2021-2022 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 courses PHYS 220, 303, 321, 407, 424. A brief 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 220, SPRING 2021. The instructor reports that approximately 78% of students have mastered satisfactorily (grades B and A: between 75-100%) the main goals in this discipline: "*they are expected to be able to formulate Physical problems in the language of Python and to use mathematical and computational skills to solve physical problems*". About 17% of the students reached a satisfactory level (grade C: between 60 -75%). Note that within this SMALL group of students, at least 1 out of 6 students were going through personal issues that prevented him/her from completing the assignments. About 5% of the students have failed the course with (grade D or F: less than 60%). We should notice that within this group of two students who have failed, their grades also seems to be related to personal issues and inability to dedicate time to the discipline than difficulty with the subject itself. On the other hand, it is interesting to note that this course was very challenging for at least 4 students, 11%, but they have managed to pass due to persistence and not missing any assignment.

PHYS 303, FALL 2021. The instructor brings up, as he has done before, the issue that the learning goal to *"Apply the Fermi distribution and Bose-Einstein distributions to model problems (e.g., electrons in solids, heat capacity of solids, blackbody radiation)"* is unrealistic. The instructor also brings up an issue that we encountered for different sources: in previous years: weak mathematical preparation.

PHYS 321, SPRING 2022. The major comment of the instructor is that the students were not prepared for the intensity of the course: "They were too willing to give up on homework problems that were unfamiliar or that took any length of time. Also, there were several students who had scheduled too many difficult classes for the semester. These students were mentally and emotionally exhausted by the middle of the semester.

PHYS 407, SPRING 2021. The instructor points out the high DFW rate and argues that it is due to students taking the upper level course PHYS 407 very early. He calls for an urgent meeting of the self assessment and curriculum committees with the goal of setting prerequisites to stop unprepared students from taking 407. A good place to discuss this issue in in the early fall faculty meeting dedicated to self-assessment.

PHYS 424, FALL 2021. This class had several groups of students who worked together regularly. This really seemed to power their work. One drawback was that each group had one student that seemed to be using it as a crutch. Overall, this was a very engaged class. *Repeated comment from previous years:* 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.

COMMITTEE OVERALL EVALUATION

The main point on which action should be taken is that students are now allowed to reach PHYS 407 prematurely. This will have to change as soon as possible, to provide a more reasonable class sequence and to avoid the high failure rate seen in this course.

LEARNING GOAL SELF ASSESSMENT INDIVIDUAL COURSE REPORT

Self-Assessment Report – Spring 2022
Introduction to Computational Physics – PHYS220
Adriana Rocha Lima – Department of Physics – UMBC – June 6th, 2022

1. Overview of PHYS220 - Spring 2022

This is my third time teaching PHYS220, although the first time with the full semester in person. There was a total of 36 students enrolled in this course and no withdrawals were seen in this semester. Figure 1 shows the major programs of the students that completed PHYS220 during the Spring 2022 semester. Most of the students were seniors from the Physics, Computer Engineering, and Mathematics program. A total of 13 out of 36 students were non-seniors

