Physics 2005-2006 Report

Core Curriculum Courses

The physics 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 a similar range of 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 (or team). 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.

Expected Results

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.

Assessment Tools

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 varies, 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.

Assessment Results

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 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. In the past two years this test was administered in the *College Physics 203* lecture course. The results of the tests confirmed the suspected outcome that linked student's difficulties in comprehending physics concepts to various identifiable deficiencies in math preparation.

Since the results from two consecutive years were practically identical, the tests were not repeated in the year of the current report. Instead, the assessment probe was redirected to the question of the effectiveness of developing the skills of critical thinking. The laboratory components of the core sequences were found most appropriate for this task, as they are least dependent on the teaching styles of individual faculty members; the procedures are uniform across the lab sections and the student composition is a sampling from all the lecture sections.

In *College Physics* the testing was aimed at the gradual improvement of the critical thinking skills. In a selected group of lab sections the grades were split in two portions, one corresponding to laboratory techniques and data presentation, the other to analysis and interpretation of the data which is a good measure of the critical thinking skills. A linear fit applied to the average score of consecutive experiments (performed in the first semester of the course) showed the mean increase from 32/50 to 41/50 point score.

In *Physics with Calculus* the testing was aimed at the final outcome. The assessment tool was a uniform test offered as a final exam administered in all sections of the laboratory, Phys 271. Students were given hypothetical (though realistic) data to analyze and interpret. The grading method was uniform and the average score was 82%, a satisfactory result.

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 the professor and students 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 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 instructor gives a brief lecture about a new topic and 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 professor 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 supports two core laboratory courses. Over the last eight years the experiments have been systematically redesigned to include computer-interface technology of data collecting. The goal was to introduce students to modern technology; however, the principal objective was to improve the quality of teaching data analysis which is the fundamental element of the scientific method and critical thinking. In the classic experiments using electro-mechanical measuring equipment, the amount of data was small, generally restricted to measuring the initial and final values, and the analysis was limited to comparison of the results of calculations with expected values of physical quantities and making estimates of uncertainties. In contradistinction, the computer-interface experiments are able to take data at a rate of thousands per second and allow students to explore the physical process, not only its final outcome. However, to interpret such data requires designated software and procedures with which students are not familiar. Therefore, most of the analysis needs to be performed in class under the professor's supervision. Until now the equipment resources were limited to obsolete 1990-vintage computers recycled from the writing center computer labs. They were adequate for data acquisition, but unable to run recent versions of software applications needed for analyzing them. Thanks to the College, it became possible to fully re-equip two computer-interface labs for *Physics with Calculus* labs.

The labs became fully operational within a year. In the first semester of implementation, this included testing of the equipment and building of the intranet system in both labs (by the laboratory manager W. Holdren), trial run of the second-semester experiments, and creation of the alpha version of the manual (by Professor J. Berlinghieri). In the next semester, each faculty member was assigned one section of PHYS 272, the experiments were collectively discussed, and the manual accordingly revised. At the same time Professor Berlinghieri and Briggs worked on the trial experiments for the first semester of the course.