Name of Department: Physics and Astronomy
Year: 2015-2016
Name of Preparer: Joe H. Mehaffey

Program Mission Statement

The mission of the Department of Physics and Astronomy is to provide a quality background in the principles of physics and health physics that will result in our graduates being well prepared for careers in industry and scientific research or for graduate school. Additionally, the department supports the University's general education goals by providing all students with an exposure to the fundamental natural laws of the physical universe and to the methods of scientific inquiry.

PROGRAM LEARNING OUTCOMES

The department seeks to produce Computational (CP) and Health Physics (HP) graduates who

1. possess a thorough understanding of the physical principles on which the universe operates.
2. can apply physical principles in solving problems related to the physical world, which includes using computers to model physical systems and processes (CP).
3. are experienced in research activities, including the interpretation and communication of results.
4. possess a thorough understanding of the types, sources, detection, and measurement of ionization radiation, the biological effects of such radiation, and of the methods of reducing human exposure (HP).
5. recognize the importance of intellectual honesty, professional ethics and personal integrity in the pursuit of knowledge and personal goals alike.

Student Learning Outcomes (SLOs)

SLO#1.0: Students in Physics 201, on average, will perform at the 80% level or above when demonstrating knowledge of introductory physics concepts such as acceleration and Newton's Laws.

SLO#2.0: Students in Upper Level Research Physics courses, on average, will perform at the 80% level or above when demonstrating knowledge of advanced physics concepts.

SLO#3.0: Students in Upper Level Research Physics courses, on average, will perform at the 80% level or above [Baseline = 60%] when demonstrating competency in presenting technical information via both oral and written communication

SLO#4.0 Students in Upper Level Research Physics courses, on average, will perform at the 80% level or above [Baseline = 60%] when demonstrating the use modern laboratory techniques.

SLO#5.0 Graduating Physics students will demonstrate an appreciation for physics including its significance and practical relevance at the 70% positive endorsement level or above [Baseline = 60%

The complete master plan for these assessments can be found in Appendix I.

Assessment Methods

SLO#1.0: Students in Physics 201, on average, will perform at the 80% level or above [Baseline =] when demonstrating knowledge of introductory physics concepts such as acceleration and Newton's Laws by *performing at the 80% level or above (baseline =60%) on the Departmental Pretest/Posttest form*.

SLO#2.0: Students in Upper Level Research Physics courses, on average, will perform at the 80% level or above [Baseline = 60%] when demonstrating knowledge of advanced physics concepts as *measured by the Departmental Exit Survey given in the spring semester of the senior year*.

SLO#3.0: Students in Upper Level Research Physics courses, on average, will perform at the 80% level or above [Baseline 60%] when demonstrating competency in presenting technical information via both oral and written communication as *measured by a departmental faculty members using a standard rubric*.

SLO#4.0 Students in Upper Level Research Physics courses, on average, will perform at the 80% level or above [Baseline =60%] when demonstrating the use modern laboratory techniques *as measured by a departmental hands-on assessment in Physical Science 101 Laboratory measuring students' abilities to conduct experiments, identify trends in the data, and draw conclusions supported by the evidence they gathered.*

SLO#5.0 Graduating Physics students will demonstrate an appreciation for physics including its significance and practical relevance at the 70% positive endorsement level or above [Baseline =] *as measured by the Colorado Learning Attitudes About Science Survey (CLASS), which measures students' self-reported beliefs about physics and their physics courses and how closely these beliefs about physics align with experts' beliefs.*

Assessment Results

SLO#1.0: Students in Physics 201, on average, performed at the 68% level or above [Baseline = 60%] when demonstrating knowledge of introductory physics concepts such as acceleration and Newton's Laws. Since our goal was 80%, this target was not achieved.

SLO#2.0: It was projected that for 2015-2016, that students in Upper Level Research Physics courses, on average, would perform at the 80% level or above [Baseline = 60%] when appraising their knowledge of advanced physics concepts as *measured by the Departmental Exit Survey given in the spring semester of the senior year*.

100% of the students in Upper Level Research Physics courses perform at the 80% level or above when appraising their knowledge of advanced physics concepts. Since our goal was 80%, this target was achieved.