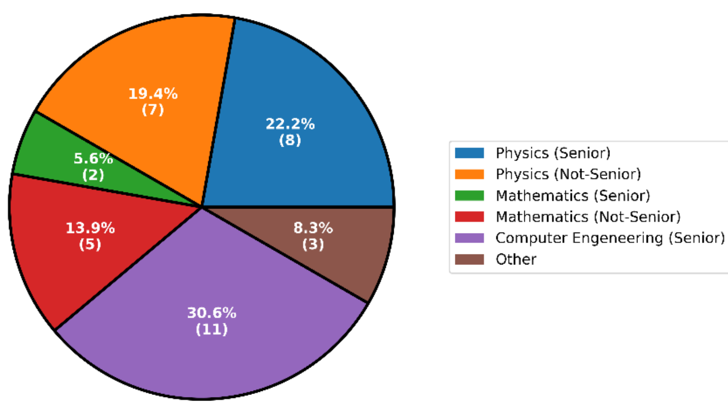
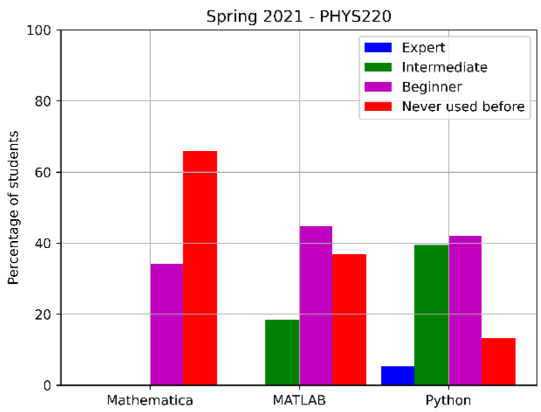


Figure 1. Profile of the students that completed PHYS220 during the Spring 2022.

2. Analyses of the Specific goals for PHYS220

2.1 "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".

On the first day of class, students completed a questionnaire about their proficiency level in Mathematica, MATLAB, and Python. Interestingly, the number of students that have never used Python in the beginning of the semester has decreased from 8 to only 1 student between 2020 and 2022. Figure 2 shows the normalized distribution of their responses. We can see that the students consider themselves, in general, less familiar with Mathematica and MATLAB than Python.



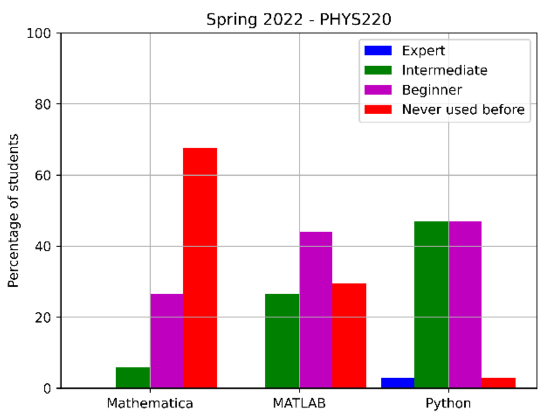


Figure 2. Level of proficiency in Mathematica, MATLAB, and Python declared by students on the first day of class for 2021 (on the left) and 2022 (on the right).

Different from the Spring 2020 class, Python was the only programming language used in the Spring 2021 and Spring 2022. The use of multiple software packages in addition to a high programming language seems not be compatible with what students can learn in one semester. The idea is that focusing on one language gives more time for students to practice and get deeper in the intricacies of the language. Students learned basic commands for data analysis, reading and saving data, scatter and density plots, histograms, error bars, chi-squared plots, probabilities distributions, and Gaussian fitting in Python. In addition to the examples given in class, the students were able to practice what they learned in homework, one take-home midterm exam, and a final Python Project (consisting of proposal, oral presentation, and report). During the semester, students also completed a total of six in class assignments. These assignments were activities initiated in class consisting of a problem covering the content taught on that day. The completed assignment was due by the end of the following day. Approximately, 90% of the students have mastered (scores above 80%) this goal in the class assignment, but only around 60% of the students were able to fully reapply and interpret these concepts (scores above 80%) in a different Physics problem in the homework.

2.2. "Use Monte Carlo methods to simulate and understand random walk problems, such as photon transport in isotropic-scattering medium".

The students learned how to use random number generators and its application to Monte Carlo integration, pi determination, and simulation of Brownian motion. The problem of applying Monte Carlo method to simulate particle deposition on surfaces was the topic of one of the teams for the Final Python Project and it was presented to the class. Approximately 75% of the students have mastered (scores above 80%) Monte Carlo integration and simple problems using Monte Carlo method.

2.3. "Write programs to solve Physics problems involving ordinary differential equations, such as projectile motion with drag and non-linear oscillations".

