2016-2017 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 2016 courses PHYS 303, 330L, 407, and on the Spring 2017 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 of this document.

PHYS 303, FALL 2016. As the instructor notes "*the class was largely divided into students who were able to largely answer nearly all of the questions, and those who struggled with even simple questions. This again suggests that learning goals were achieved by a certain fraction of the students, but there was a segment of the class that completely missed the goals. Unfortunately, this segment of the class appears to be larger than previously*."

By the end of the semester, student's performance dropped and this explains the unsatisfactory performance in goal 6. However, an important improvement was noticed, as students, contrary to Fall 2015 were able to apply concepts to novel situations. As the instructor notes *"This may reflect an emphasis during the semester on in-class discussion and demonstrati*ons, homework problems, and quiz questions that emphasized this skill."

PHYS 330L, FALL 2016. As reported by the instructor, the learning goals have been largely achieved, with a markedly improvement over the semester in the quality of the lab report writing. The instructor does not propose any changes.

PHYS 407, FALL 2016. The instructor reports that a fraction between 50% and 80% of the class achieved a good understanding of the different topics of the class. The instructor proposes more emphasis on real world challenge problems with little prescribed information, more emphasis on how motors/generators work, and spending more time on special functions.

PHYS 220, SPRING 2017. Following the suggestion of the instructor from last year, learning goal #4, regarding numerical solution of partial differential equations has been taken out, as there was no time for it. The instructor reports high mastery of the learning material from most of the students and agreement between direct and indirect assessment.

PHYS 321, SPRING 2017. The instructor commends that "the most remarkable progress was achieved on writing up longer solutions in a clear and organized manner". However, "There were substantial problems with using advanced mathematics – primarily multivariable calculus and differential equations – in a physical context". To remedy that he proposes to "to put together a set of problems in pure mathematics that will address specific skills and assign them as homework before the same skill appears in a physical context." The instructor suggests a series of changes, in the spirit of last year's suggestions: "An increase on the emphasis of Newtonian mechanics, including somewhat more complex problems and problems that require careful use of vectors, components, and scalars, as well as conservation laws alone or in combination with Newton's laws. Further limit the time spent on oscillations to how to use matrices and cases where the Lagrange equations of motion is advantageous. Restricting the treatment to rotational motion to rotation about an arbitrary but fixed axis. Increase attention to non-inertial frames and reduce the time spent on Hamiltonian mechanics. Finally, maintain attention to rigorous mathematics, particularly the clear handling of vectors and scalars and keep emphasizing the importance of organized and clearly commented work”.

PHYS 424, SPRING 2017. The instructor is satisfied that the learning goals have been in general achieved by the majority of the students. The instructor mentions that he used all problems and exams to reach his evaluation, as they could all map to the learning goals, and asks guidelines from the committee on how to proceed in the future. He is ambivalent about the indirect assessment this year, as input was only provided by eight students that did identify themselves. He again focuses on the material overlap issue between PHYS 324 and 424 and he suggests turning QM into a two semester junior level class using a single book, and shifting PHYS 324 to the senior year making it essentially a capstone course. These are changes that the curriculum committee should discuss.

COMMITTEE OVERALL EVALUATION: The committee finds that during this second transitional year of implementing the learning goal self-assessment, no major deficiencies were identified. However, a series of changes fine-tuning the course content have been identified and the committee is in full agreement with their implementation. These, along with specific changes such as addressing the overlap between PHYS 224 and PHYS 321 need to be discussed by the curriculum committee.

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.

Starting with year 2016-2017, 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 REPORTS

Self-Assessment of Learning Goals for PHYS 303, Fall 2016

Assessment is based on questions on the two mid-term exams, and on the final exams, that corresponded to each of the learning goals. The questions were chosen at the beginning of the course, and student scores for each of the questions were compiled.

Overall, achievement of the learning goals was mixed, and was perhaps lower than the previous time the course was taught, in Fall 2015. As before, the class was largely divided into students who were able to largely answer nearly all of the questions, and those who struggled with even simple questions. This again suggests that learning goals were achieved by a certain fraction of the students, but there was a segment of the class that completely missed the goals. Unfortunately, this segment of the class appears to be larger than previously.

The effectiveness of the course this semester was affected by the large fraction of students who were simultaneously enrolled in this course and in PHYS 407. Many of these students were overwhelmed by the demands of the two courses, and their performance suffered, especially during the later part of the semester. This is particularly reflected in the final learning goal, which was the last one taught during the semester (see below). It is clear that, by this point, student attention in the course was lacking.

