Institutional Effectiveness Report

Name of Program/Department:	**Programs: Physics, Industrial Engineering, Mechanical Engineering** **Department: Physics and Engineering**
Year:	**2021-2022**
Name of Preparers:	**Larry Engelhardt (Physics), Lorna Contron-Gonzalez (Industrial Engineering), Rahul Renu (Mechanical Engineering)**

Mission Statement

The Department of Physics and Engineering seeks to offer courses in astronomy, engineering, physical science, and physics that are taught by full-time faculty members with appropriate advanced degrees dedicated to science education at the University level. The faculty strive for excellence in instruction, research, and discipline-related service to the community. The courses offered in the department range in level from introductory courses that expose non-science majors to scientific thought to advanced courses that cover contemporary topics in physics and engineering. The laboratory experience is required in appropriate courses to illustrate the importance of experimentation to the scientific endeavor and engineering profession. For the majors in the department, the opportunity to undertake undergraduate research is offered and professional internships are encouraged. Majors graduating from programs in the department are expected to be proficient in oral and written communication, familiar with the scientific and engineering literature, and aware of the importance and usage of technology in science and engineering. Students completing the majors offered by the department will be prepared for careers in industry and scientific research or for graduate school.

Executive Summary

Understanding of introductory physics concepts was assessed in PHYS 201 and PHYS 202. In PHYS 201, all of the benchmarks were met, but students continue to struggle with the assessment in PHYS 202. We developed a new lab activity for PHYS 202 Lab which did improve the results on this assessment, so we will improve upon this new activity for next year. For the last two years, the introduction of individual take-home lab kits for PHYS 202 Lab has resulted in a large improvement on the assessment of experimental skills, so we have expanded this strategy to PHYS 216 Lab which also uses similar equipment.

Upper-level physics students demonstrated – in both direct and indirect assessments – that they were both competent and confident in their technical skills and in their preparation for future endeavors. The Health Physics (HP) majors completed a direct assessment of their HP-specific knowledge. The one Computational Physics (CP) major did not complete the CP-specific assessments that were sent to him, so we are planning to revise the computational activity that is sent out before graduation in order to make it less time consuming for the graduating seniors.

Concerning the Industrial Engineering program, assessment activities follow the ABET guidelines. The program has received ABET accreditation and will continue to be evaluated by ABET. Of the 7 Student Learning Outcomes (SLOs), student performance met 5 of the SLOs. For the two SLOs that did not meet the benchmark, there are plans to better address these topics in the ENGR 101 course.

The Mechanical Engineering (ME) program just began in Spring 2020 and graduated its first cohort is May 2022. The program is on track for evaluation by ABET in Fall 2023. Current ME students were assessed in several courses, and most of the SLOs were met. One of the SLOs was not met likely due to students being unable to anticipate all aspects of teamwork dynamics. Corrective measures include providing students more instruction on team formation and performance dynamics.

For the General Education courses, the students' experimental skills and their interpretation of experimental results was assessed. In 6 of the 7 categories, the students did not meet the benchmark of 70%, but were close to meeting the benchmark (above 60% in each category). In one category, the students did meet the benchmark of 70%. Due to changes that have been made in PSCI 101 Lab, this assessment is no longer well aligned with the activities that take place in lab, so we will be revisiting how the Gen Ed goals are addressed in PSCI 101, and we might modify the PSCI 101 Lab assessment for next year.

Physics (Computational Physics and Health Physics)

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 (Physics)

SLO #1: Students will demonstrate knowledge of introductory physics concepts.
Benchmark performance: Students in Physics 201 will, on average, answer 70% of the post-test questions correctly in each category. (**PLO #1 & #2**)

SLO #2: Students will demonstrate knowledge in upper-level physics concepts.
Benchmark performance: 90% of students will demonstrate gains in post-test scores given at the end of PHYS 418 and PHYS 406 compared to pre-tests administered at the start of PHYS 316 and PHYS 306. (**PLO #1 & #4**)

SLO #3: Students will be able to use modern laboratory techniques to measure and analyze experimental data.
Benchmark performance: 90% of our graduates will indicate on an exit survey that they feel very competent or fairly competent with regard to their laboratory skills. (**PLO #3**)

SLO #4 Students will be able to competently present technical information via both oral and written communication.
Benchmark performance: 90% of the students in Physics 419, and will receive a score greater than 80/100 based on a faculty assessment of their oral presentations. (**PLO #3**)

SLO #5 Students will demonstrate competency in physics-relevant computer skills.
Benchmark performance: 90% of our graduates will indicate on an exit survey that they feel very competent or fairly competent with regard to their computational skills. (**PLO #2**)

SLO #6: Students will have an appreciation for physics including its significance and practical relevance.
Benchmark performance: Greater than 70% of the responses given by our graduates on the Colorado Learning Attitudes About Science Survey will be "expert-like". (**PLO #1**)

SLO #7: Students will be prepared for a career or further study upon completion of the program.
Benchmark performance: 90% of our students will indicate on an exit survey that they feel very competent or fairly competent as to how well they think the program has prepared them for a career or further education after college. (**PLO #5**)

Methods (Physics)

SLO #1 Students will demonstrate knowledge of introductory physics concepts. (Direct)

In PHYS 202, a 6-question pre/post instruction survey was administered. (The survey is included in Appendix A.)

- Baseline post-test scores
  - Fall 2019: 65%, 18%, 26%, 38%, 15%, 94%
  - Fall 2020: 31%, 14%, 24%, 21%, 24%, 66%
- Benchmark & Target: 70% on all six questions of the post-test

In PHYS 201, a 3-question pre/post instruction survey was administered. (The survey is included in Appendix B.)

- Baseline post-test scores
  - Spring 2020: 70%, 25%, 50%
  - Spring 2021: 80.5%, 32%, 61%
- Benchmark & Target: 70% on all 3 questions of the post-test

SLO #2 Students will demonstrate knowledge in upper-level physics concepts. (Direct)

Students choosing to major in Physics choose a concentration in either Health Physics (HP) or Computational Physics (CP), so we separately assess HP and CP students for their upper-level physics knowledge. For HP, an assessment (Appendix C) was administered at the beginning of PHYS 316 as a pre-test and at the end of PHYS 418 as a post-test. For CP, we administered a assessment that covers the content of all of the upper-level CP courses (Appendix D).

- Baseline post-test scores and gains for HP
  - Spring 2020: The average post-test score was 68%. No pre-test results were available because the assessment was new that year.
  - Spring 2021: All students showed pre/post gains. The average post-test score was 63%, and the average pre-test score was 50%, for an average normalized learning gain of 26%.
- Baseline post-test scores and gains for CP:
  - Spring 2020: Not assessed.
  - Spring 2021: The average post-test score was 82%. No pre-test results were available because the assessment was new that year.
- Benchmark & Target: 90% of students will demonstrate gains in the post-test scores as compared to pre-test.

