Physics 99 course description, Fall 2016

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1. Description of PHY 99

PHY 99 is a prerequisite for PHY 121/121P and PHY 122/122P, but is not intended to be a *barrier* to these classes. It is intended to identify students who have sufficient mastery of algebra, geometry and trigonometry to succeed in the introductory physics courses, and to send them on their way with as little fuss as possible. By the same token it also exists to find students who may not succeed in introductory physics *without* more practice in these topics, and to help them achieve sufficient basic-math mastery, also with a minimum of fuss. Our goal is for all of the students to pass, one way or the other.

In the course of PHY 99 we assess skills which are *in principle* covered in high-school math classes, but which are not emphasized in the calculus classes students take in their freshman year. Over the course of several years of studying homework and exam results in PHY 121-122, we have identified many specific math skills used in physics problem-solving, mastery of which is lacked by large fractions of the students. These specific skills are too numerous simply to re-teach in PHY 121/121P -- or for that matter in MTH 161-162 -- without omitting crucial physics/engineering concepts needed in subsequent courses.

The focus of PHY 99 is basic algebra, geometry and trigonometry, with algebraic, geometric and trigonometric expressions in the forms usually found in the equations of science and engineering, rather than just one or two variables and integers; also in the use of several math concepts simultaneously or sequentially. Specifically:

Factoring algebraic expressions; simplification of ratios
Many uses of the quadratic formula
Inequalities in algebraic expressions and in graphs of functions
Solving algebraic equations
Solving systems of algebraic equations
Length, area and volume of regular geometric entities
Trigonometry of triangles and the unit circle
Solution of problems that *combine* the seven previous features
Trigonometric identities and their proof
Graphs of trigonometric and algebraic functions

Work in PHY 99 is divided into four modules. Because of the importance of the simultaneous or sequential application of math skills in physics and engineering, the four modules are not designed to treat the above list of topics as separate entities to be discussed in the order written; instead, combination of multiple tools is used throughout. All four modules make heavy use of algebra; multiple-variable problems occur throughout the last three. The modules are

a. Algebra I (mostly single-variable)
b. Algebra II (multi-variable)
c. Geometry and Trigonometry I
d. Geometry and Trigonometry II (including some proofs)

Each of these four modules is supported by a large selection of problems for students to solve, which is served to each of them on line, by WeBWorK. Each module's WeBWorK content consists of

- a homework/workshop problem set, itself consisting of 25 problems. Each student's homework sets will be similar to those of his/her classmates, to facilitate discussion in workshop and among students who are working on the same module.

- a bank of mastery quizzes, delivered by WeBWorK's Gateway/Quiz feature. Quizzes consist of 4-5 problems drawn from a bank much larger than the homework set, but which includes essentially all of the homework problems. Each quiz delivered is therefore essentially unique. Care has been taken to ensure that the quizzes will also be as similar in level of difficulty as can be managed. As soon as a student finishes each homework set, the mastery quizzes for that module are automatically unlocked. Students will take these quizzes on line but will be monitored as they do so. As soon as a mastery quiz is passed, the next homework set is automatically unlocked.

Here's how the course *functions*.

- In the first course meeting, a Basic Math Assessment (BMA) will be given. This exam -- an in-class, paper and pencil test, graded by humans -- will be similar to those given last year, four of which are offered as practice exams on the PHY 99 website. The first course meeting will be after Fall Break. We hope, by starting close to Spring Registration, to avoid having two distinct waves of students progressing through PHY 99: the ones who register at the start of the semester, and the ones who don't realize that they have to take PHY 99 until they seriously consider their Spring courses and schedule.

- Students who receive a passing score on this test – 18 of the maximum 24 points – automatically get credit for PHY 99 and are allowed to register freely for Spring's PHY 121/121P; they don't need to do anything else in PHY 99. The rest of the content is for the students who do not pass the first time.

- Students who receive less than a passing score must work through the modules. (Others can too, if they like.) This means that, for each module, each student does the WeBWorK homework assignment, attending the associated workshop for help; and then demonstrates proficiency in the module's material by taking a mastery quiz. If a student does not pass the mastery quiz, they receive on-the-spot guidance from the instructor, are given more practice to do, and prepare to take another of the module's mastery quizzes. This cycle is repeated until the student passes a mastery quiz. After passing a module's mastery quiz, the student moves on to the next module's homework and quiz battery. All four modules need to be mastered, to be allowed to take the Basic Math Assessment again.

- Two workshops are scheduled each week, to facilitate groupwork and individual guidance in learning how to solve the homework problems. There may be a small number of lectures, if the instructor deems them necessary, and other math resources will be supplied as well. In principle, all the students have learned the material before; they just need practice and advice in problem-solving, rather than yet another class.

- The BMA will be given twice more, toward the end of the semester, for students who have practiced and demonstrated mastery in the WeBWorK modules. Students must receive a passing score on the BMA, in order to get credit for PHY 99. You'll be pleased to know that more than 80% of students have passed the BMA on their first try – and virtually all others on their second try – after working through the WeBWorK modules.

