2017-2018 SELF-ASSESSMENT REPORT FOR THE LEARNING GOALS OF THE UNDERGRADUATE PHYSICS PROGRAM AT UMBC.

This document is based on the self–assessment reports by the instructors of the Fall 2017 courses PHYS 303, 330L, 407, and on the Spring 2018 courses PHYS 220, 321, 424. An executive summary for each course follows (focusing on the issues identified), along with a short overall evaluation of the Program in its entirety. The individual reports can be found as appendixes to this document.

PHYS 303, FALL 2017. The instructor is in general satisfied with the learning goal assessment, with the possible exception of learning goal 4, "*Understand and predict changes in thermodynamic variables during phase transformations*".

He suggests small changes such as *"Make in-class exams shorter by decreasing the number of parts in the multiple part questions and instead of asking for derivations, I will request short answers stating which equations/physical phenomena/mathematical approach they will use to solve the issue in hand, which would still require an in-depth understanding of the course material. Prepare study guides for exams including which topics we covered in the course and with specific emphasis on what I expect the students to know."*

PHYS 330L, FALL 2017. As reported by the instructor, the learning goals have been largely achieved. Regarding learning goal 2 ("Write a mature laboratory report which includes the most common elements and organization of scientific papers published in journals today"), the instructor notices "*At the beginning of the course, only one student was writing the quality of report close to what we expect by the end. By the end of the course, all were writing in the formal style we require, with no informal language, with proper use of citations, and with mature use of images and plots."* The instructor does not propose any changes.

PHYS 407, FALL 2018. The instructor is in general satisfied, but reports that *"students understand electrostatics better than magnetostatics."* He proposes *"More example problems in magnetostatics. This will take longer instruction time. I propose that we add a tutorial session for each week. The tutorial session will be taught by teaching assistants. I will prepare the materials for each subject."*

He also brings up a general issue: *"The assessment plan provides a nice overview of the strong and weak areas in student learning. It seems that the purpose is well served. However, it would be difficult to compare student learning in different semesters, especially when course taught by different professors. We need to think about how to make the assessment more objective in the long run."*

PHYS 220, SPRING 2018. The instructor reports high mastery of the learning material from most of the students and agreement between direct and indirect assessment. No changes are proposed.

PHYS 321, SPRING 2018. The instructor found the class lacking knowledge and motivation to an extreme. He ended up failing 2/3 of the students. He found that the class had an inability to connect math and physics. We copy from his report: "*There was plenty of help available, but few students came to my office hours or asked help from the TA. In spite of repeated warnings, the answer to the difficulties was rampant copying of homework solutions* *from the web. Even copies from my sample solutions posted in previous years were turned in as solutions. Repeatedly failing pop-up quizzes on selected homework problems had no effect. Alarming intermediate reports on standing after the midterm exams did not result in more effort. At the end, of the 21 students only 7 passed with a C or better, there were 6 Ds, 6 Fs and 2 incompletes.*" We hope that this was a "bad apple" cohort, although something similar is noted below for PHYS 424.

PHYS 424, SPRING 2018. The instructor notes that *"this was the least motivated and least interested group I've taught in my 12 years at UMBC".* Although all learning goals were achieved satisfactorily, he raises the following issues:

"I really struggled to get this group of students involved in the class discussions. It was also the first time (in 12 years) that I had students regularly skipping class. I tried everything I could think of to engage these students, but nothing seemed to work. At times I felt like a failure, and I must admit that this semester was not a rewarding teaching experience for me. A subset of 5 - 7 students were engaged, interested, and motivated. I felt very bad for these particular students, as I'm fearful that being part of this lackluster cohort may have made their 4-year UMBC Physics Major experience not very positive."

Repeated comment from 2016 and 2017: It's time to make a big change: I strongly recommend that the Undergraduate Curriculum Committee make Quantum Mechanics a 2-semester course, from a single textbook. QM 1 should be in Spring of the junior year, and QM 2 in the Fall of the senior year. Modern physics should still be included in the curriculum, and should come sometime before QM 1. UMCP's course progression is a good template.

Repeated comment from 2016 and 2017: I found that every single HW and Exam problem was related to one of the 6 learning goals. I just chose an arbitrary subset to do my assessment. Is that the idea? I guess I'm a little confused on the methodology we should use. Also, when I said a student "mastered" a problem, I used "C+'ish" or above type of work. Is that OK, or do you need a further breakdown?"