SLO #3 Students will be able to use modern laboratory techniques to measure and analyze experimental data. (Both Indirect & Direct)

Indirect: An exit survey (Appendix E) was completed by the three physics majors who graduated this year.

- Baseline:
  - Spring 2020: All students indicated that they felt either very competent (80%) or fairly competent (20%) in their acquired laboratory skills.
  - Spring 2021: All students indicated that they felt very competent in their acquired laboratory skills.

- Benchmark & Target: 90% of graduates will indicate that they feel either very competent or fairly competent with regard to their laboratory skills.

Direct: The ability of students to connect an electric circuit containing resistors in parallel was measured in the PHYS 202 Laboratory. The assessment (Appendix F) consists of two parts: Part 1) constructing the parallel circuit without a meter, and Part 2) constructing the same circuit but with a meter properly inserted to measure current.

- Baseline:
  - Fall 2019: 22% of students completed the assessment correctly.
  - Fall 2020: 70% of students completed the assessment correctly.
- Benchmark & Target: 70% of students will complete the assessment correctly.

SLO #4 Students will be able to competently present technical information via both oral and written communication. (Both Direct & Indirect)

Direct: In PHYS 419, students completed a scientific literature review and presented their findings in an oral presentation. (Appendix G includes the rubric used for assessing the oral presentations.) The oral presentations were assessed by multiple faculty using a common rubric (Appendix G).

- Baseline:
  - Fall 2019: 91% of the students (10 out of 11) scored better than 80% on their oral presentations.
  - Fall 2020: 88% of the students (7 out of 8) scored better than 80% on their oral presentations.
- Benchmark & Target: 90% of the students in Physics 419, and will receive a score greater than 80/100 based on a faculty assessment of their oral presentations.

Indirect: In an exit survey (Appendix E) that was completed by the three physics majors who graduated this year, students assessed their level of competence in both (a) giving presentations of scientific/technical work, and (b) technical writing.

- Baseline:
  - Spring 2020: 100% of the respondents indicated that they felt either very competent (60%) or fairly competent (40%) in giving presentations of scientific/technical work; and 100% of the respondents indicated that they felt either very competent (60%) or fairly competent (40%) in technical writing.
  - Spring 2021: 100% of the respondents indicated that they felt either very competent (25%) or fairly competent (75%) in giving presentations of scientific/technical work; and 100% of the respondents indicated that they felt either very competent (50%) or fairly competent (50%) in technical writing.
- Benchmark & Target: 90% of graduates will indicate that they feel either very competent or fairly competent with regard to their laboratory skills.

SLO #5 Students will demonstrate competency in physics-relevant computer skills. (Both Indirect & Direct)

Indirect: In an exit survey (Appendix E), that was completed by the three physics majors who graduated this year, students assessed their level of competence with regard to their computational skills.

- Baseline:
  - Spring 2020: 80% of the respondents indicated that they felt either very competent (20%) or fairly competent (60%) with regard to their computational skills.
  - Spring 2021: 100% of the respondents indicated that they felt either very competent (75%) or fairly competent (25%) with regard to their computational skills.
- Benchmark & Target: 90% of graduates will indicate that they feel either very competent or fairly competent with regard to their computational skills.

Direct: One Physics majors graduated with a concentration in Computational Physics, but he did not complete the computational project (Appendix H) that was delivered to him electronically at the end of their final exams. Typically, submissions have been separately scored by two faculty.

- Baseline:
  - Spring 2019: Average score was 47%.
  - Spring 2020: Not delivered.
  - Spring 2021: Average score was 69%.
- Benchmark & Target: Students will achieve an average score of 70%.

SLO #6: Students will have an appreciation for physics including its significance and practical relevance. (Indirect)

The Colorado Learning Attitudes About Science Survey (CLASS) was completed by the three physics majors who graduated this year. (www.colorado.edu/sei/class), and the percentage of 'expert-like' responses was recorded.

- Baseline:
  - Spring 2020: 78% of responses were expert-like.
  - Spring 2021: 76% of responses were expert-like.
- Benchmark & Target: Greater than 70% of the responses will be expert-like.

SLO #7 Students will be prepared for a career or further study upon completion of the program. (Indirect)

In an exit survey (Appendix E), that was completed by the three physics majors who graduated this year, students assessed their level of preparation for a career or future studies.

- Baseline:
  - Spring 2020: 80% (4 out of 5 students) indicated that they felt very well prepared for future studies or for future employment, and 20% (1 student) felt not very well prepared.
  - Spring 2021: 100% of the respondents indicated that they felt either very well prepared for a career or future studies (75%) or fairly well prepared (25%).
- Benchmark & Target: 90% of graduates will indicate that they feel either very well prepared or fairly well prepared for future studies or for future employment.

Results (Physics)

SLO #1 Students will demonstrate knowledge of introductory physics concepts. (Direct)

PHYS 201 Results: In Spring 2022, N = 40 students took the pre-test, and N = 26 students took the post-test. (Appendix B) On all three questions, students showed significant pre/post gains, improved over the baseline, and met the benchmark of 70%. On all three questions, students also improved from their baseline results. For Question 1 (understanding acceleration), the number of students who correctly indicated that acceleration includes both speeding up *and* slowing down increased from 33% (pre) to 92% (post). For Question 2 (understanding Newton's 1st Law), the number of correct responses increased from 15% (pre) to 96% (post). For Question 3, the number of students who were able to correctly apply Newton's 3rd Law increased from 25% (pre) to 85% (post).

PHYS 202 Results: In Fall 2021, N=36 students took the pre-test, and N=37 students took the post-test. (Appendix A) The pre-test averages for each of the six questions were 31%, 11%, 19%, 8%, 22%, 50%; and the post-test averages for each of the six questions were 65%, 43%, 22%, 68%, 35%, 89%. For 5 of the 6 questions (all but #3) there was both a significant pre/post gain and a significant improvement over the baseline results. However, for 5 of the 6 questions (all but #6), the scores did not meet the 70% benchmark. These results are discussed in the "Action Items" on Page 10.

SLO #2 Students will demonstrate knowledge in upper-level physics concepts. (Direct)

Health Physics Assessment (Appendix C): Two students took the pre-test, and the same two students took the post-test. The average score on the pre-test was 37%, and the average score on the post-test was 61%, with both students showing pre/post gains.

For Computational Physics, we administer an assessment that covers the content of all of the upper-level CP courses (Appendix D). There was one Computational Physics graduate this year, but he did not complete the assessment.