- If a student who did not pass the first BMA does not master all four modules, or does not pass one of the subsequent BMAs, then s/he is *extremely* likely to be in need of a full course in basic math, before s/he will be ready to succeed in the introductory physics courses – or, for that matter, the introductory calculus courses. Therefore, such a student may not register for PHY 121/121P or PHY 122/122P, without a more extensive demonstration of basic-math mastery. At the moment this result is indicated

in the system by issuing the student No Credit for PHY 99. Suggestions for less student-demoralizing ways to communicate the result to subsequent instructors would be most welcome.

2. Outcomes

Here is how the course *works*. Mastery of basic math at the level of the BMA is a good predictor of success in PHY 121/121P, as shown by the tight and statistically very strong correlation between BMA scores and common PHY 121/121P final exam scores (Figure 1; see Masi et al. 2015 for complete details). In fact it is the best predictor of introductory-physics success we have found, even better than MTH 161/MTH 141 placement and AP scores.

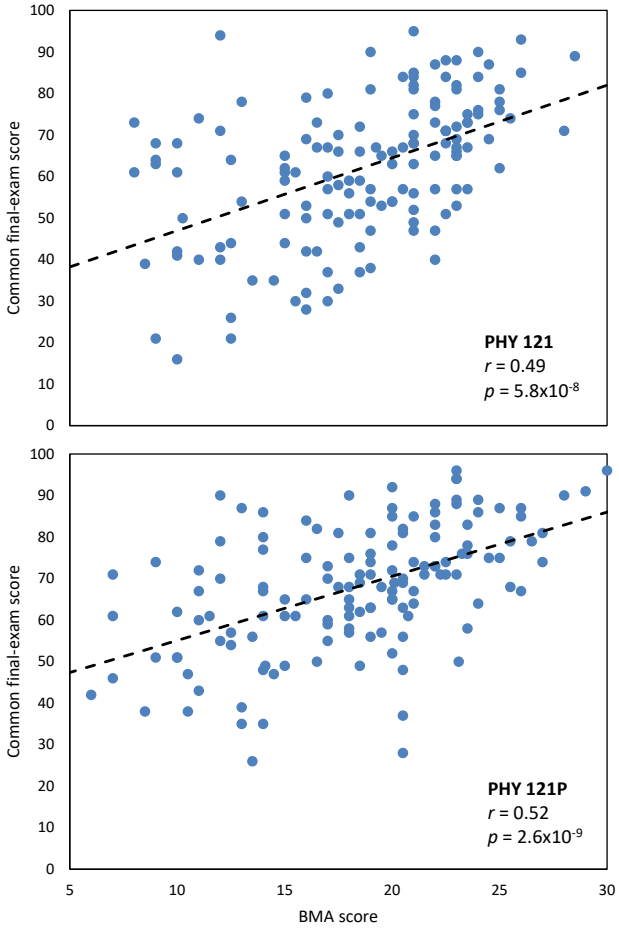

Figure 1: final-exam score *vs*. BMA score in PHY 121 and 121P, Spring 2014 (Figures 1 and 2 of Masi et al. 2015). The dashed lines are linear regressions to the data. Regression statistics are given at lower right: linear correlation coefficient (Pearson's r) and the probability p that a correlation with the given value of r could have been drawn from a random distribution of scores.

3. PHY 99 and EAS 101-105

As of Fall 2015, the basic-math curriculum of PHY 99 is incorporated into EAS 101-105, the Introduction to Engineering courses required of all freshman engineering majors except those in computer science. Although each EAS 10x instructor will choose different, specialized examples and applications of basic math, all of them will offer their students assignments in which they will practice all of the math skills, individually and in combination, as in PHY 99. Student mastery of the basic math skills will be assessed in EAS 10x by their scores and grades on the appropriate parts of these assignments. A passing grade in EAS 10x is intended to certify the same level of basic-math mastery as getting credit for PHY 99.

Thus the Physics and Astronomy Department accepts any of EAS 101-105 as a substitute for PHY 99, in the prerequisites for PHY 121/121P and PHY 122/122P.

4. Credit in PHY 99

We have designed the four modules of workshop problems and mastery quizzes to be the same scope of work as four weeks of a regular course, so we have specified it to be worth one credit hour. We in Physics and Astronomy, and our Hajim School colleagues who use material similar to PHY 99's as part of the EAS 101-105 courses, believe that this has a minimal or zero impact on other aspects of each student's schedule.

Our main goal in PHY 99 is for the students to demonstrate mastery in the elements of basic math listed above, individually and in combination, by achieving a passing score on a Basic Math Assessment. We define "passing" by the scale common in high-school math classes: achievement of at least 66.7% of the maximum score on the test. Since our goal for student performance is binary, the College Curriculum Committee allows us, unusually, to use the zero-credit-hour, Credit/No Credit scheme for PHY 99.