Physics Department 2004-05 Annual Report

Mission statement:

1. The primary objective of the Department of Physics is to provide students with the best environment for learning the science of Physics. The department serves a diversified palette of academic majors. For some students it is more important to learn Physics as an operational tool for work in science, while others seek to develop critical thinking and analytical reasoning through learning Physics. Therefore the primary mission of the Department is to provide full academic support of:

> **1 a.** a B. S. major in Physics and a minor in Applied Physics in The Citadel's day program,
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> **1 b.** the core curriculum courses in Physics on the calculus and non-calculus level, as well as general elective courses in Astronomy to adequately meet the needs of all non-physics majors in the day program, and
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> **1 c.** honor program courses, professional elective courses for engineering programs and a graduate course in the pedagogy of physics, when requested by coordinators of the appropriate programs.

The core curriculum courses consist of the *College Physics* and *Physics with Calculus* lecture/lab sequences. Although they differ in the degree of complexity and prerequisite mathematical background, they essentially cover similar topics. They also address the core requirements in the areas of (a) written communication, (b) critical thinking, (c) logical reasoning, and (d) resource and reference usage in a very similar manner.

a. Written communication.

All core curriculum courses have a weekly two-hour laboratory. A different experiment is performed each week, and a written report on each laboratory is required of each student. Besides scientific data in the form of tables, graphs and equations, each report must contain a prose summary of the results. These written sections form an important part of the report, and they are graded not only for critical thinking and logical reasoning, but also for the proper writing style compatible with the standards of scientific reporting.

b. Critical thinking.

Physics is intrinsically a program of reasoning that arises from critical examination and critical thinking. Its conclusions are almost universally derived from fundamental laws which themselves are the result of critical observation and induction. Predictions that arise theoretically, often from a vast and complex mathematical apparatus devised by centuries of formulation and deduction, are subjected to critical examination by carefully conceived and controlled experiments. Physics has historically been called Natural Philosophy because Nature itself is the final arbiter of its conclusions.

Developing critical thinking is the essence of teaching Physics. It is regularly exercised in class, laboratory, laboratory reports and examinations by logically deriving predictions from first principles and then verifying the results with experimental facts.

c. Logical reasoning.

In Physics all predictions are derived from first principles by means of logic and mathematics, which is itself a derivative of the art of logic. In this aspect all physics courses, whether core or in major, are alike – even in the simplest and most general classes, the ordered derivation steps are outlined in their logical sequence by the professor. The only difference between the basic and advanced courses lies in the complexity of the logical process and mathematical apparatus involved. Logic and mathematics are also the principal tools for solving assigned problems.

d. Resource and reference use.

At the introductory level of the core courses in physics one emphasizes the development of concepts and techniques; the research component of these sequences consists of direct experimentation in the laboratory. The main reference is the textbook, which typically includes information far exceeding the material that can be covered in class. However, on occasion the faculty may include topical papers in the course material to allow students to investigate applications of course concepts and techniques.

In addition to its primary mission the Department also engages in service.

2. In service to its own faculty, the college, and the scientific community, the Department

2 a. provides conditions conducive to faculty research and scholarly development,

2 b. encourages faculty participation in scholarly societies and organizations,

2 c. invites outside speakers and supports a professional seminar program.

3. In service to the community and the local school systems, the Department sponsors and conducts events that popularize science and promote interest in studying scientific disciplines.

Expected results:

1. Teaching.

Physics is the study of the fundamental laws of nature and how they explain the phenomena of the observable world. The Department fulfills its teaching mission by helping students develop critical reasoning. The students are shown how the same fundamental laws govern all physical phenomena and serve as the foundation of science. This requires that they not only understand the laws of physics, but also acquire sufficient empirical facts and laboratory experience to logically apply the scientific method to interpret empirical data.

Philosophically, the measures of success in teaching and learning are similar for all core physics lecture and laboratory courses. They include assessment of learning, critical thinking, and problem solving skills. However, the criteria applied to science and engineering majors reflect that these students are expected to adopt the principles of physics as tools of their future profession. These different degrees of expectations are summarized as follows.

1 a. Physics majors graduating with good grades should be adequately prepared for graduate study in physics or closely related disciplines. Physics minors with good grades should find that their physics experience augments their preparation for graduate studies or professional certifications. The curriculum will be broad enough to prepare all physics majors for careers in fields such as education at the secondary level, research and industrial scientific laboratories, high-technology branches of the Armed Forces, and other careers that require analytical thinking with a mathematical and scientific background.