COMMITTEE OVERALL EVALUATION

The committee finds that during this third year of implementing the learning goal self-assessment, no major deficiencies were identified. However, the extremely poor performance of many students in PHYS 321 and PHYS 424 is worrisome and we need to be vigilant to ensure that something like that does not happen again. A question we should discuss is the uniformity of a C-grade for all courses throughout the curriculum.

The repeated proposal by the instructor of PHYS 424 to create a pair of QM courses in the junior year, and to change PHYS 324, that currently has overlapping material with PHYS 424, to a capstone stone course with elements from the different disciplines is a major one and should be discussed in the context of restructuring our BSc curriculum.

We still need to implement that all the learning goals of all courses used should be evaluated numerically by the instructors in terms of the percentage of the class that achieved a B or better level understanding of the corresponding material, as this is manifested by their performance of carefully selected problem(s) embedded in the exams and/or homework.

LEARNING GOAL SELF ASSESSMENT COURSE REPORTS

Self-Assessment of Learning Goals for PHYS 303, Fall 2017

This assessment is based on the questions of three in-class midterms, two take-home midterm-extensions, three quizzes and the final exam. Specific learning goals were reported in the syllabus and the scores were compiled according to exam/homework performance.

There are extensive amounts of topics to be covered in one semester. For this reason, the pace of the course was generally high. In order to make sure that the students learned/understood the topics, they were assigned weekly homeworks (a total of 13 homework) with multiple questions to practice the topics with real world examples. During office hours, based on students' requests and needs, I both restated the topic of that week and went over students' individual questions. Students who attended these office hours regularly scored better in the homeworks and exams than others. Not limited to office hours, I allowed students to come to my office and ask/discuss whatever they wanted whenever we both were available. I also answered any questions asked via e-mail within a day.

During the semester, I was asked several times to postpone the deadline of the homeworks due to other workload such as homeworks/reports/projects for other courses (PHYS 407 and PHYS 330L). I was flexible with the deadlines and accepted all homeworks submitted before I posted the solution manual (generally 3-5 days after the deadline). Some students complained about getting back their homeworks/grades late, but this was a predicted consequence of flexible deadline homework submissions. The top ten highest graded homeworks were counted towards the grading and the average of homeworks was 85/100.

I conducted three exams during the semester. In each 50-minute exam, there were three questions. Two of them (somewhat modified) were either from homework or from the questions I solved in the class. Third question was generally a challenging question. My aim with these challenging questions was to foster the synthesis ability of the students where they would need to use their overall knowledge from the course and creativity in order to solve the question. Solving the question would also teach them new things. This question generally had several parts, so that the students could earn partial credits. All of the exams also contained 25 bonus points. The class average for in-class exams was ~60/100. In order for them to increase their grades, the students were provided additional take-home questions for every midterm exam. The grading was done by taking the average of in-class and take-home exams for the final grade. Without the examination stress and more time, take-home exams had an average of >90/100 although they included challenging questions as well.

Improvements can be made to examinations such as:

-Make in-class exams shorter by decreasing the number of parts in the multiple part questions and instead of asking for derivations, I will request short answers stating which equations/physical phenomena/mathematical approach they will use to solve the issue in hand, which would still require an in-depth understanding of the course material.

-Prepare study guides for exams including which topics we covered in the course and with specific emphasis on what I expect the students to know.

Assessment of specific learning goals follows:

1. *Derive thermodynamic properties of a model system (work done, internal energy, heat capacities, enthalpy, …)*

This was very similar to one of the first midterm questions. Out of 31 students, 8 of them scored perfectly. 19 of them got partial credits with scores more than 50%. This indicates that the majority of the students learned the concept well, although there is room for improvement. Thermodynamic concepts are known to be difficult to grasp and may need continuous reinforcement throughout the semester.

2. *Understand how thermodynamic properties differ in interacting systems.*

One of the quizzes was focusing on this subject together with 3 homeworks. All of the averages of homeworks were greater than %80 and the quiz averaged and 74%. None of the students (25 attended) scored lower than %50 on the quiz. This indicates that the majority of the students mastered the concept.

3. *Apply thermodynamic rules to and calculate thermodynamic parameters of engines and refrigerators.*

Half of the 2nd and 3rd midterm questions were on this subject. Students had many examples solved on this subject (including in-class quizzes, questions and homeworks). Out of 29 registered students, only 4 and 2 of them scored lower than %50 in the 2nd and the 3rd midterms, respectively. The averages of these questions were %79 and %84 in the 2nd and 3rd midterms, respectively. This indicates that the majority of the students mastered the concept.