The two students who took the assessment did show pre/post gains, which did meet out benchmark for this SLO, that 90% of students will demonstrate gains in the post-test scores as compared to pre-test.

SLO #3 Students will be able to use modern laboratory techniques to measure and analyze experimental data. (Both Indirect & Direct)

Indirect: All three students indicated that they felt very competent in their acquired laboratory skills, which did meet the benchmark for this SLO.

Direct: N=32 students completed the assessment in PHYS 202 Lab. All 32 students completed Part 1 correctly, and 25 students (78%) completed Part 2 correctly. This result is an improvement over the baseline, and it meets the benchmark of 70%.

SLO #4 Students will be able to competently present technical information via both oral and written communication. (Both Direct & Indirect)

Direct: There were N = 9 students who completed the assessment in PHYS 419 (Appendix G). They received an average score of 84% on their oral presentations. 67% of the students (6 out of 9) scored better than 80% on their oral presentations, which is below our benchmark that 90% of the students will receive a score greater than 80% based on a faculty assessment of their oral presentations; but the three students who didn't score 80% were not far below this threshold (with scores of 73%, 74%, and 75%).

Indirect: In an exit survey (Appendix E) that was completed by the three physics majors who graduated this year, 100% of the respondents indicated that they felt either very competent (67%) or fairly competent (33%) in giving presentations of scientific/technical work; and 100% of the respondents indicated that they felt either very competent (67%) or fairly competent (33%) in technical writing. This did meet our benchmark of 90% of graduates feeling at least fairly competent in these skills. These results are similar to our baseline from last year.

SLO #5 Students will demonstrate competency in physics-relevant computer skills. (Both Indirect & Direct)

Indirect: In an exit survey (Appendix E), that was completed by the three physics majors who graduated this year, 100% of the respondents indicated that they felt either very competent (67%) or fairly competent (33%) with regard to their computational skills. This did meet our benchmark of 90% of graduates feeling at least fairly competent in these skills.

Direct: One Physics major graduated with a concentration in Computational this year, but he did not complete the computational project (Appendix H) that was delivered electronically at the end of their final exams. This assessment is discussed in the "Action Items" on page 10.

SLO #6: Students will have an appreciation for physics including its significance and practical relevance. (Indirect)

The Colorado Learning Attitudes About Science Survey (CLASS) was completed by the three physics majors who graduated this year (www.colorado.edu/sei/class), and the percentage of 'expert-like' responses was 88% which did meet the benchmark for this assessment of 70%. This result exceeded the baseline of 76% from last year. For reference, this assessment was also administered in Physics 200 (to N=50 underclass students) who had 50% 'expert-like' responses.

SLO #7 Students will be prepared for a career or further study upon completion of the program. (Indirect)

In the exit survey (Appendix E), that was completed by the three physics majors who graduated this year, 100% of the respondents indicated that they felt very well prepared for a career or future studies. This did meet our benchmark of 90% of students feeling at least fairly well prepared.

Action Items (Physics)

SLO #1: Students will demonstrate knowledge of introductory physics concepts

This was assessed in both PHYS 201 and PHYS 202. In PHYS 202, students have struggled to meet the benchmark on this assessment for several years. Several of the questions on the assessment (Questions 1, 2, and 4 of Appendix A) deal with the dynamics of charged particles, so we developed a new lab activity for PHYS 202 Lab titled "Electric and Magnetic Field Charge Dynamics" which was implemented for the first time in Fall 2021. As a result, we saw significant improvement over their baseline scores on Questions 1, 2, and 4; and the benchmark was almost achieved for Questions 1 and 4 (65% and 68%). We will attempt to make improvements to this lab activity for Fall 2022 to further improve the performance on these questions. For Questions 3 (electrical current) and 5 (charge distribution), we will explore the possibility of adjusting the assessment to more precisely identify the source of student confusion. (For Question 3 especially, several concepts are packed into a single question, making it difficult to know what part is causing the students' difficulty.)

SLO #4 Students will be able to competently present technical information via both oral and written communication.

In PHYS 419, this benchmark was not met, although the students were all close to the benchmark. We have revised the course description for PHYS 419 for Fall 2022 from specifying that the students "will prepare a formal scientific review article on a physics topic" to now stating that the students "will pick a topic that is relevant to their future plans and will produce both a written report and an oral presentation". We hope that this will help to improve the students' level of commitment to their report and presentation.

SLO #5 Students will demonstrate competency in physics-relevant computer skills.

We have had difficulty getting students to complete, and do well on, the computational project (Appendix H) that is distributed before graduation. To help with this, we are going to consider adjusting this assessment to make it less time-consuming, in order to help make sure that it gets completed.

General Action Items:

Within the department, we are discussing our desires for future outcomes to decide whether or not we want to identify new Targets that differ from the Benchmarks. We are also discussing PLO #5 – for students to "recognize the importance of intellectual honesty, professional ethics, and personal integrity in the pursuit of knowledge and personal goals alike" – which is not well aligned with the SLOs that we assess.

Industrial Engineering Program

Program Learning Outcomes (PLOs)

The Program Learning Outcomes for the Industrial Engineering (IE) program at FMU have been developed as a representation of acknowledged and anticipated needs of the program's constituents. Internally, they are referred to as Program Educational Objectives (PEOs), as to follow the Accreditation Board for Engineering and Technology (ABET). These learning outcomes also represent and support the educational mission of Francis Marion University, the Department of Physics and Engineering, and the IE Program. These objectives are statements of expected accomplishments of Industrial Engineering graduates within 3-5 years of graduation:

a. Obtain an advanced degree (e.g., MS, MBA, PhD) at an accredited institution.
b. Spearhead/lead a corporate project or research initiative (e.g., Six Sigma, facility acquisition/location).
c. Organize or significantly support structured community outreach/education efforts and activities.
d. Acquire skills/knowledge through certification in areas not on the IE degree plan.

With an emphasis on development and retention of local talent (e.g., Pee Dee Region), the PEOs emphasize career responsibility and advancement, dedication to life-long learning, and a desire to support and develop the social and community structures where program graduates reside. Repeatedly, these three areas (pursuit of career opportunities, life-long learning, and community service) became the focal point of conversation with program constituents when discussing their ideal FMU IE graduates.

Student Learning Outcomes (SLOs)

The Industrial Engineering program follows the expected outcomes from the Accreditation Board for Engineering and Technology (ABET) for student assessment. These seven outcomes are a modification of previous ABET outcomes and were implemented in the Industrial Engineering curriculum in the Fall of 2019. In addition, the outcomes support the program educational objectives and represent expected student capabilities upon graduation.