SLO#3.0: Students in Upper Level Research Physics courses, on average, performed at the 87% level [Baseline 60%] when demonstrating competency in presenting technical information via both oral and written communication as *measured by a departmental faculty members using a standard rubric*. Since our goal was 80%, this target was achieved.

SLO#4.0 Students in Upper Level Research Physics courses, on average, performed at the 87% level or above [Baseline =60%] when demonstrating the use modern laboratory techniques *as measured by a departmental hands-on assessment in Physical Science 101 Laboratory measuring students' abilities to conduct experiments, identify trends in the data, and draw conclusions supported by the evidence they gathered.* . Since our goal was 80%, this target was achieved.

SLO#5.0 Graduating Physics students demonstrated an appreciation for physics including its significance and practical relevance at the 72.23% positive endorsement level [Baseline = 60%] *as measured by the Colorado Learning Attitudes About Science Survey (CLASS).* Since our goal was 70%, this target was achieved.

Action Items

SLO#1.0: Students in Physics 201, on average, performed at the 68% level or above [Baseline = 60%] when demonstrating knowledge of introductory physics concepts such as acceleration and Newton's Laws. Since our goal was 80%, this target was not achieved.

Since the target was not achieved, the department decided to make changes to bring about improved student achievement. Instructors in these courses have developed activities for their students that match as nearly as possible the real-world tasks Physics and Astronomy professionals in the field. The tasks students are required to undertake are complex, ambiguous, and multifaceted in nature, requiring sustained investigation. The expectation is that this inquiry will draw on the existing talents and experiences of students, building their understanding of course content through participation.

SLO#2.0: It was projected that for 2015-2016, that students in Upper Level Research Physics courses, on average, would perform at the 80% level or above [Baseline = 60%] when demonstrating knowledge of advanced physics concepts as *measured by the Departmental Exit Survey given in the spring semester of the senior year*.

SLO#3.0: Students in Upper Level Research Physics courses, on average, performed at the 87% level [Baseline 60%] when demonstrating competency in presenting technical information via both oral and written communication as *measured by a departmental faculty members using a standard rubric*. Since our goal was 80%, this target was achieved. We will continue to monitor and work to enhance this outcome in 2016-2017.

SLO#4.0 Students in Upper Level Research Physics courses, on average, performed at the 87% level or above [Baseline =60%] when demonstrating the use modern laboratory techniques *as measured by a departmental hands-on assessment in Physical Science 101 Laboratory measuring students' abilities to conduct experiments, identify trends in the data, and draw conclusions supported by the evidence they gathered.* . Since our goal was 80%, this target was achieved. We will continue to monitor and work to enhance this outcome in 2016-2017.

SLO#5.0 Graduating Physics students demonstrated an appreciation for physics including its significance and practical relevance at the 72.23% positive endorsement level [Baseline = 60%] *as measured by the Colorado Learning Attitudes About Science Survey (CLASS).* Since our goal was 70%, this target was achieved. We will continue to monitor and work to enhance this outcome in 2016-2017.

Appendix I

Physics Major: Master Assessment Plan

Student Learning Outcome (knowledge outcome, skills outcome, or attitude outcome)	Description of Assessment (direct or indirect)	Where/When the Assessment will be performed	Plans for subsequent improvement
1. Students will demonstrate knowledge in introductory physics concepts. **(Knowledge outcome)**	Pre/post-test of students, measuring and reporting knowledge gains. **(direct)** Survey of students at end of course. **(indirect)**	Internally developed pre/post in each of PHYS 201 and 202. Multiple choice administered online (pre) and as part of final exam (post) Online survey administered near end of course.	Results will be analyzed and used as a basis for data-driven decisions on improved/new instructional/curricular approaches.
2. Students will demonstrate knowledge in upper-level physics concepts. **(Knowledge outcome)**	Pre/post-test of students, measuring and reporting knowledge gains. **(direct)** Survey of students at end of course. **(indirect)**	Internally developed pre/post-test. Pre-test given at start of PHYS 316 (HP) and PHYS 306 (CP). Post-test given at end of PHYS 418 (HP) and PHYS 406 (CP). Exit survey in Spring of senior year.	Results will be analyzed and used as a basis for data-driven decisions on improved/new instructional/curricular approaches.
3. Students will be able to use modern laboratory techniques to measure and analyze experimental data. **(Skills outcome)**	Instructor assessment of students' laboratory techniques and students' written analysis. **(direct)** Survey of students at end of program. **(indirect)** Survey of alumni 2-5 years post-graduation. **(indirect)**	In PHYS 202, instructors asked to document this direct assessment based on performance in one, instructor-chosen laboratory experiment. Exit survey in Spring of senior year. Alumni survey post-graduation	Results will be analyzed and used as a basis for data-driven decisions on improved/new instructional/curricular approaches.

