700
I30	selected	6 May 96	tape 13,14 side 2,1	T5	0/300	545/70
I31 **F**	selected	7 May 96	tape 14 side 1,	T3	30/30	540/700
I32	selected	7 May 96 2:00 PM	tape 14 side 1	T3	30/30	615/70
I33 **F**	selected	8 May 96 2:00 PM	tape 14 side 1	T3	Didn't have exam so we went on to general interview	390/700

Interviews Exam #3 question: Short Answer # 1

Cockpit Physics

Student #	Volunteer or selected?	date and time of interview	recorded on tape #	Section	score on short answer problem #1	Score on GR#3
ZJ20 IZ8 IZ21	volunteered	30 April 96 3:30 PM	10,11 side 2,1	T3	30/30	560/700
ZJ15 IZ2 IZ22	volunteered	1 May 96 11:00 AM	tape #11 side 1,2	T3	30/30	420/700 C
IZ23 **F**	selected	2 May 96 9:00 AM	tape #12 side 1	T3	30/30	600/700 A
IZ24	selected	2 May 10:00 AM	tape 12 side1	T1	30/30	620/700
IZ25	selected	2 May 96 1:00 PM	tape 12 side 1,2	T3	30/30	325/700 F
IZ26 **F**	selected	6 May 96	tape 12 side 2	M1	30/30	635/700 A
IZ27	selected	6 May 96	tape 13 side 1,2	M3	30/30	400/700

Appendix IV-C: Swan and Mirani 15 Minute Observations

Observations Cockpit Physics Whole Class

date	teacher initiated	student initiated	whole group	small group	individual T to S	individual S to T	individual S to S	context		process		msc	
								Q	C	Q	C	Q	C
1/25/96	21	8	1	24	1	3	0	13	0	0	10	0	3
1/30/96	21	7	27	0	0	0	0	20	2	2	3	0	1
1/31/96	17	12	0	17	5	8	0	7	0	12	10	0	0
2/5/96	9	15	5	7	0	12	0	0	0	8	16	0	0
2/21/96	35	3	29	0	6	3	0	18	0	2	9	5	4
2/26/96	32	7	34	0	0	5	0	23	1	5	9	0	1
3/4/96	25	1	12	0	13	1	0	20	2	2	0	0	2
3/12/96	25	8	22	1	5	5	0	16	3	2	6	3	1
3/18/96	24	2	18	1	5	2	0	12	1	2	11	0	0
4/16/96	26	5	27	0	3	1	0	14	3	2	9	0	3
4/13/96	8	7	10	0	1	3	1	9	0	3	0	2	1
5/1/96	46	6	33	18	0	0	0	2	3	7	39	0	0
mean	24.1	6.8	18.2	5.67	3.25	3.58	.08	12.8	1.25	3.92	10.2	.83	1.3 3

Observations Cockpit Physics Small Group

date	teacher initiated	student initiated	whole group	small group	individual T to S	individual S to T	individual S to S	context Q	context C	process Q	process C	msc Q	msc C
1/25/96	10	18	0	10	1	1	15	7	6	0	12	0	1
1/30/96	6	24	0	6	1	4	18	11	5	8	6	0	0
1/31/96	4	23	2	5	0	1	18	7	2	3	15	0	0
2/5/96	18	18	19	6	0	1	10	5	3	5	19	0	4
2/13/96	3	28	1	1	1	0	28	8	6	3	13	0	1
2/14/96	5	29	1	5	0	1	27	5	2	7	19	0	1
2/26/96	1	33	0	1	0	1	32	11	8	2	10	0	10
3/4/96	0	19	0	0	0	2	17	7	5	5	2	0	0
3/12/96	3	22	0	6	0	0	19	8	1	2	9	2	0
3/18/96	10	18	1	11	4	3	9	10	8	1	2	1	6
4/4/96	4	16	0	4	0	0	15	6	6	0	5	1	0
5/1/96	8	14	4	6	0	1	11	1	1	7	12	0	1
5/6/96	6	16	20	4	0	1	13	3	10	0	8	0	1
4/24/96	7	3	0	7	0	3	0	6	0	4	0	0	0
mean	6.07	20.1	3.43	5.14	0.5	1.36	16.57	6.79	4.5	3.36	9.43	.29	1.79

Observations Control Whole Class

Date	teacher initiated	student initiated	whole group	small group	individual T to S	individual S to T	individual S to S	context Q	context C	process Q	process C	msc Q	msc C
1/10/96	6	5	6	0	0	1	0	6	1	1	3	0	0
1/11/96	19	1	12	0	4	0	0	14	1	2	2	1	0
1/23/96	10	2	12	0	0	0	0	7	1	2	2	0	0
1/2396	18	10	20	0	0	8	0	11	2	8	5	1	1
1/25/96	40	0	40	0	0	0	0	24	0	4	5	4	2
1/30/96	25	8	14	0	15	5	0	19	2	3	6	0	3
2/1/96	16	3	15	0	1	3	0	6	0	8	3	0	2
2/5/96	20	2	15	0	5	2	0	17	2	1	1	0	2
2/6/96	15	0	15	0	0	0	0	7	0	2	1	5	0
2/12/96	15	2	16	0	0	1	0	6	1	1	3	0	0
2/14/96	29	6	23	0	7	5	0	19	7	1	5	3	0
2/20/96	21	12	11	0	11	10	0	23	1	1	3	3	2
2/26/96	30	4	18	0	14	2	0	24	0	4	1	2	3
2/27/96	45	0	45	0	0	0	0	36	0	0	4	5	0
4/10/96	8	1	9	0	0	0	0	4	0	3	0	2	1
4/4/96	14	2	16	0	0	0	0	12	0	1	0	0	3
4/11/96	10	9	15	0	4	0	0	13	4	1	1	0	0
3/23/96	6	10	11	0	0	5	0	12	1	0	0	2	1
4/25/96	12	13	17	0	0	8	0	20	0	3	0	2	0
5/1/96	20	4	20	0	1	3	0	22	0	1	0	1	0
5/6/97	9	5	11	0	2	1	0	9	0	4	0	0	1
5/7/96	17	10	12	13	2	1	0	0	1	9	16	0	2
mean	18.4	4.95	17.0	.59	3.0	2.5	0	14.1	1.09	2.73	2.77	1.4	1.05