An improvement over the last time the course was taught, in Fall 2015, is that problems in which students needed to apply concepts to novel situations did not seem to pose great difficulties, compared to more familiar problems. This may reflect an emphasis during the semester on in-class discussion and demonstrations, homework problems, and quiz questions that emphasized this skill.

Assessment of specific learning goals follows.

1. Derive the thermodynamic properties of a model system (e.g., two-state paramagnet, ideal gas) by determining its multiplicity

For a midterm-exam question that required application of this concept to a novel situation, 6 students answered nearly entirely correctly, and 15 more answered at least partially, out of a total of 28. This indicates that the majority of the students have mastered the concept to the point where they can apply it to a situation that they have not seen before.

2. Derive the thermodynamic properties of a model system (e.g., paramagnet, ideal gas) using Boltzmann factors and the partition function

For a final-exam question that required application of this concept to a novel situation, 4 students answered nearly entirely correctly, and 14 more answered at least partially, out of a total of 23. This indicates that the majority of the students have mastered the concept to the point where they can apply it to a situation that they have not seen before.

3. Calculate the entropy change during a thermodynamic process (e.g., heating under constant pressure or constant volume, phase change).

For a relatively straightforward midterm-exam question that involved this concept, 16 students answered entirely correctly, and 5 more answered at least partially, out of a total of 24. The question was similar to a homework problem that they had previously encountered, but this nonetheless demonstrates reasonable mastery of the concept.

4. Determine relationships between state variables for a thermodynamic process (e.g. adiabatic or isothermal compression, Joule-Thomson expansion).

For a final-exam question that involved this concept, 10 students answered entirely or nearly entirely correctly, and 9 more answered at least partially, out of a total of 28. The question was moderately difficult, so this indicates reasonable achievement of the learning goal.

5. Determine the efficiency of a heat engine (e.g., Carnot cycle).

For a midterm-exam question that required application of this concept to a novel situation, 4 students answered nearly entirely correctly, and 14 more answered at least partially, out of a total of 25. This indicates that the majority of the students have mastered the concept to the point where they can apply it to a situation that they have not seen before.

6. Apply the Fermi distribution and Bose-Einstein distributions to model problems (e.g., electrons in solids, heat capacity of solids, blackbody radiation).

For a final-exam question that involved this concept, 5 students answered entirely or nearly entirely correctly, and 4 more answered at least partially, out of a total of 25. The question was reasonably difficult, but was identical to a homework problem that they had previously encountered. This indicates that the learning goal was not accomplished.

Self-Assessment of Learning Goals for PHYS 330L, Fall 2016

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 latter-half "laser measurements" lab which is deliberately vague.

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 we expect by the end. By the end of the course, all but two 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 one who withdrew) passed the course, and thus successfully accomplished 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 one 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 2016

A cutoff value of 60% proficiency will be used.
Metric used is the fraction of students achieving > 60%.
Specific examples of general concepts used in quizzes/exams given here.

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.

85% of students initially had little to no skill in vector calculus, despite math prerequisites
70 % of students achieved adequate proficiency (> 60%)
Intuitive understanding of geometry of vector fields: 60%

2. Solve problems in electrostatics that manifest an understanding of the divergence of electrostatic fields, the electric potential, and work and energy in electrostatics.

Geometric properties of vector fields (div, curl) and inherited from div, curl of point charges
and time-independent current elements from superposition > 80%
Forces between charge distributions (pt. charge/dipole, dipole/dipole, induced dipole/dipole): 70%

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.

Computation of electrostatic fields by application of Coulomb's Law: 71%
Gauss's Law: 80%
Boundary value problems for Laplace's equation: 50%
Concept of orthogonality: > 80%; ability to apply correctly: 40%
Laplace's equation and Earnshaw's Theorem: < 30%

4. Understand electric fields in matter, through being able to solve problems involving the field of a polarized object, the electric displacement, and dielectrics.
Understanding/application: > 75% for simple geometries
Laplace equation with boundary conditions between different media: > 65%

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.

Solving for magnetic field of simple symmetric current distributions
Ampere's Law: 80%; Biot-Savart Law: 50%
Solving for motion of charged particle in combined E & B field: >70%
Spreading of a beam in a quadrupole (static) magnetic field: 30%
Distortion of charge distribution in static electric field: 30%

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.