Student Learning Outcome (knowledge outcome, skills outcome, or attitude outcome)	**Description of Assessment (direct or indirect)**	**Where/When the Assessment will be performed**	**Plans for subsequent improvement**
4. Students will be able to competently present technical information via both oral and written communication. **(Skills outcome)**	Faculty will assess student presentations. **(direct)** Faculty assessment of student review article. **(direct)** Survey of students at end of course. **(indirect)**	PHYS 419 presentations PHYS 419 review articles Exit survey in spring of senior year	Results will be analyzed and used as a basis for data-driven decisions on improved/new instructional/curricular approaches.
5. Students will demonstrate competency in physics-relevant computer skills. **(Skills outcome)**	Instructor assessment of an appropriate assignment in upper-level course. **(direct)** Survey of students at end of program. **(indirect)**	PHYS 417 or 418 (HP) PHYS 306 or 406 (CP) Exit survey in spring of senior year.	Results will be analyzed and used as a basis for data-driven decisions on improved/new instructional/curricular approaches.
6. Students will have an appreciation for physics including its significance and practical relevance. **(Attitude outcome)**	Survey of students at end of program. **(indirect)** Survey of alumni 2-5 years post-graduation. **(indirect)**	Exit survey in spring of senior year. Alumni survey post-graduation.	Results will be analyzed and used as a basis for data-driven decisions on improved/new instructional/curricular approaches.
7. Students will be prepared for a career or further study upon completion of program. **(Attitude outcome?)**	Counting the number of graduates entering a career supported by the physics program. **(direct)** Counting the number of graduates entering graduate school. **(direct)**	Exit survey in spring of senior year. Exit survey in spring of senior year. Alumni survey post-graduation.	Results will be analyzed and used as a basis for data-driven decisions on improved/new instructional/curricular approaches.

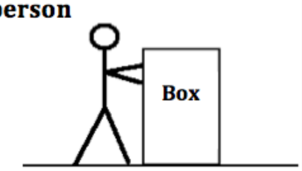
Student Learning Outcome (knowledge outcome, skills outcome, or attitude outcome)	**Description of Assessment (direct or indirect)**	**Where/When the Assessment will be performed**	**Plans for subsequent improvement**
7. (cont.) Students will be prepared for a career or further study upon completion of program. **(Attitude outcome?)**	Counting the number of alumni working in a career supported by the program. **(direct)** Counting the number of alumni in graduate school. **(direct)** Asking graduates to assess their level of preparation for their career/graduate school. **(indirect)** Asking alumni to assess the role the program played in preparing them for their current career/studies. **(indirect)**	Alumni survey post-graduation. Exit survey in spring of senior year. Alumni survey post-graduation.	Results will be analyzed and used as a basis for data-driven decisions on improved/new instructional/curricular approaches.

Appendix II
Test of Introductory Physics Concepts

The three questions below were taken from the final exam for Physics 201 in spring 2016 (questions #1, 4, and 14 from the exam). These questions test the students' understanding of three concepts that are both fundamental to the study and physics and very conceptually difficult. N = 46 students took this exam, and results are provided below each question. The students also answered the same questions in a pretest at the beginning of the semester.

1. Which of the following runners is/are accelerating? (Circle each runner that has non-zero acceleration.)
   A. A runner that starts from rest and speeds up to 15 miles per hour (mph).
   B. A runner that slows down from 15 mph to a stop.
   C. A runner that runs along a straight track at a constant speed of 15 mph.
   D. A runner that runs around a circular track at a constant speed of 15 mph.