4. *Understand and predict changes in thermodynamic variables during phase transformations.*

This was one of the hardest topics covered in the class. I received many questions and the attendance to the office hours was the highest when we were covering this subject. First homework average was %71; however, the following one had an average of %92. The second midterm had a simple question about this subject and the average score for the question was %76. The learning goal was accomplished, but one can make improvements in teaching this subject.

5. *Apply the Fermi distribution and Bose-Einstein distributions to model real life problems/examples.*

Homeworks 13-14 and the final exam (including the takehome part) were covering these topics. The averages of the take-home exam and the homeworks were greater than %80, but in-class final-exam average which consisted of difficult questions was %60. This indicates that the learning goal was accomplished, but it can be improved, such as spending more time during lecturing. I spent last 3 weeks on these subjects.

Self-Assessment of Learning Goals for PHYS 330L, Fall 2017

This course will be used to assess learning outcomes 3 and 4 using the methods described below. By the end of the course, students should be able to:

1. Follow a general laboratory guide and develop specific strategies for accomplishing prescribed measurement goals using available lab materials and equipment.

Assessment: The students were all able to do this at an acceptable level at the beginning of the course, with only minimal guidance. By the end of the course, students were comfortable following the guide and coming up with strategies entirely on their own, as judged by observing the groups during lab hours.

2. Write a mature laboratory report which includes the most common elements and organization of scientific papers published in journals today.

Assessment: At the beginning of the course, only one student was writing the quality of report close to what we expect by the end. By the end of the course, all were writing in the formal style we require, with no informal language, with proper use of citations, and with mature use of images and plots.

3. Replicate the key experiments demonstrating the nature of light and optical systems, such as: measuring the speed of light, measuring the wavelength of a laser using a Michelson interferometer, measuring the thickness of an object using thin-film interference, characterizing single and double slits using a laser, and measuring Brewster's angle.

Assessment: All students (excepting those who withdrew) passed the course after successfully completing the above experiments.

4. Demonstrate an understanding of the concepts behind modern optics technology, such as laser gyros, holographic films, and fiber optic cables.

Assessment: All students (excepting those who withdrew) passed the course, and thus successfully demonstrated this understanding in written reports. We additionally tested their understanding with two oral examinations during the semester. Students generally performed very well (A-level) on these oral presentations.

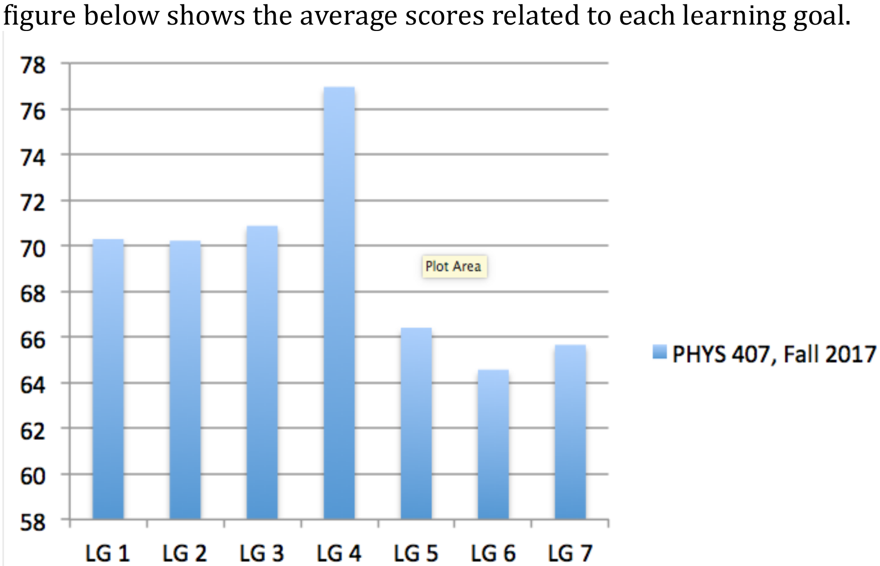
Self-Assessment of Learning Goals for PHYS 407, Fall 2017

I. Learning Goals of PHYS 407

1. Have a working understanding of vector analysis, of the physical meaning of differential operators such as the div and curl, and of related theorems such as the divergence, Gauss's and Stokes' theorems.
2. Solve problems in electrostatics that manifest an understanding of the divergence of electrostatic fields, the electric potential, and work and energy in electrostatics.
3. Demonstrate an ability to solve problems in electrostatics by solving Laplace's equation, and by using the method of images, or of separation of variables.
4. Understand electric fields in matter, through being able to solve problems involving the field of a polarized object, the electric displacement, and dielectrics.
5. Demonstrate an understanding of magnetostatics, through the ability to solve problems involving the Lorentz force and the Biot-Savart Law, as well as the divergence and curl of the magnetic field and vector potential of the magnetic field.
6. Understand magnetic fields in matter, through solving problems involving magnetization, the field of a magnetized object, the auxiliary field H, magnetic susceptibility and permeability and ferromagnetism.
7. Demonstrate an understanding of the electromotive force, the electromagnetic induction, and Maxwell's equations.