Emphasis on exploring magnetic fields with permanent magnets (dipole)
Group project: Explain principles behind simple E&M toys, or create one (8 groups)
6 groups: Fair explanations of given toy examples
2 groups: Used imagination & applied learned physics

7. Demonstrate an understanding of the electromotive force, the electromagnetic induction, and Maxwell's equations.

Ability to derive Maxwell's equations; find E, B for plane wave: 75%
Solve simple generator problem, explain transformer: > 70%
Given electric field with curl, find B field & current distribution: 40%
Exam on Induction/Maxwell's equations; 50%

Recommendations:

More emphasis on real world challenge problems with little prescribed information.

More emphasis on how motors/generators work; more concrete examples

Spend more time on special functions (e.g. Legendre polynomials) & orthogonality.

Self-Assessment of Learning Goals for PHYS 220, Spring 2017

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 2016. 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.

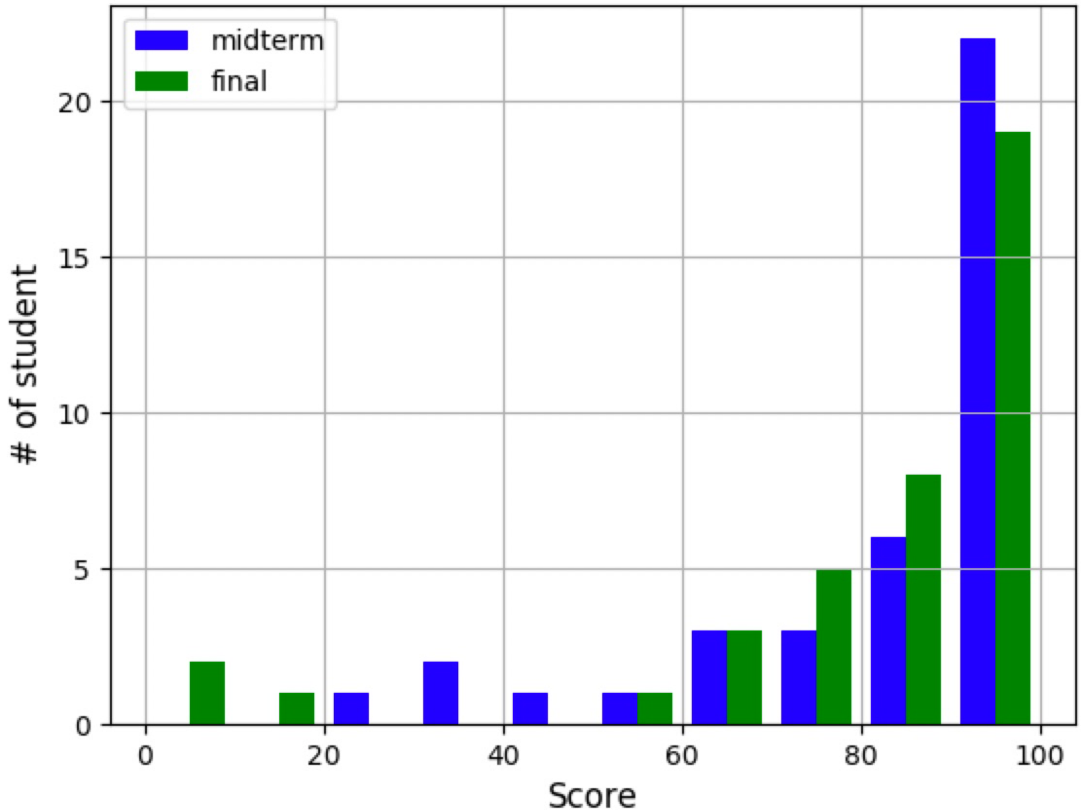


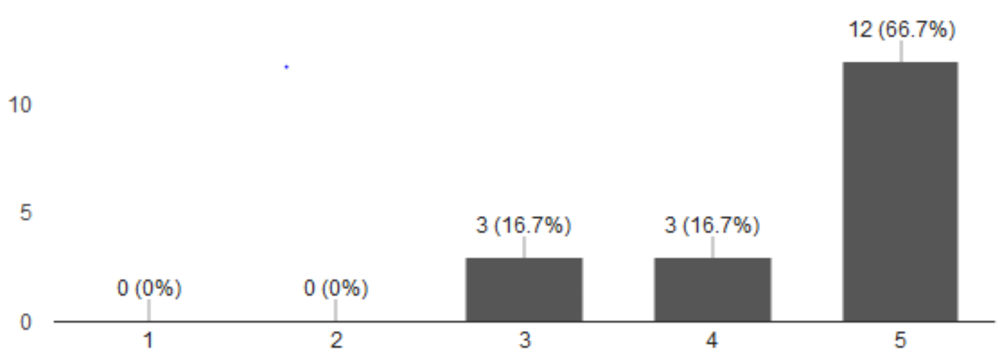
Figure 1 Distribution of the scores for the midterm and final project.