Problems 4 – 7 all refer to the figure on the right, which shows a person pushing a large box to the right with a constant velocity.



4. The net force that is being exerted on the box will be…
   A. To the right
   B. To the left
   C. Up
   D. Down
   E. None of the above

14. Someone left a shopping cart sitting on some railroad tracks, and it got hit by a freight train. When the train hit the cart, was the force exerted on the shopping cart bigger, smaller, or the same as the force exerted on the freight train? Briefly explain/justify why your answer is correct and why your answer makes sense.

Appendix III
Computational Physics Institutional Effectiveness Assessment

Please complete the following project in about an hour's time. Please track how much time it takes you to complete this project, from start to finish. Record the time at the top of your submission. Please complete this project on your own, without consulting any outside help from other people, the Internet, textbooks, etc.

Situation: Consider a system of two positive point charges. They are placed initially a distance $\boldsymbol{d}$ apart from each other.
Goal: Find each object's position and velocity, and the system's kinetic and potential energy as a function of time, $\boldsymbol{t}$.
Quantitative Details: - Use $\boldsymbol{d = 10}$ cm for the initial separation. - Pick a value for the charge of each object, using units of $\boldsymbol{\mu}$C (micro-Coulombs), letting each object have a different charge than the other object. - Pick a value for the mass of each object, using units of kg (kilograms), letting each object have a different mass than the other object. - The following value might be useful:

$$\boldsymbol{k_e = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \ \frac{\mathrm{N\ m^2}}{\mathrm{C^2}}}$$

Procedure:

1. Write down the equations of motion for the system, identifying relevant variables of interest.
2. Implement code to solve the equations of motion, so that you know each object's position and velocity, and the system's kinetic and potential energy at any time t.
3. Produce and describe plots for the position and velocity for each object, as well as the system's kinetic and potential energy. (Use whatever time scale turns out to be most interesting/insightful for the problem.)
4. Comment on your code's numerical accuracy. (What have you done to test/verify the numerical accuracy?)
5. Do your results make sense physically?
    1. How are you able to assess whether or not your results are *qualitatively* reasonable
    2. How are you able to assess whether or not your results are *quantitatively* reasonable?

Rubric:

	1 point	3 points	5 points
Physical Equations	Correct equations not identified.	Coulomb force is clearly intended, but “small” errors are present.	Correct Equation for Coulomb force, etc.
Code Implementation	Flaws in implementation	“Small” errors in code. Or a correct implementation of an “inferior” method, e.g., Euler method.	Correct implementation of Euler-Cromer or Runge-Kutta method.
Visualization and Plots	Plots and/or description are poor.	Plots clearly presented and described, but the time scale is not well-chosen.	Plots with well-chosen time scale. Described well in clear physical terms.
Numerical Assessment	Some minimal attempt at numerical assessment.	Some appeal is made to the size of the time-step being “small enough”.	Multiple time-step sizes tested, to see that results converge. May also refer to conservation of energy.
Physical Assessment	Description suggests uncertainty or lack of confidence in results.	Some communication that motion is “reasonable” – particles move in correct directions, etc.	Checks that energy is conserved; particles move in correct directions; possible analytical check on velocity.

Appendix IV

Assessment of General Education courses

As an assessment of the department's general education offerings, the Physical Science 101 Laboratory was used to measure students' abilities to conduct experiments, identify trends in the data and draw conclusions supported by the evidence they gathered. Early in the semester a pre-test was given followed by a post-test at the end of the semester. Students were given questions to answer by experimentation as outlined below. Specifically, the pre-test involved identifying factors affecting the acceleration of a cart rolling down an inclined plane and the post-test used a simple pendulum and its time period in much the same way.