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

The Student Outcomes are intended to enable students to achieve the program's PEOs within 3-5 years of completion of the BSIE degree. As illustrated in Table 1, each student outcome supports at least two PEOs.

Table 1. Mapping of Relationship Between Student Outcomes and Program Educational Objectives

			Student Outcomes							
			1	2	3	4	5	6	7	Total
Program Educational Objectives (PEOs)	Obtain Advanced Degree from Accredited Institution	a	X					X	X	**3**
	Lead Industrial Project/ Research	b	X	X	X	X	X	X		**6**
	Organize or Engage in Community Outreach Efforts	c		X	X	X	X			**4**
	Acquire skills/knowledge through certification in areas not in the ME curriculum	d			X	X		X	X	**4**

When interpreting the importance of student outcomes in achieving PEOs, it is helpful to consider how the absence of a given, mapped, outcome may influence attainment of the corresponding PEO. As an example, students unable to demonstrate proficiency in student outcome a) 'an ability to apply knowledge of mathematics, science, and engineering' would almost certainly be unable to obtain an advanced degree (Masters, PhD, MBA) and would likely be deemed unfit to spearhead/lead a major corporate initiative (these two PEOs require proficiency and skill in math, science and engineering). This same student, however, would certainly be able to organize community activities and acquire certifications (many non-technical certification opportunities exist for motivated individuals to pursue). In this way, the PEOs are intrinsically supported by those indicated student outcomes, which are deemed essential to PEO attainment.

Assessment Methods (Industrial Engineering)

The Industrial Engineering program evaluates student performance using the eleven outcomes required by the Accreditation Board for Engineering and Technology (ABET). These outcomes are measured at least twice throughout the academic year in more than one course. In addition, all specific outcomes for each course are measured twice during the same semester (Start of Semester and End of Semester). Table 2 illustrates the framework used for evaluating student performance, including the mapping of all Student Outcomes to engineering courses (ENGR) and the illustration of measurement through the four-year curriculum of the program.

Table 2. Map of Student Outcomes Assessment for Industrial Engineering Curriculum

ABET Student Outcome Platform for FMU Industrial Engineering
Reduction/Sampling of Assessment of Student Outcomes (2019)

			ABET Student Outcomes							
Semester/year	Course	Title	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***Total***
Sp1	101	Intro to Engineering			**x**	**x**	**x**			3
Sp1	201	Engineering Graphics		**x**					**x**	2
Sp2	220	Materials Engineering		**x**						1
Fa2	301	Engineering Mechanics	**x**			**x**				2
Sp2	355	Production/Operations Mgmt						**x**		1
Fa3	310	Electronics								0
Fa3	320	Statistics for Engineers			**x**			**x**		2
Sp3	330	Engineering Economy				**x**				1
Fa3	350	Manufacturing Processes					**x**	**x**	**x**	3
Sp4	356	Quality Control						**x**		1
Sp3	373	Operations Research	**x**		**x**					2
Fa4	420	Human Factors		**x**		**x**	**x**			3
Fa4	467	Supply Chain	**x**							1
Fa4	468	Production Planning								0
Sp4	470	Facility Design		**x**						1
Sp4	480	Senior Design	**x**	**x**	**x**	**x**	**x**	**x**	**x**	7
Varies	397	Research in IE								0
Varies	497	Special Topics								0
		Total	4	5	4	5	4	5	3	

Instructors can evaluate students by either assigning specific work that assesses these outcomes or by selecting work or portions of work that are required for course credit(s). Each work evaluation is graded using a qualitative scale of: *excellent, acceptable, or unacceptable.* The measure used to evaluate student performance is the *percentage of students who perform equal or better than "acceptable" by the end the semester at the end of each course*. The target for this measure is **70%**. Note that the term "end of semester" is used in the assessment, which has been defined as assessments that take place during the last two full weeks of classes or during the final exams.

Assessment Results for 2021-2022 (Industrial Engineering)

The summary of the data gathered for the academic year 2021-2022 is shown in Figure 1. As the figure depicts, outcomes 4 and 5 resulted below the target measure of 70%. This is the first time in the last three years that outcomes have been below the benchmark measure.

As a continuous improvement method, the faculty of the program met to evaluate the results of the student outcomes assessment and the student outcomes assessment map previously shown in Table 2. The faculty agreed that the outcome assessment will remain as mapped and will be evaluated again in 2023. However, each outcome was discussed to find proper actions needed to improve those outcomes for the upcoming academic years. Those actions are discussed in the next section.

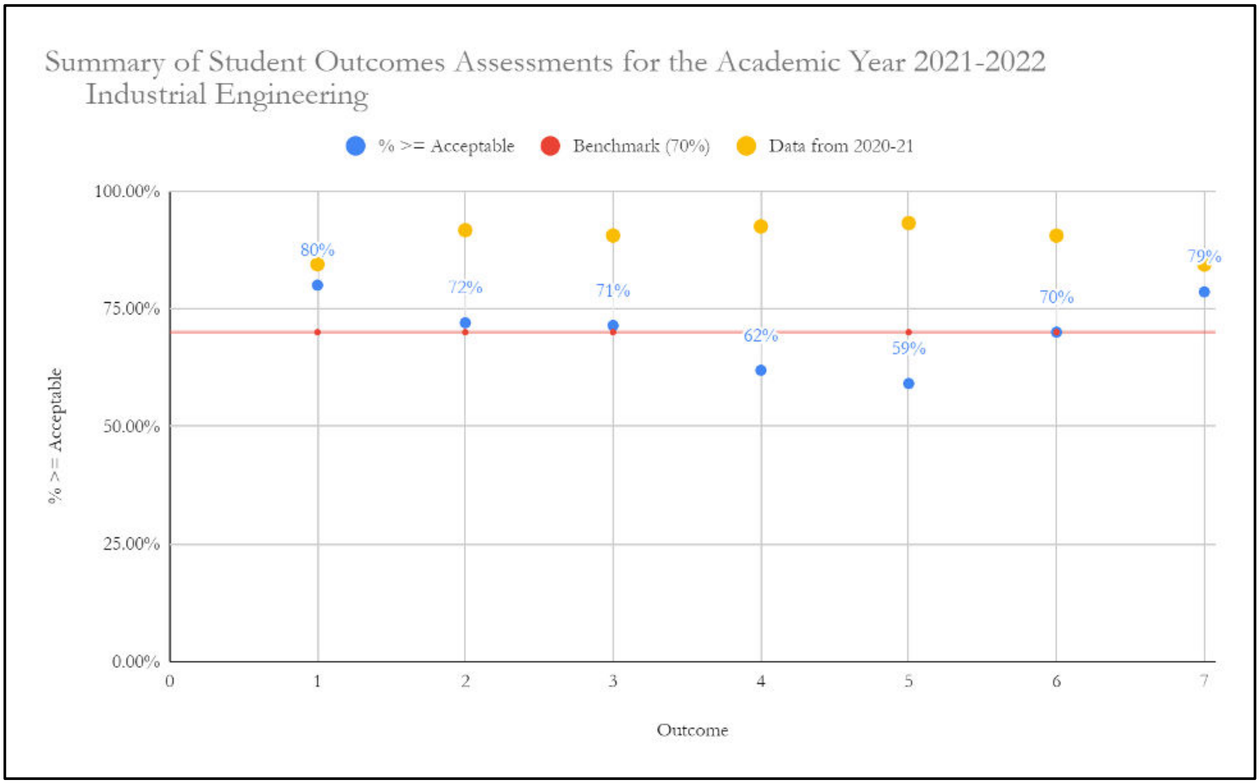


Figure 1. Summary of Student Outcomes Assessments by Outcome with Benchmark (70%) and compared to 2020-2021 Academic Year