1 b. The common goal of calculus- and algebra-based physics core courses is to introduce a student to the scientific method as a process of discovery of the logical structure of nature. Students will learn to use appropriate mathematical skills to carry out calculations and compare theoretical results with observations. In addition, after completing the physics core curriculum sequence with good grades, engineering and non-physics science majors will be adequately prepared for passing the physics portions of standard graduate school or professional qualifying examinations such as the EIT or MCAT.

Non-science majors should be able to apply the basic laws of classical physics to a wide variety of the many problems of everyday life amenable to algebraic/trigonometric solution. They should have facility in distinguishing the problem constants and variables, in isolating one variable as a function of others, their relative significance, and the interrelating equations that facilitate or admit solutions.

1 c. The Department will offer on request, consistent with departmental profile, special honors seminars, specifically designed professional elective courses for engineering and professional students, and a graduate course in the pedagogy of physics. In the past such courses were needed only sporadically, therefore the only expectation is that the Department is able to respond to course requests with the best professional effort and flexibility.

2. Scholarly work.

2 a. Ideally, all Physics faculty members should be active in research and scholarly development at least on a level that warrants their successful competition for CF grants. Publication in internationally recognized journals is the ultimate goal, although this cannot be expected from all the faculty members at all periods of their career.

2 b. The faculty will maintain memberships in scholarly societies and organizations.

2 c. The Department will invite a prominent scientist to visit The Citadel and give one or two lectures of interest to the Charleston science community. Local speakers and visitors will give talks of interest to science faculty and science majors.

3. Service.

The Department will enhance its visibility by concentrating on events directed towards students of local schools. The Department will also work with other organizations in such matters as science and teacher education. As often as possible, these activities will be conducted with the active participation of cadets.

Assessment tools.

1 a. The Department will maintain a database of information pertaining to the educational and career achievements of its graduates. This information will be periodically updated by mail survey. Particular attention will be paid to the number of physics majors that apply to graduate schools and their success rate. In contrast to most undergraduate Physics programs many of our better students enter military service. Most of these enter graduate programs after several years of service, thus data must be collected over an extended period.

The numbers of graduating Physics majors are small and, due to statistical constraints, establishing arbitrary thresholds would not be proper. Instead, the data will be compared with the results of career surveys conducted by the American Physical society.

Ideally, the majority of Physics majors should take the discipline-specific Graduate Record Examination. Actually, only some students take the test, they specifically prepare for it, and they are under no obligation to reveal their scores. Therefore, an alternative method will be adopted. Each final examination in Classical Mechanics, Optics, Thermodynamics, Modern Physics, Quantum Mechanics and Electromagnetism will include problems taken from the GRE database. Since it is recognized that the faculty may have individual scoring methods, these particular problems will be assigned two grades: one consistent with the scoring method of the professor, and a standard letter grade. Records will be kept of the average scores, the correlations between these scores and students' final grades in the course, and students' final GPR in the major. These data are intended to be a measure of the performance of the Department as a whole, and over an extended period of time. Therefore, the database will not include any direct reference to the identities of particular students or professors.

The curriculum for Physics majors includes two senior courses: *Research Planning* followed by *Senior Research Project*. The Department will use these courses as an assessment tool in the area of student preparation to logically apply the scientific method to interpret empirical data on the advanced level.

The culmination of the *Research Planning* is a review paper associated with the student's chosen project. This paper addresses the scientific and historical background, relevant related topics, and expected lines of research for the project. The evaluation of this paper assesses the ability of Physics majors to communicate scientific content; to critically analyze and synthesize reference sources; and to present a thorough, logically consistent research plan.

The assessment is completed at the end of the *Senior Research Project* when students submit final reports on the actual results of their research in both written and oral form to a panel of Physics faculty.

The Department will periodically review the breadth of the curriculum in the physics major. No formal tool for such review is necessary; it will be conducted by faculty survey and discussion.

1 b. In the core sequences the Department assesses the degree of student understanding of physical concepts by means of standardized skill tests created on the department level and administered at the end of a semester in both sequences of core courses.

The skill tests will include a combination of problems focused on the specific objectives of the core courses, such as: the ability to employ mathematical techniques on an appropriate level, the application of critical thinking through identifying relevant information, and setting up a strategy for problem solving, knowledge of the fundamental principles of Physics and most relevant experimentally proven facts.