The students learned different numerical methods to solve first and second order ODEs, such as Euler's method, 4th Order Runge-Kutta, solutions over infinite ranges, and ODEs of more than one variable. The students had the opportunity to apply those concepts solving Physics problems, such as, Lorentz equations, solving a low-pass filter, the spring-mass system, the nonlinear pendulum, and the double pendulum. Approximately 80% of the students have mastered this specific goal in the class assignments, and around 60% have mastered this goal in the homework.

2.4. "Write programs to solve Physics problems involving partial differential equations, such as finding the electrostatic potential and simulating heat diffusion".

The students had the opportunity to work on problems of finding the electric potential, solving Laplace's equation, and the Poisson's Equation to solve the Electrical Potential in presence of charge. Approximately 90% of the students have mastered this specific goal in the class assignments, and around 60% in the homework.

2.5. "Demonstrate a good mastery of basic data analysis methods, such as linear regression, uncertainty analysis, null hypothesis testing, and Fourier analysis".

Uncertainty and error analyses were discussed in multiple problems. Physical Interpretation and application of the Discrete and Fast Fourier Transform were presented to the class with examples, such as, analysis and filtering of signals and image deconvolution. Fourier analysis applied in the processing of sounds of musical instruments and in the diagnosis of heart rate diseases were some of the topics chosen by the students for the Final Python project developed by the teams and it was presented to the class as oral presentation. Approximately 90% of the students have mastered this specific goal in the class assignments, and around 60% in the homework.

3. Final considerations

In summary, considering their final scores, approximately 78% of students have mastered satisfactorily (grades B and A: between 75-100%) the main goals in this discipline: "*they are expected to be able to formulate Physical problems in the language of Python and to use mathematical and computational skills to solve physical problems*". About 17% of the students reached a satisfactory level (grade C: between 60 -75%). Note that within this group of students, at least 1 out of 6 students were going through personal issues that prevented him/her from completing the assignments. About 5% of the students have failed the course with (grade D or F: less than 60%). We should notice that within this group of two students who have failed, their grades also seems to be related to personal issues and inability to dedicate time to the discipline than difficult with the subject itself.

On the other hand, it is interesting to note that this course was very challenging for at least 4 students, 11%, but they have managed to pass due to persistence and not missing any assignment.

From the point of view of the instructor, the main challenge to be overtaken when teaching PHYS220 again is to provide faster and personalized feedback for the class assignments and homework.

Statistical Mechanics 303: Learning goals and assessment (Fall 2021):

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

   Most of the students did not appear to have any major difficulties with these tasks. Problems in the assignments and on the final exam were solved satisfactorily.

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

   Typically, this is a rather simple task and the students performed generally well.

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

   Like in most problems in thermodynamics the students did very well.

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

   Like in most problems in thermodynamics the students did very well

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

   Like in most problems in thermodynamics the students did very well

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

   Personally, I consider this an unrealistic learning goal. As a 300-level class 424 is not a pre- requisite, and thus the only exposure to quantum mechanics comes through 324. However, it is illusionary to believe that the students have already grasped concepts like degeneracy (if even covered in 324). Thus, neither the Fermi-Dirac nor the Bose-Einstein distribution can be derived in a comprehensive manner. To work around this issue, I discussed analogous *classical problems which eventually do lead to the same distributions. However, I am convinced that maybe only one or two students really made the connection to quantum statistics.*

General remarks:

Fall 2021 was the first semester that we returned to campus after remote teaching from almost 1.5 years. This posed significant challenges for several students that seemed overwhelmed with the new situation (face to face, yet hidden behind masks). Over the course of the semester, my class (starting with 27 students) experienced one emotional breakdown, one family emergency, 2 hospitalizations, a threat of self-harm, and several COVID cases and scares. To my big surprise, this did not stop most of the students to work even harder and study as best as they could. In the end, more than half the class managed to achieve the letter grade B or better.