Measureable Outcome	Pre-Test Score	Post-Test Score
Identify all testable variables that might affect desired property (cart's acceleration, pendulum's time period) **Gen Ed goals: #3, #6**	(N=91) 7	(N=65) 7
Design experimental tests to eliminate (rule out) variables that do not affect the desired property. **Gen Ed goals: #5, #6**	7	7
From experimental results, identify trends in the data related to variables that do have a significant effect on the desired property, such as direct or inverse relationships. **Gen Ed goals: #5, #6**	6	8
Demonstrate proficiency in the data collection and analysis process; accurate measurements and computations. **Gen Ed goals: #3, #5, #6**	7	7
Identification and minimization of sources of experimental errors, both random and systematic; computation of *percent difference* or *percent error* where appropriate. **Gen Ed goals: #3, #5, #6**	4	7
Demonstrate ability to draw valid conclusions based on experimental results; recognize strengths and limitations of experimental process. **Gen Ed goals: #3, #6**	7	7
Where appropriate, develop an empirical equation that describes a particular relationship (such as that between the pendulum's length l and its time period T). **Gen Ed goals: #3, #6**	N/A	6

Applicable General Education program goals include:

#3: The ability to use technology to locate, organize, document, present, and analyze information and ideas.

#5: The ability to use fundamental mathematical skills and principles in various applications.

#6: the ability to demonstrate an understanding of the natural world and apply scientific principles to reach conclusions.

Commentary: These results seem to indicate only modest improvements over the semester, the largest measureable gains coming in the category of errors analysis, which is curious. A likely explanation is that the pre-test is conducted much like a typical lab exercise where the students are given much more guidance in the form of a written procedure. This may result in too much 'help' for our purpose here and thus inflates their pre-test scores. Going forward, we plan to let the students design their own procedure, which will almost certainly result in lower but more accurate pre-test scores. We propose, therefore, that the evaluation process itself be improved before any other changes to the curriculum can be suggested.

MASTER PLAN FOR THESE ASSESSMENTS

Three questions representing fundamental concepts were given to 46 students in Physics 201 in a pre-test at the beginning of the semester and again as a post-test at the end of the semester. (See Appendix II for a complete description.) The results are summarized below:

N=46 students	Pre-test % correct answers	Post-test % correct answers
Q. #1 (acceleration)	14%	35%
Q. #2 (Newton's 1st Law)	18%	78%
Q. #3 (Newton's 3rd Law)	42%	91%

Conclusions: Students showed dramatic gains in their understanding of Newton's Laws, but are still struggling with the concept of *acceleration* as a *vector* quantity.

SLO#5 Students will demonstrate competency in physics-relevant computer skills.
(Skills outcome, direct measure)

There were 8 Physics majors that graduated with a concentration in Computational Physics in Spring 2016. Six of the 8 students completed a computational project that was delivered to them electronically at the end of their final exams. The problem description that was sent to the students is provided in Appendix III along with the scoring rubric. These six submissions were separately scored by Drs. Engelhardt & McDonnell.

Tasks being assessed:

1. Write down the equations of motion for the system, identifying relevant variables of interest.
2. Implement code to solve the equations of motion, so that you know each object's position and velocity, and the system's kinetic and potential energy at any timet.
3. Produce and describe plots of the position and velocity for each object as a function of time.

4. Produce and describe a plot of the system's kinetic and potential energy as a function of time.
5. Comment on your code's numerical accuracy.
6. Do your results make sense physically? List every way that you can think of to check whether or not your results are reasonable.

Average scores for the 6 submissions:

1. Physical Equations	4.79 out of 5
2. Code Implementation	4.42 out of 5
3. Visualization and Plots	4.29 out of 5
4. Numerical Assessment	2.46 out of 5
5. Physical Assessment	4.25 out of 5
Total	20.2 out of 25
Percentage	80.8%

Commentary: Overall the six students responding performed very well on this exercise, the lone exception being in the Numerical Assessment category. This category basically involves the size of the 'time step' used, where a potential trade-off is made between job processing time and ultimate accuracy of the model. Though the sample size is rather small (N=8), this might indicate an area of relative weakness within the group.

SLO#2, 3, 5, 7 Students will demonstrate knowledge in upper-level physics courses, be able to use modern laboratory techniques…, y…
(Knowledge outcomes, indirect measures)

The following data was extracted from the Exit Survey given in the spring semester of the senior year.