Table 3 provides a detailed view of the results by outcome but specifying the courses in which they were measured. This table allows faculty to plan for any actions needed on those courses in which the number of students performing at the "unacceptable" level seems to be significant. In addition, the data still reflects some of the negative effects from the COVID-19 pandemic. Actions that may be taken for those courses in which outcomes.

Table 3. Summary of Student Outcomes Assessment by Course for Academic Year 2021-2022

Semester	Course	Outcomes Measured	Excellent	Acceptable	Unacceptable	% >= Acceptable
Fall	*ENGR301*	1	0	3	1	**75%**
		4	0	2	2	**50%**
	ENGR320	3	0	2	1	**67%**
		6				
	ENGR350	5	3	2	1	**83%**
		6	2	1	4	**43%**
		7	2	3	0	**100%**
	ENGR420	2	1	1	0	**100%**
		4	1	1	0	**100%**
		5	0	0	2	**0%**
	ENGR467	1	0	3	0	**100%**
Spring	*ENGR101*	3	1	6	3	**70%**
		4	3	2	4	**56%**
		5	3	1	6	**40%**
	ENGR201	2	2	3	5	**50%**
		7	1	3	1	**80%**
	ENGR220	2	1	3	1	**80%**
	ENGR330	4	1	1	0	**100%**
	ENGR252	6	0	3	2	**60%**
	ENGR356	6	0	4	0	**100%**
	ENGR373	1	3	1	0	**100%**
		3	4	0	0	**100%**
	ENGR470	2	1	2	1	**75%**
	ENGR480	1	0	2	2	**50%**
		2	2	2	0	**100%**
		3	0	2	2	**50%**
		4	0	2	2	**50%**
		5	0	4	0	**100%**
		6	0	4	0	**100%**
		7	0	2	2	**50%**

Action Items (Industrial Engineering)

Actions from 2020-2021 assessments:

From last year's assessment, several outcomes were below the target level in a few courses. The following lists implementations made to improve those outcomes:

- ENGR101 - Outcome 4
  - Both instructors included a complete module on engineering ethics, the National Society of Professional Engineers (NSPE). Instructors also held team discussions and in-class activities to improve student's understanding of the engineering ethics and etiquette.
- ENGR 201 - Outcome 7
  - The new instructor of the course used an assignment about layers in AutoCad where students had to figure out how to use this feature.

Opportunities and resolutions from 2021-2022 assessment results:

- In the course ENGR 101, Outcome 4 was significantly below the benchmark, at 56%. After discussion, faculty concluded that it may be overwhelming for first-year students to understand and digest the code of ethics and that faculty members need to be reasonable with expectations.
  - Resolution: Find case studies that are clearly relevant to a smaller set of codes from the code of ethics.
- In the course ENGR 101, Outcome 5 was also well below the target, at 40%. Faculty agreed that students will need more guidance to understand expectations in the course.
  - Resolution: Rather than changing the assessment method, faculty agreed that they need to make clear expectations in class using clear guidelines, rubrics, and metrics that will help students understand what is expected from them.
- In the course ENGR 201, Outcome 2 resulted in 50% for the IE students, which is also below the target. After discussion, it seems like communication among teammates should have been addressed and that this outcome was difficult to assess with the final class project.
  - Resolution: Providing a template may help alleviate and improve the assessment.
- In ENGR 252, Outcome 6 was below the target, at 60%. After discussion, faculty thought that the delivery method of the assessment (online) may have affected this assessment.
  - Resolution: The measure itself will not change, but delivery of the assessment will change (online to in-person).
- In the course ENGR 301, Outcome 4 resulted in 50%, which is below the target. After discussion, it seems like this was clear underperformance from the IE students, failing to correctly apply concepts to conduct analysis and solve problems. It also seemed like the assessment used included engineering ethics, as well.
  - Resolution: No changes to assessment will be implemented. Instructor suggests strengthening ethics instruction from 101.

- In the course ENGR 320, Outcomes 3 and 6 were close, but still under the target, at 67%. It seemed to the faculty that this was due to poor performance from the IE students when answering open-ended questions about inference from data.
    - Resolution: Method of assessment may not change, but instructor will change in Fall 2022. Therefore, this will be discussed with the next instructor and the faculty will evaluate in 2023.
- In the course ENGR 350, Outcome 6 was just at 43%, way below the 70% target. It seemed like overall, students missed the mark on the given design assignment and working in teams. Peer reviews were used for assessment.
    - Resolution: Similar assessments will be used in the future. Strengthen and emphasize the importance of teamwork.
- In the ENGR 420, Outcome 5 had 0%. There were only two students enrolled in this course, which severely affected the outcome measured. The assessment method used was a special class project, which the students failed to complete successfully.
    - Resolution: Method of assessment will most likely go back to In-Class Laboratory activities.
- In the Senior Design course, ENGR 480, Outcomes 1, 3, 4, 7 were all 50%, below the 70% target. After discussion, faculty agreed that the main reason for these results was the underperforming senior cohort.
    - Taking these outcomes together, resolutions include:
        - encouragement and reassurance about their ability to carry senior design projects on their own
        - Emphasis on identification of relevant data and performance measures.
        - Emphasis on the importance of documenting the reasoning and importance of all the recommendations they suggest.
        - Emphasis and encouragement to think outside the box and become clear leaders of the project.
- Results by outcome
    - Outcomes 4 and 5 under the 70% Benchmark
        - Resolution:
            - By addressing the outcomes by course (above) we foresee an improvement in individual courses, which will also improve the results by outcome.
            - Overall, the IE cohorts are smaller than ever. As the sample size decreases, the data for student outcomes becomes limited and less representative of the strengths of the program.