II. Learning Goal assessment

Student performance on the final exam was used to assess the above learning goals. The figure below shows the average scores related to each learning goal.



In the figure shows that performance for LG 1 to LG 4 are close or above 70%, while the average scores for LG 5, LG 6, and LG 7 are between 64% and 66%. It is clear that student understand electrostatics better than magnetostatics.

III. Changes proposed as a result of this learning assessment

More example problems in magnetostatics. This will take longer instruction time. I propose that we add a tutorial session for each week. The tutorial session will be taught by teaching assistants. I will prepare the materials for each subject.

IV. Reflections on assessment plan

The assessment plan provides a nice overview of the strong and weak areas in student learning. It seems that the purpose is well served. However, it would be difficult to compare student learning in different semesters, especially when course taught by different professors. We need to think about how to make the assessment more objective in the long run.

V. Example problems

Problem 3. A non-conducting sphere of radius R has a potential on its surface given by $V(r = R,\theta) = V_0 \sin^2\theta = V_0\left(1-\cos^2\theta\right)$. Assume that $V(r \to \infty) \to 0$.

a) Indicate clearly with a sketch and/or a graph what the voltage looks like on the surface of the sphere.
b) Solve for $\sin^2\theta$ in terms of the Legendre polynomials. That is, show how $\sin^2\theta$ can be written as a sum of the Legendre polynomials. (LG 3)
c) Solve for the voltage $V(r,\theta)$ everywhere outside the shell ($r > R$). (hint: don't remember the formulas? Check the formula pages). (LG 3)
d) By considering the form of the solution $V(r,\theta)$ in the limit $r \to \infty$, solve for the total charge on the sphere and the dipole moment of the sphere. Explain your reasoning. (LG 3)

Self-Assessment of Learning Goals for PHYS 220, Spring 2018

1. Background:

Introduction to Computational Physics (PHYS 220) is a mandatory course for physics major students. Physics student usually take this course during their junior or senior years. As prerequisite for PHYS220, the students must have completed PHYS 122 or MATH 152 and CMSC 104 or CMSC 201 all with a grade of C or better.

PHYS220 is offered in the spring of 2018. A total of 40 students registered this course.

The learning goals specified in the assessment plan include:

1. Use a software package (e.g., Mathematica or Matlab) or high-level programming language (e.g., Python or IDL) to write modularized programs and plot simple figures, such as scatter plots, time series, histograms, and 2D contours.
2. Use Monte Carlo methods to simulate and understand random walk problems, such as photon transport in isotropic-scattering medium.
3. Write programs to solve physics problems involving ordinary differential equations, such as projectile motion with drag and nonlinear oscillations.
4. Demonstrate a good mastery of basic data analysis methods, such as linear regression, uncertainty analysis, null hypothesis testing, and Fourier analysis.

2. Direct assessment

The scores for the midterm project are used for the ***direct assessment*** of the learning goals 1, 2 and 3. The scores for the final project are used for the ***direct assessment*** of the learning goals 1, 2 and 4. The results are shown in the plot below.