In order to assess the degree of preparation of incoming students, a questionnaire on basic physics and science concepts will be given at the first class meeting. Since a student's ability to succeed in a physics course strongly depends on the degree of his/her proficiency in mathematics, the questionnaire will also include a few basic math problems appropriate to the level of the course. Since no prior experience in physics is expected and the mathematical preparation of the incoming students vary, the purpose of this questionnaire will be solely for professor's information to help him/her in optimizing the pedagogical approach to the course.

The laboratory segment of the calculus-based introductory physics course will be partially assessed by means of an end-of-term exam. This test determines if certain laboratory concepts and techniques have in fact been learned by students receiving passing grades in the course and mastered by students receiving above -average grades. This final will consist of questions concerning physics concepts, instrumentation use, data recording and analysis, and report writing. The results of this exam will be incorporated in the student's final grade.

The assessment of the non-calculus laboratory sequence focuses on the evaluation of students' comprehension of the classical scientific method. In selected class sections, the portion of the lab reports that is a reflection of students' ability to use the scientific method and articulate logical conclusions from experimental data will be graded separately to assess the development of such skills through the duration of the course.

2 a. Faculty participation in research and scholarly work is assessed by its measurable output: refereed publications, written non-refereed reports, acknowledgments of other scholars, and successful competition for external and internal support of research, equipment acquisition, and professional development funding.

2 b. The opportunity to participate in professional formal and informal networks that result in much faster access to current scientific developments within the discipline is an important benefit drawn from membership in a scholarly organization. This benefits not only the member, but also the department as a whole by increasing its collective scholarly potential. Therefore, one of the Department's goals is to be represented in local and national organizations spanning a spectrum of subdisciplines of physical science.

3. The determining criterion of the quality of popularization is community response and the numbers of participating public.

Assessment Results.

1 a. (Program in the major). Although it is not feasible to maintain complete records of the career path of graduates, as a rule that Physics majors find desirable employment even before they graduate. This year was no exception. Seven majors graduated with an average cumulative GPA of 3.5. Of seven, six received military commissions, one was accepted to a graduate school (MUSC, other applications pending). One former major successfully completed a graduate program at MIT.

The Department continues its efforts to maintain contacts with the known physics alumni. A database is maintained and the responses received thus far are periodically analyzed. In order to help our majors in making career decisions, we use monthly SPS lunch meetings (in which all majors participate) to conduct discussions of the opportunities the education in Physics offers. We brought four former majors to talk about their job experiences.

The assessment of the upper-division lecture courses in Classical Mechanics, Optics, Thermodynamics, Modern Physics, Quantum Mechanics and Electromagnetism is currently conducted by including problems taken from the GRE (Physics-specific) database. The preliminary data indicate that students are well prepared for this exam, although the small size of the sample does not yet permit any quantitative statistical analysis.

This year the final exam in *Thermodynamics* consisted of six problems taken from a collection of problems given on Ph.D qualifying exams at several leading U.S. universities. The distribution of grades was not different than that from regular exams. While obviously only a subset of the problems from the collection was suitable for the final, he results indicate that students are adequately prepared for graduate-level courses.

1 b. (Core curriculum courses) The department is concerned about the validity of conclusions inferred from data collected from small numbers of students tested, or from data obtained from an inhomogeneous sample of tested students. It takes a pool of about a thousand of respondents to produce an answer to a simple yes-or-no question with about 3% reliability. It is therefore scientifically impossible to statistically evaluate the data that were collected from a 30-student class that was administered a multiple-question, multiple-answer test. This is especially true for any attempts to measure the improvement of teaching effectiveness over a short period of time of only several years.

For this reason the Department decided to assess the degree of student understanding of physical concepts by means of standardized skill tests created on the department level and administered in both core sequences. The database of questions for the skill test has been assembled. The questions will be included in the future tests given to students in the core sequences. They will be fully implemented next academic year; however the assessment tests for the PHYS 203 (*College Physics*) course have been administered in one lecture section. An identical test has been administered to two sections in 2003. This year's results fully confirmed the conclusions from two years ago, which linked student's difficulties in comprehending physics concepts with identifiable deficiencies in math preparation. Below, we compare the current year results with those obtained in 2003. The current year scores are printed in boldface.