Mechanical Engineering Program

Program Learning Outcomes (PLOs)

FMU's Mechanical Engineering (ME) program, which began in Spring 2020, has PLOs that have been developed as Program Educational Objectives (PEOs). These were developed as a representation of acknowledged and anticipated constituency needs and also serve to support the educational mission of Francis Marion University and the ME program. These objectives are statements of expected accomplishments of Mechanical Engineering graduates within 3-5 years of graduation.

In March 2022 at the FMU ME Advisory Board Annual Meeting, board members reviewed the PEOs and provided feedback. In addition, feedback from an external Accreditation Board for Engineering and Technology (ABET) accreditation consultant (Dr. Al Ferri) also provided feedback. FMU faculty reviewed the feedback and updated PEOs as follows. In particular, PEO #1 has been revised to more accurately represent goals for ME program's students. This process (of receiving and incorporating feedback from the relevant stakeholders) follows the program's continuous improvement plans.

1. **Become an ethically-sound engineer who is gainfully employed in an engineering-related field.**
2. **Employ technical communication, leadership, and teamwork skills to lead projects.**
3. **Pursue further education and/or training (graduate studies, professional engineering licensures, certification etc.)**
4. **Serve the community by engaging in outreach activities, which includes non-profit organizations such as universities, charities, and local governments.**

With an emphasis on development and retention of local talent (e.g., Pee Dee Region), the PEOs emphasize career responsibility and advancement, dedication to life-long learning, and a desire to support and develop the social and community structures where program graduates reside. These three areas (pursuit of career opportunities, life-long learning, and community service) are the focal point of conversation with program constituents when discussing their ideal FMU ME graduates.

Student Learning Outcomes (SLOs)

The Mechanical Engineering program assesses students on the following seven outcomes, following the expected outcomes from the Accreditation Board for Engineering and Technology (ABET) [https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/#GC3]. These outcomes represent expected student capabilities upon graduation.

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

These SLOs relate to PLOs as described in **Table 4**.

Table 4: SLO to PLO Mapping for Mechanical Engineering

		Student Learning Outcomes						
		1	2	3	4	5	6	7
Program Learning Objectives	Become an ethically-sound engineer	X		X	X		X	X
	Lead projects		X	X	X	X		
	Further education	X				X	X	X
	Community service		X	X		X		

Assessment Methods (Mechanical Engineering)

The ME program evaluates student performance using the seven outcomes from the Accreditation Board for Engineering and Technology (ABET). These outcomes are measured at the end of each semester, at least. In this academic year, the Mechanical Engineering program faculty conducted only ***direct assessments.*** Data from these assessments are used to identify opportunities to improve the curriculum as well as individual course content. Instructors can evaluate students by either assigning specific work for accreditation or by selecting work or portions of work that are required for course credit(s). Each work evaluation is graded using a qualitative scale of: ***excellent, acceptable, or unacceptable***. The measure used to evaluate student performance is the percentage of students who perform equal or better than "acceptable" by the end of each course.

Baseline, Benchmarks, and Targets: The benchmark and target is 70%. **Table 5** provides information regarding previous year's data which serves as a baseline. **Table 6** illustrates the mapping of all Student Outcomes to mechanical engineering courses.

Table 5: Baseline for each SLO

SLOs	2020-2021 Baseline
1	90%
2	80%
3	83%
4	80%
5	100%
6	83%
7	69%

Table 6: ABET Student Outcome Platform for FMU Mechanical Engineering

			ABET Student Outcomes							
Semester/Year	**Course**	**Title**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Sp1	101	Intro to Engineering			x	x	x			**3**
Sp1	201	Engineering Graphics		x					x	**2**
Sp2	220	Materials Eng.		x						**1**
Fa2	301	Engineering Mechanics	x			x				**2**
Sp2	250	Mechanics of Materials	x	x					x	**3**
Fa3	310	Electronics								**0**
Fa3	320	Statistics			x			x		**2**
Sp3	330	Engineering Economy				x				**1**
Fa3	350	Manufacturing Processes					x	x	x	**3**
Sp3	370	Fluid Mechanics	x			x				**2**
Sp4	402	Sys. Dynamics and Controls		x						**1**
Fa4	400	Thermo and HMT			x		x	x		**3**
Fa4	401	Design of Mechanisms	x	x					x	**3**
Fa4	468	Production Planning								**0**
Sp4	411	Design for Manf. & Assembly		x		x			x	**3**
Sp4	480	ME Senior Design	x	x	x	x	x	x	x	**7**
Varies	397	Research in IE								**0**
Varies	497	Special Topics								**0**
		Total	**5**	**7**	**4**	**6**	**4**	**4**	**6**	

Assessment Results (Mechanical Engineering)
FMU's Mechanical Engineering curriculum shares the following courses with its Industrial Engineering curriculum: ENGR101 (Introduction to Engineering), ENGR201 (Engineering Graphics), ENGR220 (Materials Engineering), ENGR301 (Engineering Mechanics), ENGR310 (Electronics), ENGR320 (Statistics for Engineers), ENGR330 (Engineering Economy), ENGR350 (Manufacturing Processes), and ENGR468 (Production Planning).
While assessing Student Outcomes in the above-mentioned shared courses, data was gathered that would help instructors differentiate ME students' responses from those of IE students. The assessment results presented below are based on the responses from ME students alone, and therefore represent assessment results of the ME program only.

Table 7: Summary of End of Semester Student Outcomes for Academic Year 2021-2022 (by Course) – Mechanical Engineering

Fall 2021				
	SLO	**% "Excellent"**	**% "Acceptable"**	**% "Unacceptable"**
ENGR301	Outcome 1	15%	65%	20%
	Outcome 4	15%	60%	25%
ENGR320	Outcome 3	0%	57%	43%
	Outcome 6	0%	71%	29%
ENGR350	Outcome 5	0%	57%	43%
	Outcome 6	14%	57%	29%
	Outcome 7	40%	40%	20%
ENGR401	Outcome 1	0%	43%	57%
	Outcome 2	0%	100%	0%
	Outcome 7	0%	0%	100%
ENGR411	Outcome 2	50%	33%	17%
	Outcome 4	50%	33%	17%
	Outcome 7	33%	67%	0%

		% "Excellent"	**% "Acceptable"**	**% "Unacceptable"**
ENGR101	Outcome 3	26%	46%	29%
	Outcome 4	19%	44%	38%
	Outcome 5	34%	26%	40%
ENGR201	Outcome 2	15%	44%	41%
	Outcome 7	25%	50%	25%
ENGR220	Outcome 2	30%	60%	10%
ENGR250	Outcome 1	13%	69%	19%
	Outcome 2	13%	63%	25%
	Outcome 7	19%	69%	13%
ENGR330	Outcome 4	25%	50%	25%
ENGR370	Outcome 1	33%	67%	0%
	Outcome 4	33%	33%	33%
ENGR400	Outcome 3	33%	33%	33%
	Outcome 5	33%	50%	17%
	Outcome 6	17%	83%	0%