N=9 students	Very Competent	Fairly Competent	Not very Competent	Not at all Competent
Assess your level of content knowledge in your major	4	5	0	0
Assess your level of competence with regard to computational skills	1	7	1	0
Assess your level of competence with regard to laboratory skills	5	4	0	0
Assess your level of competence with regard to technical writing	4	5	0	0
Assess your level of competence with regard to giving a technical presentation	3	7	0	0
How well do you think that the courses in your major have prepared you for the next steps (life, career, further education) that you will be taking after college?	5	4	0	0

What is your grade point average?	>3.5	3.0-3.5	2.5-3.0	< 2.5
N=9 students	3	4	1	0

Commentary: Clearly the majority of students surveyed indicated that their major program prepared them at least reasonably well in terms of knowledge base and technical competencies. Roughly half of these students indicated plans to attend graduate school within the next year or two. In open-ended questions, the majority of students indicated they felt a very good sense of community, appreciated the relatively small class size, and felt that their professors genuinely cared about students' best interests and well-being. Among student suggestions for improvements in the program were the development of a workshop or class to help students 'learn the ropes' for preparing for graduate school (applications, writing a CV, GRE preparation, etc.) Other suggestions include more course offerings in Astronomy and an increased emphasis on two math courses (linear algebra and numerical analysis) that a student deemed especially helpful.

SLO#4 Students will be able to competently present technical information via both oral and written communication. (Skills outcome, direct measure)

One component of this objective is that the students give presentations on their research projects in Physics 397 (Research in Physics), 419 (Senior Seminar in Physics) and 420 (Senior Research in Physics). The department faculty using the criteria listed below graded these presentations. A total of 22 presentations were given, 13 in the fall semester and 9 in the spring.

Knowledge of the Subject--Does the student understand the topic that is being presented? (50 points)

Clarity of the Presentation--Is the topic explained in a clear and understandable manner so that a scientifically literate person can follow it? (20 points)

Presentation Skills--Does the student articulate the presentation well? Does the presenter avoid the use of "uhm", 'uhh', etc…? Does the presenter simply read from the slides? Does the presenter make good eye contact with the audience? Does the presenter show appropriate enthusiasm for the topic? (20 points)

Use of Visual Aids--Does the presenter use appropriate technology, software, and demonstrations in presenting the topic? (10 points)

Maximum score (100 points)

Results/Commentary: The mean score for the presentations was 87 ± 6.4. Only one of the presentations received a score below 70% (It was 62). These students performed quite well and clearly demonstrated that research is one of their strengths.

SLO#6 Students will have an appreciation for physics including its significance and practical relevance. (Skills outcome, Attitude outcome, indirect measure)

Of the 13 seniors that graduated with a degree in Physics in Spring 2016, nine completed the CLASS and a survey about their experiences at FMU & beyond.

CLASS Description:
The Colorado Learning Attitudes about Science Survey (CLASS) measures students' self-reported beliefs about physics and their physics courses and how closely these beliefs about physics align with experts' beliefs. The surveys ask students questions about how they learn physics, how physics is related to their everyday lives, and how they think about the discipline of physics. The CLASS survey probes student's attitudes and beliefs and distinguishes those of experts from novices. The CLASS was written to make the statements as clear and concise as possible. Students are asked to respond on a Likert-like (5-point agree to disagree) scale to statements such as: "I study physics to learn knowledge that will be useful in life." or "After I study a topic in physics and feel that I

understand it, I have difficulty solving problems on the same topic." or "To learn physics, I only need to memorize important equations and definitions."

Results/commentary: The CLASS results were consistent with the results from Spring 2015, and both sets of seniors (2015 & 2016) scored significantly higher than the Fall 2015 Physics 200 students, which we have identified as the pre-test population.

Seniors, Spring 2015 – Percentage of expert-like responses: 78.1 ± 4.6 (N=8)
Seniors, Spring 2016 – Percentage of expert-like responses: 77.1 ± 2.4 (N=9)
Physics 200, Fall 2015 - Percentage of expert-like responses: 61.5 ± 2.0 (N=65)

Each uncertainty reported above corresponds to 1 standard deviation of the mean.

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Where appropriate, develop an empirical equation that describes a particular relationship (such as that between the pendulum's length l and its time period T). **Gen Ed goals: #3, #6**	N/A	6

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