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.

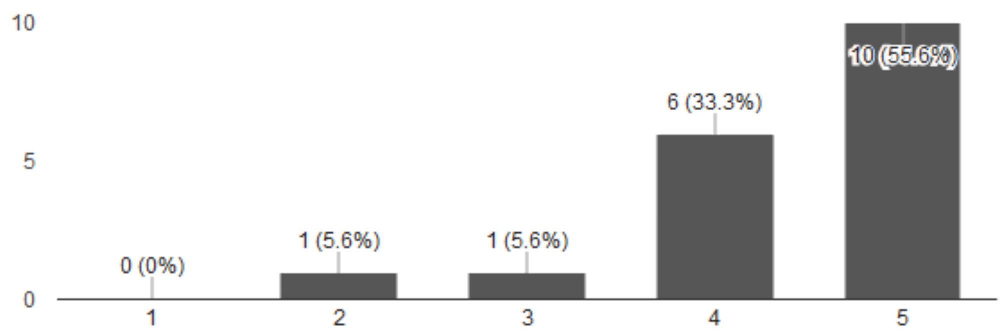
I am able to use a software package (e.g., Mathematica or Matlab) or high-level programming langrage (e.g., Python or IDL) to write modularized programs and plot simple figures, such as scatter plots, time series, histograms, and 2D contours.

18 responses



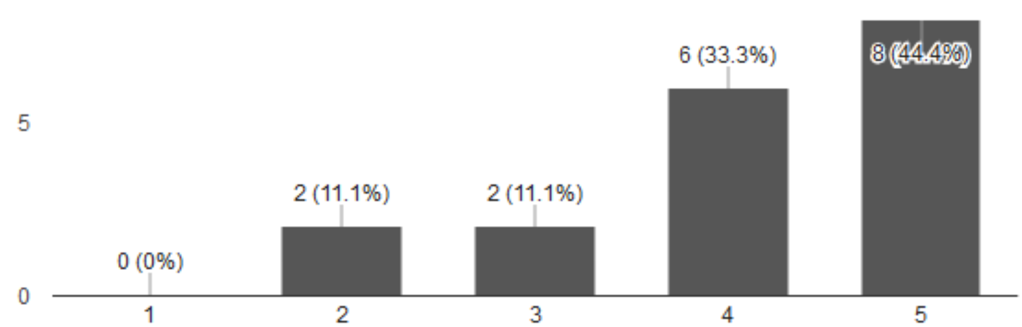
I am able to use Monte Carlo methods to simulate and understand random walk problems, such as photon transport in isotropic-scattering medium.

18 responses



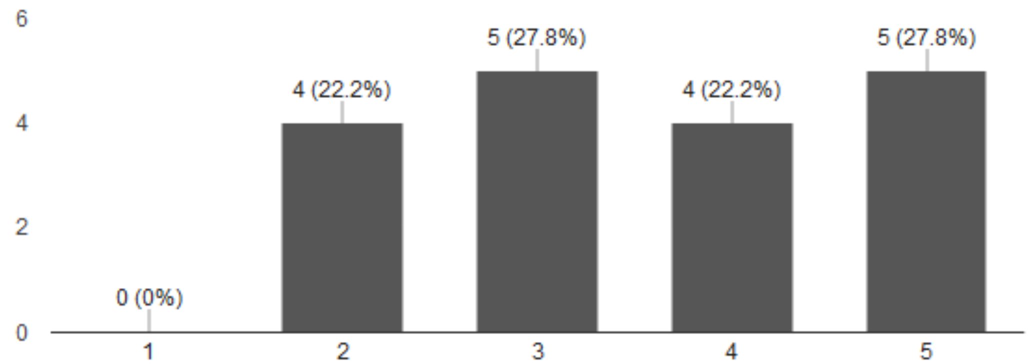
I am able to write programs to solve physics problems involving ordinary differential equations, such as projectile motion with drag and nonlinear oscillations.