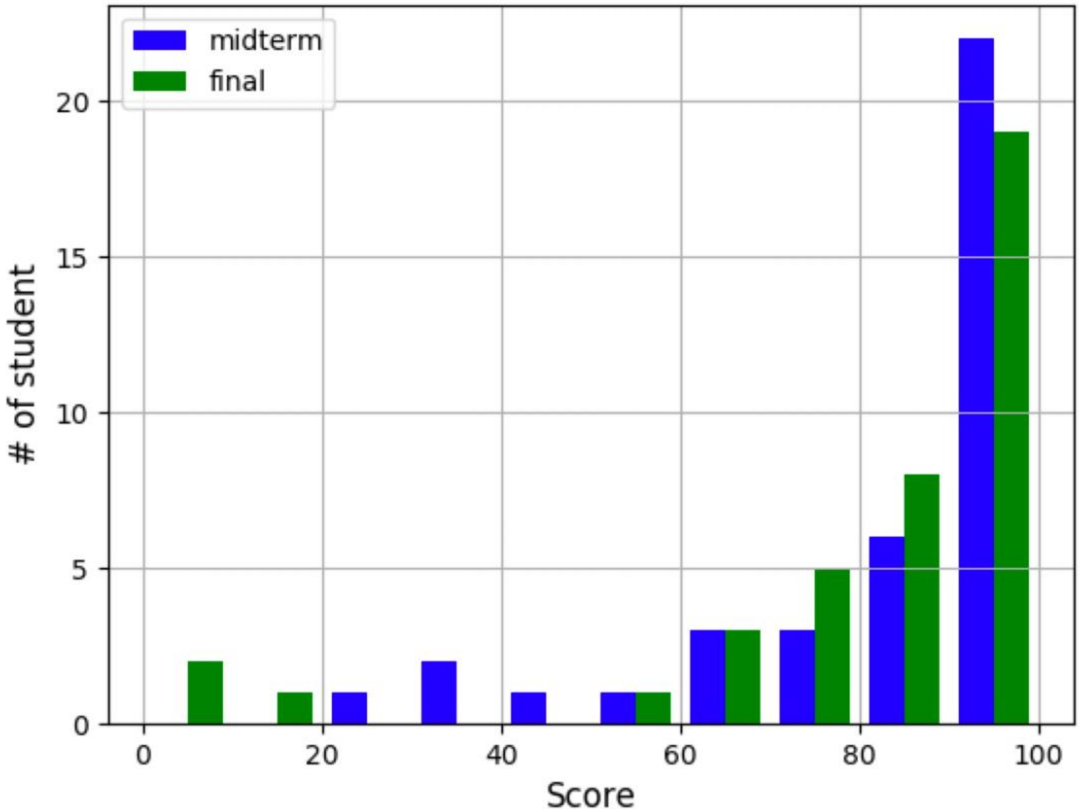
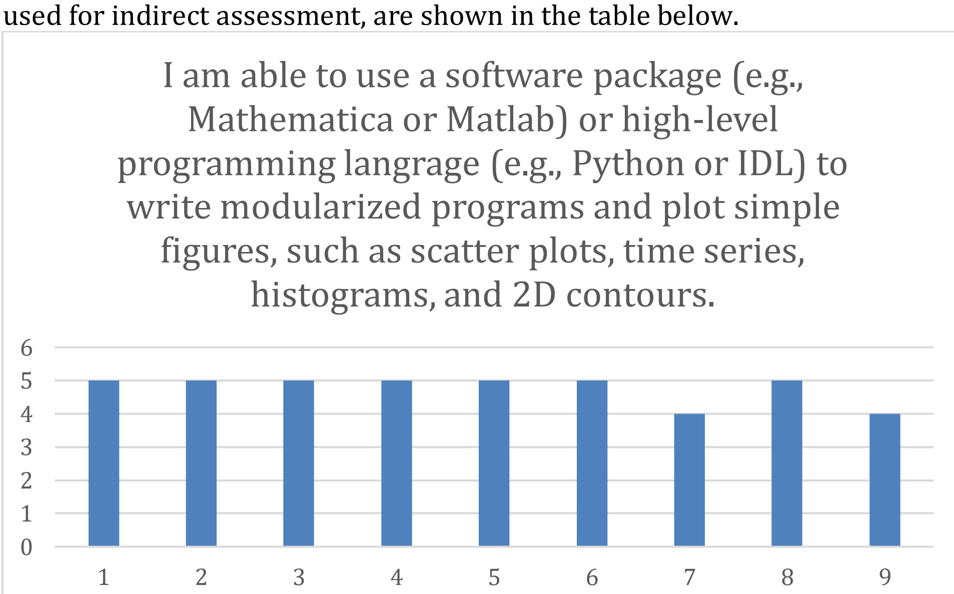
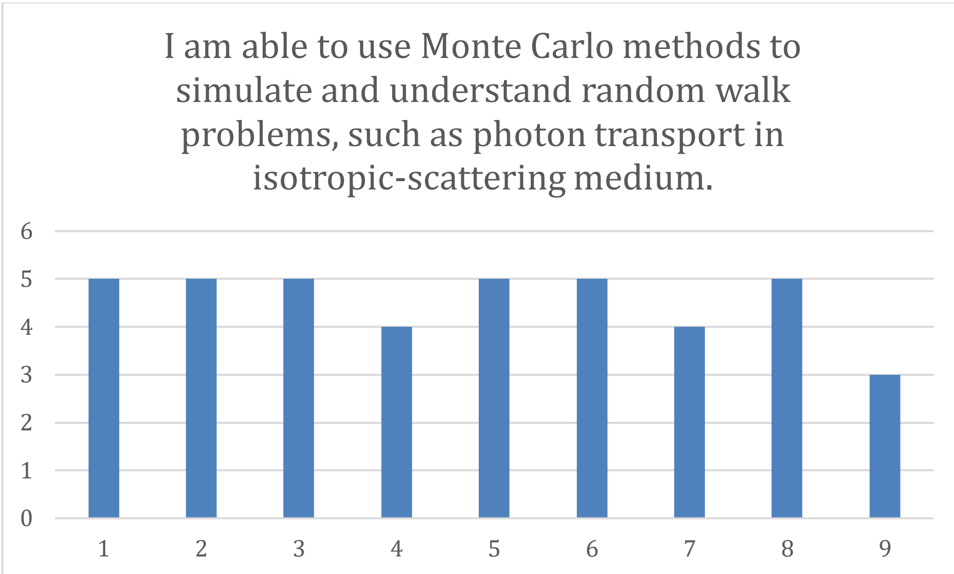