Quantitative assessment (success in %):

1. 1) 90%
2. 2) 90%
3. 3) 95%
4. 4) 95%
5. 5) 90%
6. 6) 70%

Learning Outcomes Assessment Report

Spring 2022 PHYS 321 "Intermediate Mechanics"

Some relevant info for this report:

- This semester's class had 23 students
- The final course grade distribution was 5 A's, 6 B's, 10 C's, 2 D
- The syllabus included the specific learning outcomes objectives.
- Grading of the course was based on:
  - 2 regular Exams (closed book, in class, 55 minutes)
  - 10 HW assignments
  - A cumulative Final Exam (closed book, in class, 2 hours).

Assessment of the 6 Learning outcomes objectives:

1. *Qualitative and qualitative understanding of basic Newtonian Mechanics.*

   My assessment based on specific the several homework assignments and a pair of semester-exam problems.

Based on these the students had a good understanding of basic forces, momentum, and energy techniques. They were able to do this on several physical systems in homework problems.

2. *Analyze of systems using Lagranigian Mechanics*

   My assessment is based on several homework problems and exam problems. The students had a good understanding the development and use of Lagrangian mechanics. This was the part of the course that the students enjoyed the most.

3. *Quantitative Understanding of Coupled Oscillators.*

   My assessment is based on specific homework problems and one exam problem on semester exam and one on the final exam. 1/2 of the students had a good understanding of this.

4. *Examination of central force problems.*

   My assessment based on several homework problems and one exam problem. 3/4 of the students performed satisfactorily.

5. *Application of non-inertial reference frames.*

   My assessment based on specific homework problems and an exam problem. Although the students could replicate the analysis, the students tried to simply memorize and not understand.

6. *Rigid-body Motion Analysis.*

   My assessment based on several homework problems and three exam problem: Approximately 1/4 of the students did very well with all aspects of this topic. 1/4 of the students struggled with simple applications. ½ of the students could not apply the material to an unfamiliar situation.

Comments:

My major comment is that the students were not prepared for the intensity of the course. They were too willing to give up on homework problems that were unfamiliar or that took any length of time.

Also, there were several students who had scheduled too many difficult classes for the semester. These students were mentally and emotionally exhausted by the middle of the semester. Advisors should place an emphasis on proper class load scheduling.

Learning Outcomes Assessment Report
Spring 2022 PHYS 407 Electromagnetic Theory
Instructor: Todd Pittman

Some relevant info for this report:

- This year's class had 23 ugrad physics majors (and 4 grad students). My assessment is based on the 23 ugrad physics majors. The final course grade distribution was for the 23 ugrad physics majors was:
  - A or B: 39%
  - C: 21%
  - DFW: 39%

- The DFW rate was terrible (9 of 23 students)-- especially for one of our advanced core courses. I suspect this may be in part due to a major flaw we have in our undergraduate advising situation. **I urge the Assessment Cmte. to call a summer meeting with the Undergrad Curriculum Cmte. and look into this issue ASAP. We need to make a change by early October 2022 (next Advising period), lest the problem may repeat!** To briefly summarize the issue:

  - Our "standard course progression" through the 4 core UL physics courses is:

    - Fall Junior year: Stat Mech. (303) [Concepts = Easy; Math = Hard]
    - Spring Junior year: Class. Mech. (321) [Concepts = Easy; Math = Hard]
    - Fall Senior Year: Quantum Mech.(424) [Concepts = Hard; Math = Easy]
    - Spring Senior Year: E&M (407) [Concepts = Hard; Math =Hard]

  - In my opinion, nearly all of our majors should stick with this "standard plan". The only students "getting ahead" by doubling-up or skipping should be the super-star straight-A type students that come into UMBC with a bunch of AP credits, etc.
    - The need for this progression is not based on the actual material (ie. the idea behind standard pre-req's), but rather on the mathematical, emotional, and personal maturity needed to tackle E&M. [see square-bracket info above]

  - **Nonetheless, transcripts show that only 7 of 23 students in my class followed the standard progression! The other 16 of 23 took**

courses out of sequence!