The *College Physics* is an algebra/trigonometry-based course that requires certain minimum proficiency in elementary mathematics, and also some familiarity with basic concepts of science. Therefore, the entry test was a simple questionnaire that included three math questions: two easy questions assessing students' familiarity with concepts relating the measurements of distance and time, and one question dealing with systems of measure.

In the first math question students were presented with a picture of a right-angle triangle with all sides and one angle named, and asked to white the expressions for the sine and tangent functions of that angle.

Only (42%, **46%**) of class was able to answer this question.

The second question asked students to solve a simple quadratic equation

$$x^2 + 2x - 3 = 0.$$

Only (36%, **34%**) of students even knew how to approach the problem, and only (25%, **27%**) actually could solve the equation.

The third question asked students to solve a pair of linear equations

$$2x - y + 3 = 0, \quad \text{and}$$

$$x + 2y = 3.$$

Only (37%, **34%**) of students knew how to begin solving the pair, and only (23%, **25%**) actually found the solution.

The fourth question asked students to verbally explain the concept of velocity.

Only (23%, **27%**) defined the velocity as the ratio of the distance traveled to the time of travel, and an additional (14%, **14%**) gave incorrect answers, but at least referred to the concepts of time and distance.

The scores for an analogous question about acceleration were (21%, **19%**) and (14%, **16%**)

The last question asked students to provide units of the international system of measures.

Only (5%, **9%**) could provide three units, and (32%,) provided one or two units.

The above figures seem to indicate that only 30-40% of students enrolled in the *College Physics* had the required minimum skills needed to succeed participate in an algebra-based course that requires quantitative reasoning. Professors teaching this course were always well aware of the problem, and the results of the assessment test confirmed their observations.

The experience shows that in *College Physics* an inordinate amount of classroom time is spent in the beginning on coaching the basics of algebra and trigonometry. Such coaching must take place early in the first semester when students learn to apply it to kinematics of rectilinear motion. This leaves no time to teach how to use somewhat more advanced tools (multivariable algebra, vectors) needed for learning more complicated physics required in motion in three dimensions, conservation laws, and in rotations. In consequence, students try to interpret three-dimensional effects with the tools developed for rectilinear motion, which often leads to misconceptions.

The exit assessment test consisted of multiple-choice questions; it's objective was to provide comparative data about students' understanding of physical concepts, and to measure their critical qualitative and quantitative thinking skills. The test questions required thorough understanding, and in order to clearly identify any weaknesses, they were generally more challenging than typical problems administered on regular tests. No specific fraction of the total number of students was expected to be able to score high on the test; instead, the questions are so formulated that any areas of weakness were clearly indicated by dramatically lower scores on the related group of questions.

The scores indeed varied in a considerably wide range, depending on the subject area. There was a very satisfactory improvement in the understanding the force concept and kinematics in one dimension; however, the scores on questions that required only qualitative reasoning were much higher than on those which involved, no matter how elementary, quantitative analysis:

The concept of velocity:	qualitative:	(88%, **91%**) correct,
	quantitative:	(66%, **65%**) correct.
The concept of acceleration:	qualitative:	(82%, **80%**) correct,
	quantitative:	(52%, **54%**) correct.
The concept of force:	qualitative:	(93%, **87%**) correct,
	quantitative:	(52%, **56%**) correct.

Interestingly, the scores on questions regarding Newton's principles of dynamics were almost identical to the scores on the quantitative questions:

First/Second Principle	(62%, **58%**) correct,
Third Principle	(57%, **65%**) correct.

This may indicate that students that answered the qualitative questions, but failed the quantitative ones did not logically derive their answers from the first principles, instead relied on intuition or association by analogy. A definite answer would require a larger statistical sample.

The second portion of the test assessed students' ability to apply similar concepts to motions in two dimensions (including the circular motion) and their understanding of conservation laws. The scores were disappointingly lower, with only 30-40 percent of students able to correctly answer any particular question. However, the subject matter covered in this part of the test demands from a student some proficiency in trigonometry and systems of equations. These were the main mathematics weakness areas documented by the entry algebra/trigonometry quiz, and indeed the success rates on the entry quiz and the second portion of the exit quiz and were almost identical. Although a larger statistical sample is definitely needed, the cumulative data suggest the following preliminary conclusions:

Students enrolling in *College Physics* have severe deficiencies in algebra and trigonometry. This inhibits their ability to develop any skill in quantitative interpretation of physical phenomena.