Figure 1 Distribution of the scores for the midterm and final project.

3. Indirect assessment

A survey was sent out to get feedbacks from the students on the learning goals. The results, used for indirect assessment, are shown in the table below.





I am able to use Monte Carlo methods to simulate and understand random walk problems, such as photon transport in isotropic-scattering medium.
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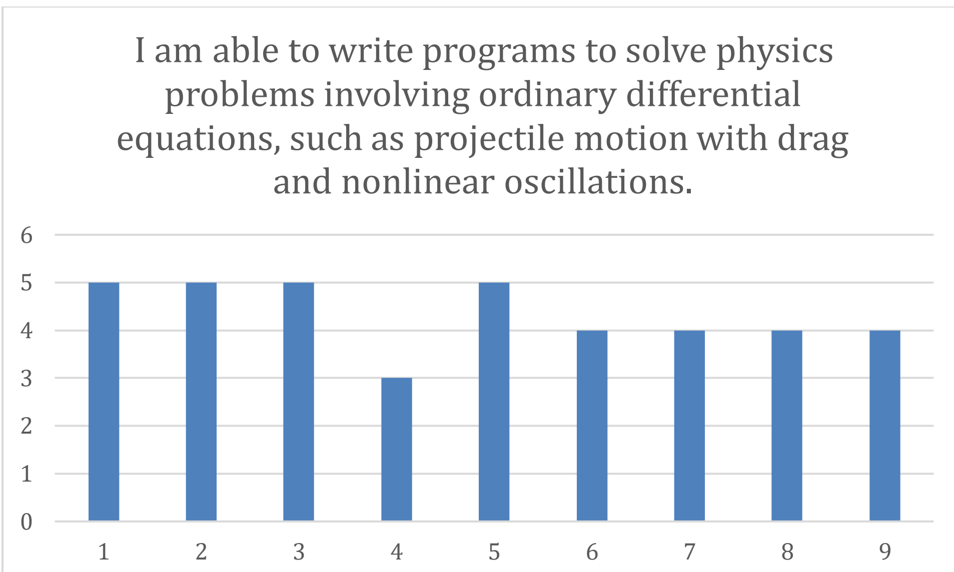

I am able to write programs to solve physics problems involving ordinary differential equations, such as projectile motion with drag and nonlinear oscillations.
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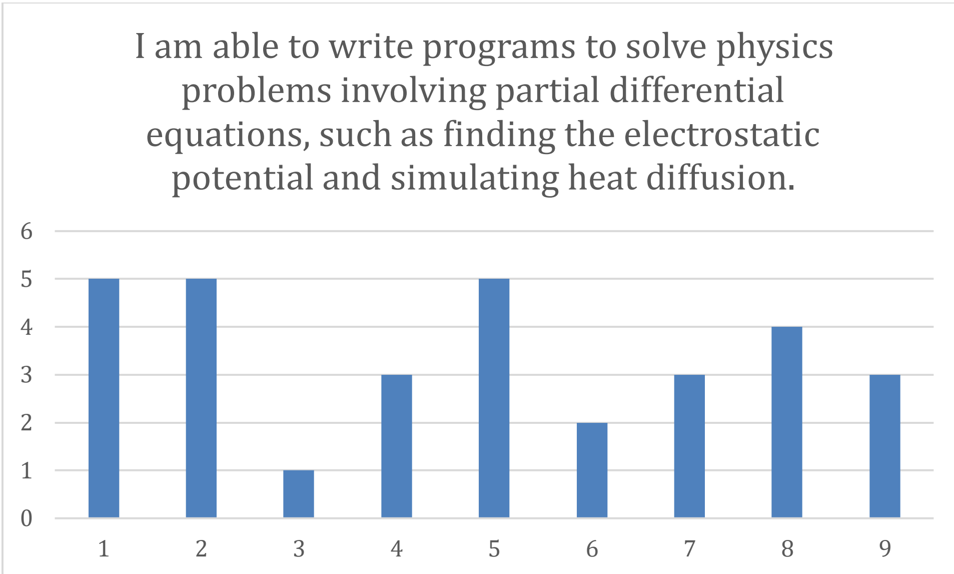