18 responses



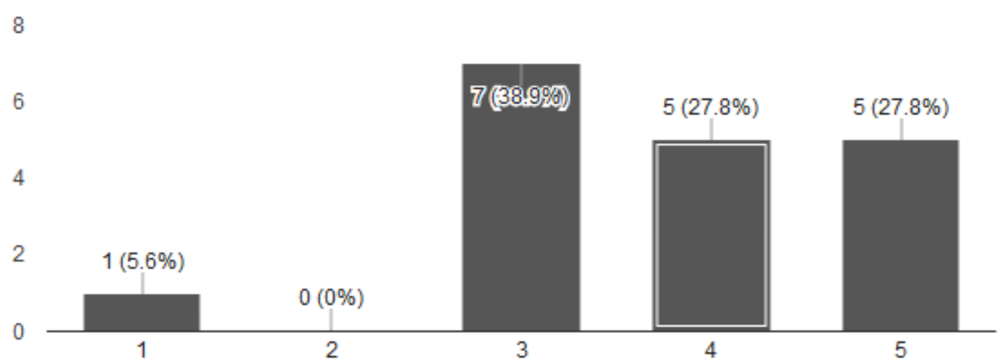
I am able to write programs to solve physics problems involving partial differential equations, such as finding the electrostatic potential and simulating heat diffusion.

18 responses



I am able to demonstrate a good mastery of basic data analysis methods, such as linear regression, uncertainty analysis, null hypothesis testing, and Fourier analysis.

18 responses



Self-Assessment of Learning Goals for PHYS 321, Spring 2017

Classical mechanics is the only area of physics that is accessible to our natural senses. Therefore, it is the ideal vehicle to teach how common experience, verbal description, sketches, intuition, qualitative assessment, mathematical formulation, algebraic and numerical solutions, plots, and quantitative interpretation can be combined to analyze a physical situation. PHYS 321 demonstrates the interplay of those components and most students taking the course made clear progress on their depths of understanding over the semester.

The most remarkable progress was achieved on writing up longer solutions in a clear and organized manner. Most students came to understand that a certain degree of neatness is necessary when working out long and complex problems. Proper use of mathematical notation and basic mathematical skills improved as well. As PHYS 321 is the first theoretical physics course for most students, these improvements prepare them for the future courses.

There were substantial problems with using advanced mathematics – primarily multivariable calculus and differential equations – in a physical context. Calculating work as a line integral and difficulties with calculating moments of inertial in the form of a volume or area integral were typical examples. Clearly knowing whether a quantity is constant or a variable and what quantity is a function of what was another weakness. I intend to put together a set of problems in pure mathematics that will address specific skills and assign them as homework before the same skill appears in a physical context.

The Assessment Plan specifically requires evaluation of seven subject areas. Most were assessed by a specific problem on the final exam, one on the second midterm a few weeks earlier. For each problem, the knowledge of students with more than 50% credit were considered satisfactory. The learning goals were also assessed indirectly by asking students about their perceived level of knowledge in each area. Of the 30 students who finished the course, 11 provided this information. The subject areas are as follows:

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

> The first problem of the final was a standard Newton's law problem with constant acceleration that could be one of the harder problems on an Introductory Physics test. Thirty students took the test and of them only 7 got at least 80%. As Newtonian mechanics is the foundation of any more advanced chapter of mechanics, this is not acceptable. The time spent on Newton's laws has to be further increased and problems on the 121-level as well as more complex problems that utilize the increased level of mathematical proficiency have to be treated. Most students felt very confident about their understanding of the subjects. The disparity suggests that they are not aware of applications that require deeper understanding of Newtonian mechanics.
> Satisfactory (over 50%): 60%

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 second question of the final test involved the motion of a particle attached to a string that is pulled through a hole in the tabletop. The overwhelming majority of the students did not realize that this was a central force situation where angular

momentum is conserved. This problem has to be addressed by a few targeted problems in the future. Student self-assessment did not reflect this problem.
Satisfactory (over 50%): 13%

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

Most students brought good understanding of oscillations from 224 as indicated by the mostly confident and correct solution of the related problem on the second midterm test. Only the application of matrix formalism and the application of Lagrangian mechanics to small oscillations were new compared to 224. Interestingly, most students were less confident about this subject. Nevertheless, the time spent and depth of treatment seems appropriate.
Satisfactory (over 50%): 68%

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

This area was tested by a mathematically demanding problem (particle sliding down a curved incline.) The results were reasonable and the difficulties were mostly mathematical rather than conceptual. Most students felt that they had a solid grasp of the material. No change is needed.
Satisfactory (over 50%): 33%