Both mathematically prepared and unprepared categories of students benefit from the course; they all acquire an understanding of the essentials of kinematics and dynamics on a satisfactory to very good level.

However, students that lack proper mathematical background do not fully achieve the goals of the course. Since the required mathematical skills are rather basic, and can be easily developed by completing the required core courses in mathematics, it might be beneficial for this category of students to take *College Physics* as the second science course, after completing their math core requirements.

Faculty conducted experiments with teaching strategies. For example Professor Hilleke has developed a new kind of assignment that has shown considerable promise in the core-curriculum sequence. If the class is studying the chapter on waves, for example, he gives the class an assignment to find ten examples of waves that the student actually observed on campus. The assignment is taken up and graded just like a homework assignment. This assignment does a number of things: a) the students must have some understanding of the phenomenon before they leave class, b) the student is thinking about the subject of the course outside of class, c) the students sees the wide applicability of the material they are discussing in class to his world, d) it gives me a large number of examples that can be discussed in class. The assignments have worked well so far. Indications are that these assignments raise the understanding of the principles discussed in class and increase the student's performance on hour exams about 5%. Data on how these assignments affect performance on the final exam will be collected from the final exam scores.

Several of Physics faculty members use a teaching technique developed by Eric Mazur of the Physics Department at Harvard. The technique is called Peer Instruction. Using this technique, the instruction gives a brief lecture about a new topic then displays a question on the board. The students individually come to their own answer to the question and the professor asks for a show of hands for each of the answers provided. Now this is where the learning takes place, the students then discuss their answers to each question with the cadets seated around them and they try to arrive at a consensus answer. The second answers are collected by the professors and the correct answer to the problem is given and discussed. The reason this method is so successful is because: 1) it gets the students involved in a discussion about the subject, 2) students are explaining Physics concepts to other students, 3) those students who do the explaining learn the most because teachers tend to learn more than students, 4) those students who do not do the teaching learn more from their fellow student than they would have from the professor anyway. The method has proven quite effective in the core curriculum science sequence.

The department now supports two core laboratories, companions to *College Physics* and *Physics with Calculus*. In the course of the last eight years both sequences have been massively redesigned, to include computer-interface methods of data collection. So far, the equipment resources were limited to obsolete 1990-vintage Macintosh computers and interfaces compatible with the type of serial interface no longer used by the industry. Thanks to the College, it became possible to fully equip two computer-interface labs for *Physics with Calculus Labs*. The older equipment will be diverted for use in the *College Physics Labs.*

The data from the analysis parts of the lab reports are being collected. It will take two or three more years to obtain a statistically relevant sample. However some general information can be already extracted, e.g. that Students in the Physics 253-254 sequence begin the year unable to write a one-page summary of their observations in a simple laboratory exercise. The first lab reports indicate that all students have some shortcomings in doing this. Only about 10% of the students can write a report at the A or B level. By the end of this semester, 84% of the students can write such a report at the level of an A or B. This shows significant improvement in the students' ability to communicate through writing.

2a. Faculty members participated in research.

In the past year Professor Adelman had nine publications, including six journal articles, and more in conference proceedings. Professor Adelman conducts research in cooperation with international scholars from several countries. He made several international trips to sustain his scholarly contacts overseas.

Professor Hilleke was engaged in classroom pedagogy research in which he exchanged ideas and results with the local CASTLE group.

Professor Rembiesa conducted research in theoretical high-energy physics. He published one article on the subject.

2 b. The faculty maintained memberships in a range of scholarly societies and organizations, such as American Physical Society, International Astronomical Union, American Geophysical Union, Forum on History of Physics, Sigma Pi Sigma honor physics society, Phi Kappa Phi honor society, Sigma Xi honor research society.

Professor Adelman served as a Commission Secretary of the Scientific Organizing Committee of the IAU, and acted as the Campus Director for the South Carolina Space Grant Consortium.

3. In the past, the Department's main community-oriented event was the Distinguished Physics Lecture, which brought some ten Nobel laureates to speak to students and faculty. Unfortunately, for three years in a row the Department's efforts to bring a physicist of such stature have been unsuccessful. The difficulty with the series seems to be financial in nature; the seminar budget does not provide for any meaningful honorarium. However, the Department invited (or co-invited) five other speakers who presented talks in the evening-seminar format.

The department maintained working links with local high schools. The annual rocket event brought a substantial group of participants. Physics majors also served under faculty supervision as judges on several science fairs in the Charleston County.