I am able to write programs to solve physics problems involving partial differential equations, such as finding the electrostatic potential and simulating heat diffusion.
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Self-Assessment of Learning Goals for PHYS 321, Spring 2018

The class in the spring of 2018 was far weaker and less motivated than classes in the previous years. I consider the performance of only about one third of the class acceptable. The rest submitted a few homework assignments, but could not demonstrate understanding of the material on the tests. Only five students submitted self-assessment. Three of them claimed complete understanding (5) of every subject, one complete lack of understanding (1) of every subject and one gave 5 or 4 to the less and more demanding subjects. As a result, I am reluctant to draw conclusions about the course from the results of this year's students.

Many students had substantial problems with using mathematics in a physical context – from elementary calculus to multivariable calculus and differential equations. Calculating work as a line integral or the center of mass and moment of inertia using integration were typical examples. Many students could not solve even the simplest differential equation. There were regular problems with basic pre-calculus mathematics and working with vectors. Many students had difficulty with connecting mathematical equations and physical situations.

There was plenty of help available, but few students came to my office hours or asked help from the TA. In spite of repeated warnings, the answer to the difficulties was rampant copying of homework solutions from the web. Even copies from my sample solutions posted in previous years were turned in as solutions. Repeatedly failing pop-up quizzes on selected homework problems had no effect. Alarming intermediate reports on standing after the midterm exams did not result in more effort. At the end, of the 21 students only 7 passed with a C or better, there were 6 Ds, 6 Fs and 2 incompletes.

The Assessment Plan specifically requires evaluation of seven subject areas. They were assessed by a specific problem on the final exam. The subject areas are as follows:

1. Use Newton's laws to set up and solve a range of physical problems.

> The first problem was on an object decelerated by friction and air resistance. The equation of motion is a separable differential equation, similar to the one discussed in detail in the textbook. Some students could write up the equation of motion and start the solution, but nobody was able to carry it through, even though the necessary integral was given as hint.
> Satisfactory result (≥ 50%) by 8 out of 19 students

2. Exhibit an understanding of energy conservation, potential energy, conservative and central forces, conservation of momentum and angular momentum, and use it to solve a range of physical problems.

> The forth problem of the final was supposed to address this subject. It was about a segment of a circle swinging down from horizontal to vertical position using conservation of energy. Unfortunately, most students were unable to determine the center of mass and did not even get to the energy conservation part of the problem.
> Satisfactory (≥ 50%): 4/19

3. Set up and solve problems related to driven and damped oscillations, along with coupled oscillators and normal modes of oscillation.

The problem on this subject was a standard two-body, three-spring problem, solved in class and on the homework with little variations.
Satisfactory (≥ 50%): 8/19

4. Use the Lagrange formalism to find and solve the equations of motion for mechanical systems.

This area was tested by a relatively simple problem involving two particles connected with a spring and sliding on perpendicular rails, one horizontal, the other vertical.
Satisfactory (≥ 50%): 10/19

5. Develop an understanding of rigid body rotational motion and use it to solve related problems.

Although a few students got partial credit, nobody was able to determine the position of the center of mass for a segment of a circle. It was a clear indication of the serious mathematical deficiencies, as the physical situation was rather obvious. One student got 75%, three about 50%, the rest zero or a few points of partial credit.
Satisfactory (≥ 50%): 4/19

6. Understand and solve problems related to the two-body central force problem.

There was no long problem related to this area. The answers to two short questions suggest that this area was covered properly.

7. Show an understanding of mechanics in non-inertial reference frames and use it to solve related problems.

The test problem related this subject was about a train circling the earth around the Equator. It is a mathematically simple but conceptually somewhat challenging case. The results were dreadful, only two students got ~50% partial credit.
Satisfactory (≥ 50%): 2/19

The discussion on Hamiltonian mechanics was shortened and simplified and scattering theory was eliminated to free up time for more in-class problems carried out with all the mathematical details. I believe it was the right thing to do, although it is difficult to support this from the results.