ENGR402	Outcome 2	0%	100%	0%
ENGR482	Outcome 1	50%	33%	17%
	Outcome 2	50%	50%	0%
	Outcome 3	0%	100%	0%
	Outcome 4	100%	0%	0%
	Outcome 5	33%	67%	0%
	Outcome 6	50%	17%	33%
	Outcome 7	50%	33%	17%

Table 8: Summary of SLOs for Academic Year 2021-2022 (by Outcomes) – Mechanical Engineering

	% "Excellent"	% "Acceptable"	%"Unacceptable"
Outcome 1	17%	60%	23%
Outcome 2	20%	57%	23%
Outcome 3	20%	52%	28%
Outcome 4	28%	44%	28%
Outcome 5	30%	37%	33%
Outcome 6	19%	63%	19%
Outcome 7	25%	49%	26%

Action Items (Mechanical Engineering)

Table 7 shows assessment results for the ME program by course, and

		% “Excellent”	% “Acceptable”	% “Unacceptable”
ENGR101	Outcome 3	26%	46%	29%
	Outcome 4	19%	44%	38%
	Outcome 5	34%	26%	40%
ENGR201	Outcome 2	15%	44%	41%
	Outcome 7	25%	50%	25%
ENGR220	Outcome 2	30%	60%	10%
ENGR250	Outcome 1	13%	69%	19%
	Outcome 2	13%	63%	25%
	Outcome 7	19%	69%	13%
ENGR330	Outcome 4	25%	50%	25%
ENGR370	Outcome 1	33%	67%	0%
	Outcome 4	33%	33%	33%
ENGR400	Outcome 3	33%	33%	33%
	Outcome 5	33%	50%	17%
	Outcome 6	17%	83%	0%
ENGR402	Outcome 2	0%	100%	0%
ENGR482	Outcome 1	50%	33%	17%
	Outcome 2	50%	50%	0%
	Outcome 3	0%	100%	0%
	Outcome 4	100%	0%	0%
	Outcome 5	33%	67%	0%
	Outcome 6	50%	17%	33%
	Outcome 7	50%	33%	17%

Table 8 shows assessment results from the ME program by outcome. For courses that did not meet the 70% target threshold, the following observations were noted and discussed by the FMU engineering faculty on May 5, 2022. It must be noted program-specific inferences may be difficult to make from outcome data from early engineering courses (first three semesters), where students still have the opportunity to change program declaration. Many students in the first three semesters are still determining which program is best suited to them.

Student Outcomes, by course, that did not meet the 70% threshold:

1. **ENGR101:**
   Outcome 4: Broad-scoped ethics case studies cause students to provide cursory evidence of applicability of numerous relevant ethics codes. This complicates the assessment of students' ability to provide strong, comprehensive justification of the applicability of relevant ethics codes.
      Resolution: For the assessment, use case studies with a more limited scope, which should have only a small (2 to 3) number of relevant NSPE ethics codes.

   Outcome 5: Students were discouraged when team-based projects began in an unfavorable manner, which included schedule conflicts and personality conflicts.
      Resolution: Students need to be instructed on what to expect when working in teams. For many of them, this is the first time working in teams. They might benefit from being made aware of Tuckman's stages of group development.

2. **ENGR201:**
   Outcome 2: The instructor (Dr. Potter) had several conversations with students which led him to believe that students are able to design solutions that meet specific needs. However, students' final reports were used as an assessment tool for this outcome. In the reports, enough students did not report on how their designs were conceived to meet specific needs.
      Resolution: Since this typically a first-year course, more assistance can be provided to the students. In this case, 2023 students will be provided with a template final report to clearly communicate expectations.

3. **ENGR320**
   Outcome 3: This was a cohort related issue. No change to assessment method or instruction is needed.

4. **ENGR350**
   Outcome 5: See ENGR101 Outcome 5. Same resolution applies here.

5. **ENGR370**
   Outcome 4: Sample size for this evaluation was 2. This could have been the cause. In addition, students were not prompt with beginning work on the assessment instrument.
      Resolution: Encourage students to begin work on the assessment instrument well in time. In this case it was a project.

6. **ENGR401**

Outcome 1: Students seemed to be lost on trying to tackle problems with multiple concepts.

Resolution: Do more combined concept problems in class.

Outcome 7: Students had to specify a motor without instruction. The scope of this problem might have been too large.

Resolution: Build student knowledge better. Do in-class problems of increasing scope to help them prepare to solve larger problems on their own.

7. **Other action items:**

   1. **Indirect assessments:** Currently no indirect assessments were conducted. The engineering faculty will develop indirect assessment methods for the forthcoming academic year.
   2. **Rubric for assessments:** The engineering faculty have determined that there is a need to the current assessment scale ("excellent", "acceptable", and "unacceptable") does not accurately represent the intent of the faculty. Therefore, the scale has been redefined to: "Excellent", "Good", "Poor"

General Education

The department assesses its general education offerings in the PSCI 101 (Physical Science I) course, specifically its laboratory component. Relevant goals of the university's general education program are identified and assessed, such as the abilities to apply scientific principles and draw conclusions supported by experimental data.

Applicable General Education program goals include:

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

#5: The ability to describe the natural world and apply scientific principles to critically analyze experimental evidence and reach conclusions.

#9: The ability to apply critical thinking skills to assess arguments and solve problems.

Measureable Outcome	Pre-Test Results (N=204)	Post-Test Results (N=197)
1. Identify all testable variables that might affect desired property (cart's acceleration, pendulum's time period) **Gen Ed goal: #5**	5.2	6.3
2. Design experimental tests to eliminate (rule out) variables that do not affect the desired property. **Gen Ed goals: #4, #5**	4.4	6.8
3. 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: #4, #5**	5.1	6.7
4. Demonstrate proficiency in the data collection and analysis process; accurate measurements and computations. **Gen Ed goals: #4, #5**	4.9	7.2
5. Identification and minimization of sources of experimental errors, both random and systematic; computation of *percent difference* or *percent error* where appropriate. **Gen Ed goals: #4, #5**	4.4	6.6
6. Demonstrate ability to draw valid conclusions based on experimental results; recognize strengths and limitations of experimental process. **Gen Ed goals: #4, #5, #9**	4.4	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: #4, #5**	N/A	6.4

Scoring follows a 1-10 scale, 10 being the highest score. Benchmark: 7/10 (70%).