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

The focus of PHYS 3231 is particle mechanics, thus treatment of this subject was almost completely restricted to the concept of principal moments and axes. Most students had good understanding of this material, as shown by the almost 80% average on the corresponding test problem. Student confidence was relatively low, as students were aware of the limitations of treating this material. Meaningful improvement would require too much additional time. If anything, emphasis can be further reduced by dropping the discussion on Euler's equation and restricting the treatment to rotation about an arbitrary but fixed axis.
Satisfactory (over 50%): 73%

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

The corresponding test problem was very similar to a homework problem, thus the weak result is probably the result of tiredness at the end of the test, more than a lack off understanding. Student perception suggests average depth of knowledge. No change is planned.
Satisfactory (over 50%): 23%

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

The test problem testing this subject was a simple exercise directly from the book (a bead sliding off a rotating rod.) The results were dismal, mostly due to mathematical rather than conceptual difficulties. Many students failed to find the solution of the equation of motion (a simple exponential) as it appeared in an unusual context.

Students reported relatively low level of understanding also. Slightly more attention is needed for this subject.
Satisfactory (over 50%): 17%

A potentially rewarding discussion on Hamiltonian mechanics and its link to quantum mechanics seems to be premature for most students. This discussion will be dropped to free up time for other subjects and Hamiltonian mechanics will be restricted to the equations of motion, phase space trajectories and Liouville's theorem.

In summary, it is recommended that

- The emphasis on Newtonian mechanics has to be further increased, including somewhat more complex problems and problems that require careful use of vectors, components, and scalars, as well as conservation laws alone or in combination with Newton's laws.
- Limit the time spent on oscillations to how to use matrices and cases where the Lagrange equations of motion is advantageous. Assume that the rest is covered in PHYS 224.
- Restricting the treatment to rotational motion to rotation about an arbitrary but fixed axis.
- Slightly increase attention to non-inertial frames.
- Reduce the time spent on Hamiltonian mechanics.
- Maintain attention to rigorous mathematics, particularly the clear handling of vectors and scalars. Keep emphasizing the importance of organized and clearly commented work.

Self-Assessment of Learning Goals for PHYS 424, Spring 2017

Some relevant info for this report:

- This year's class had 26 students.
- The final course grade distribution was 8 A's, 6B's, 7 C's, 5 D'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)
  - 12 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: 24 of 26 students (92%) mastered this objective.
   - My assessment based on participation and discussion: Nearly all 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: 18 of 26 students (69%) mastered this objective.
   - My assessment based on participation and discussion: Roughly 2/3 of students mastered this objective.

3. *Solve the Schrodinger equation for various 1D potentials.*
   - My assessment based on specific HW and Exam problems: 22 of 26 students (85%) mastered this objective.
   - My assessment based on participation and discussion: Nearly all 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: 18 of 26 students (69%) mastered this objective.
   - My assessment based on participation and discussion: Nearly all students mastered this objective (ie. much better 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: 17 of 26 students (65%) 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: 23 of 26 students (88%) mastered this objective.
    - My assessment based on participation and discussion: Nearly all students mastered this objective.

Comparison with Student Survey from Jen Salmi:

- Unfortunately, only 8 of 26 students responded to Jen's survey. I was able to see their names (not sure if that was intended?) and they were among the best in the class. There was a very strong correlation between my assessment of these 8 students and the students' self-assessment of the degree to which the learning outcomes objectives were achieved.

Comments, suggestions, and wrap-up notes:

- A large fraction (~12) of these students work together on HW and turned in virtually identical HW solutions week after week. I encourage them to collaborate, so I'm OK with this. However, I got the sense that this "group approach" used by this cohort helped the stronger students (peer mentoring), but the weaker students did very poorly on the exams compared with their HW scores.
- *Repeated comment from 2016:* We are still struggling with the overlap between 324 and 424. I've talked quite a bit with Dr. Jason Kestner about this and we haven't been able to get it figured out yet. 324 does cover the intro QM material, but the language and thought-process varies so much from book to book that I always feel the need to basically "start over" at the beginning of 424. Some minor thoughts:
    - My recommendation is that the ugrad curriculum cmte make QM a two-semester course: "QM I" Fall of Jr. year, and "QM II" Spring of Jr. year. Check around if other schools do this.
    - Use the same textbook for both semesters. Doesn't have to be the same professor, just the same textbook. Fall is Ch. 1- N, Spring is Ch. N- N'.
    - Then have "Modern Physics" in Fall of senior year; cover hot modern topics like relativity, particle physics, etc. and then survey our own dep't research areas of CM, quantum info, astro, atmos?
- *Repeated comment from 2016:* 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?