The content of the course and the amount of time spent on each subject is about right. No change is recommended. The main difficulty is to convince students that active problem solving is the only way to learn how to apply advanced mathematics to physics problems. Tutoring, review sessions, remedial discussions on relevant mathematics are necessary, but nothing works, unless students are willing to invest time and energy into active learning, that is regular problem solving on their own.

Self-Assessment of Learning Goals for PHYS 424, Spring 2018

Some relevant info for this report:

- This year's class had 23 students. My perception was that, on average, this was the least motivated and least interested group I've taught in my 12 years at UMBC.
- The final course grade distribution was 6 A's, 6 B's, 3 C's, 5 D's, 3 W's.
- The syllabus included the specific learning outcomes objectives.
- Grading of the course was based on:
  - 3 regular Exams (closed book, in class, 55 minutes)
  - 11 HW assignments
  - A cumulative Final Exam (closed book, in class, 2 hours).
- My assessment of each of the 6 learning outcomes objectives is based on:
  - Quantitative evaluation of the results of specific HW and exam problems.
  - Subjective evaluation based on classroom participation and discussions.

Assessment of the 6 Learning outcomes objectives:

1. *Explain the breakdown of classical mechanics and the development of quantum mechanics.*
   - My assessment based on specific HW and Exam problems: 15 of 23 students (65%) mastered this objective.
   - My assessment based on participation and discussion: Roughly half of the students mastered this objective.

2. *Utilize the concept of the wavefunction (and quantum states and qubits) to describe quantum systems, with emphasis on using the statistical interpretation and predicting the outcomes of measurements.*
   - My assessment based on specific HW and Exam problems: 14 of 23 students (61%) mastered this objective.
   - My assessment based on participation and discussion: Roughly half of the students mastered this objective.

3. *Solve the Schrodinger equation for various 1D potentials.*
   - My assessment based on specific HW and Exam problems: 17 of 23 students (74%) mastered this objective.
   - My assessment based on participation and discussion: Roughly 2/3 of students mastered this objective.

4. *Work with Dirac notation and the formalism of QM including the concepts of Hilbert space, operators, commutators, eigenfunctions and eigenvalues, and the uncertainty principle.*
   - My assessment based on specific HW and Exam problems: 15 of 23 students (65%) mastered this objective.
   - My assessment based on participation and discussion: Less than half of the students mastered this objective (ie. worse than HW %).

5. *Perform 3D calculations in Quantum Mechanics, using the example of the Hydrogen atom, with emphasis on the concepts of angular momentum and spin.*

- My assessment based on specific HW and Exam problems: 14 of 23 students (61%) mastered this objective.
- My assessment based on participation and discussion: Roughly half of the students mastered this objective.

6. *Analyze systems of identical particles and the concepts of fermion and boson statistics.*
    - My assessment based on specific HW and Exam problems: 16 of 23 students (70%) mastered this objective.
    - My assessment based on participation and discussion: Less than half of the students mastered this objective (ie. worse than HW %).

Comparison with Student Survey from Jen:

- Unfortunately, only 6 of 23 students responded to Jen's survey. This year I wasn't able to see their names, so I'm not sure how to correlate their responses (overwhelmingly strong) with my assessment of the degree to which the learning outcomes objectives were achieved. I'm not sure if these were the stronger students, weaker students, or a mix.

Comments, suggestions, and wrap-up notes:

- I really struggled to get this group of students involved in the class discussions. It was also the first time (in 12 years) that I had students regularly skipping class. I tried everything I could think of to engage these students, but nothing seemed to work. At times I felt like a failure, and I must admit that this semester was not a rewarding teaching experience for me. A subset of 5 - 7 students were engaged, interested, and motivated. I felt very bad for these particular students, as I'm fearful that being part of this lackluster cohort may have made their 4-year UMBC Physics Major experience not very positive?
- *Repeated comment from 2016 and 2017:* It's time to make a big change: I strongly recommend that the Undergraduate Curriculum Committee make Quantum Mechanics a 2 semester course, from a single textbook. QM 1 should be in Spring of the junior year, and QM 2 in the Fall of the senior year. Modern physics should still be included in the curriculum, and should come sometime before QM 1. UMCP's course progression is a good template.
- *Repeated comment from 2016 and 2017:* I found that every single HW and Exam problem was related to one of the 6 learning goals. I just chose an arbitrary subset to do my assessment. Is that the idea? I guess I'm a little confused on the methodology we should use. Also, when I said a student "mastered" a problem, I used "C+'ish" or above type of work. Is that OK, or do you need a further breakdown?