- We don't have pre-req's in place, so IF we believe students should follow the standard progression, we need all 15 of our ugrad Academic Advisors "forcing" this issue. But it's really really really hard for advisors to keep these kind of "unwritten rules" in mind. *Should we consider making more pre-req's to enforce the standard progression (with super-stars getting personal exemptions).*
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- The syllabus included the 7 specific Learning Outcomes Objectives (LOO's).

- Grading of the course was based on:
  - 3 regular Exams: These were 55 min, closed-book exams.
  - 10 HW assignments
  - A cumulative Final Exam: This was a 2 hour open-book online exam.

- My assessment of each of the 7 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.

- For my quantitative evaluation, I'm using "C+" performance, or better, as "mastered".

Assessment of the 7 Learning outcomes objectives:

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.*
   a. My assessment based on specific HW and Exam problems: 12 of 23 students (52%) mastered this objective.
   b. My assessment based on participation and discussion: Roughly 50% of the students mastered this objective.

2. *Solve problems in electrostatics that manifest an understanding of the divergence of electrostatic fields, the electric potential, and work and energy in electrostatics.*
   a. My assessment based on specific HW and Exam problems: 12 of 23 students (52%) mastered this objective.
   b. My assessment based on participation and discussion: Roughly 60% of the students mastered this objective.

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.*
    a. My assessment based on specific HW and Exam problems: 12 of 23 students (52%) mastered this objective.
    b. My assessment based on participation and discussion: Roughly 60% of the students mastered this objective.

4. *Understand electric fields in matter, through being able to solve problems involving the field of a polarized object, the electric displacement, and dielectrics.*

    a. My assessment based on specific HW and Exam problems: 12 of 23 students (52%) mastered this objective.
    b. My assessment based on participation and discussion: Roughly 50% of the students mastered this objective.

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*.
    a. My assessment based on specific HW and Exam problems: 12 of 23 students (52%) mastered this objective.
    b. My assessment based on participation and discussion: Roughly 50% of the students mastered this objective.

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.*
    a. My assessment based on specific HW and Exam problems: 12 of 23 students (52%) mastered this objective.
    b. My assessment based on participation and discussion: Roughly 50% of the students mastered this objective.

7. *Demonstrate an understanding of the electromotive force, the electromagnetic induction, and Maxwell's equations.*
    a. I did not leave enough time to adequately present this material. I'm unable to assess. This is my failure.

Fall 2021 PHYS 424 "Introduction to Quantum Mechanics"

Some relevant info for this report:

- This year's class had 26 students. My perception was that, on average, this was a motivated and interested group.
- The final course grade distribution was 8 A's, 7 B's, 6 C's, 4 D's, 1 F.
- 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:

7. *Explain the breakdown of classical mechanics and the development of quantum mechanics.*
   - My assessment based on specific HW and Exam problems: 80% mastered this objective.
   - My assessment based on participation and discussion: Roughly three quarters of the students mastered this objective.

8. *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: 60% mastered this objective.
   - My assessment based on participation and discussion: Roughly three quarters of the students mastered this objective.

9. *Solve the Schrodinger equation for various 1D potentials.*
   - My assessment based on specific HW and Exam problems: 76% mastered this objective.
   - My assessment based on participation and discussion: Roughly 80% of students mastered this objective.

10. *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: 75% mastered this objective.

- My assessment based on participation and discussion: Less than half of the students mastered this objective.

11. *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: (61%) mastered this objective.
    - My assessment based on participation and discussion: Roughly half of the students mastered this objective.

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

Comments, suggestions, and wrap-up notes:

- This class had several groups of students who worked together regularly. This really seemed to power their work. One draw back was that each group had one student that seemed to be using it as a crutch. Overall, this was a very engaged class.
- *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.