Benchmark: Students will score at least 7/10 (70%) on each of the seven measurable outcomes being assessed.

Baseline:

- 2019 – 2020: 8.4, 7.2, 7.2, 8.2, 8.8, 7.3, 7.0
- 2020 – 2021: 7.6, 6.8, 7.5, 7.5, 6.6, 7.0, 7.5

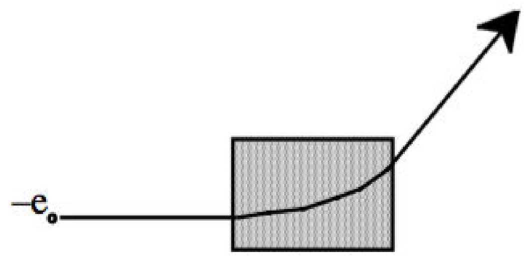
Commentary and Action Items for General Education

The benchmark (70%) was met for one of the seven outcomes. For the other six outcomes, the benchmark was almost met – with scores above 60% for all outcomes. However, this year's scores do represent a decrease from the baseline. This is likely because the PSCI 101 labs are being done differently than they were in the past, and the assessment is no longer well aligned with the activities that take place in lab. To address this, we will be revisiting how the Gen Ed goals are addressed in PSCI 101, and we might modify the PSCI 101 Lab assessment.

Appendix A: Physics 202 Pre/Post Instruction Survey

Question 1:

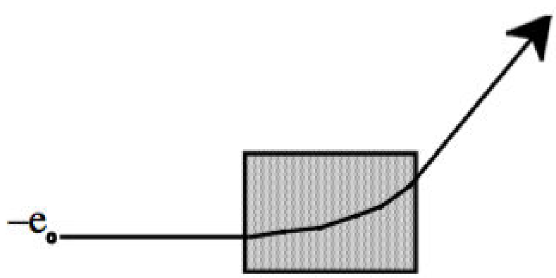
A moving electron travels along the path shown. It passes through a region of electric field (shown as the gray rectangle). There are no other charges and no other electric fields. In what direction is the electric field in the gray region?



a) To the right
b) To the top of the page
c) To the left
d) To the bottom of the page
e) Out of the page
f) Into the page
g) None of the above

Question 2:

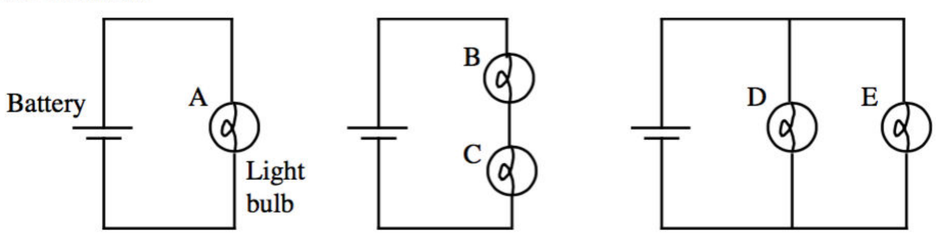
A moving electron travels along the path shown. It passes through a region of magnetic field (shown as the gray rectangle). There are no other charges and no other electric fields. In what direction is the magnetic field in the gray region?



a) To the right
b) To the top of the page
c) To the left
d) To the bottom of the page
e) Out of the page
f) Into the page
g) None of the above

Question 3:

In these three circuits, all the batteries are identical and have negligible internal resistance, and all the light bulbs are identical.

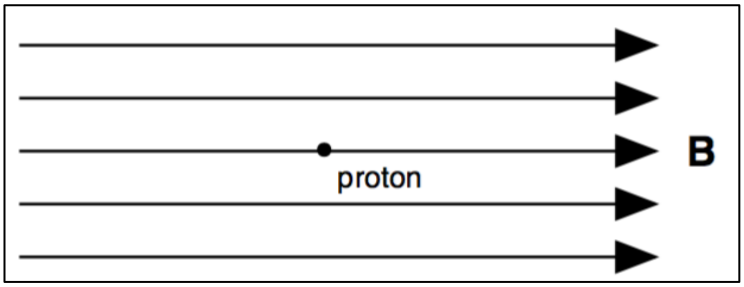


Q11 Rank all 5 light bulbs (A, B, C, D, E) in order of brightness from brightest to dimmest.

(a) A = B = C > D = E
(b) A > B = C = D = E
(c) A > B = C > D = E
(d) A > B > C > D = E
(e) A = D = E > B = C
(f) A = D = E > B > C
(g) A > D = E > B = C
(h) D = E > A > B = C
(i) None of the above

Question 4:

A proton sits in a region of constant magnetic field (shown below with arrows). There are no other charges present. What is the direction of the initial magnetic force on the proton?



a) To the right
b) To the top of the page
c) To the left
d) To the bottom of the page
e) Out of the page
f) Into the page
g) None of the above

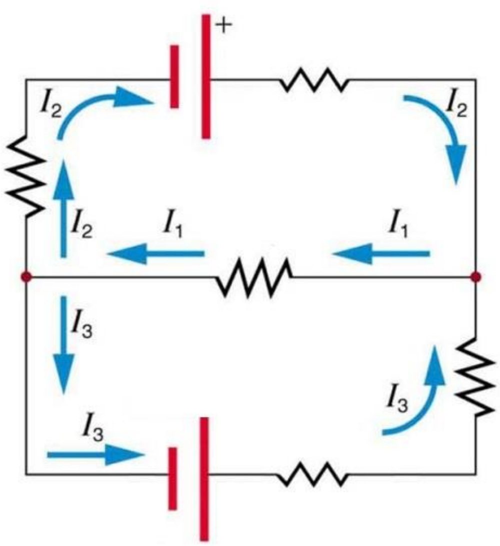
Question 5:

Two identical conducting spheres are initially separated. The left sphere has a -3 coulomb charge and the right sphere has a +2 coulomb charge. The spheres are allowed to touch each other briefly, and then they are separated. Determine the charge on the left sphere.

a) - 1 C b) $-\frac{1}{2}$ C c) 0 C d) $+\frac{1}{2}$ C e) + 1 C

Question 6:

Given the circuit below with currents (I_1, I_2, & I_3) and directions labelled below, which is a true statement?



a) $I_1 + I_2 = I_3$
b) $I_1 + I_3 = I_2$
c) $I_2 + I_3 = I_1$
d) $I_1 = I_2 = I_3$
e) None of the above

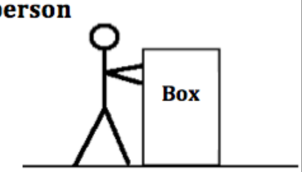
Appendix B: Physics 201 Pre/Post Instruction Survey

The three questions below were given as both pre and post tests in Physics 201. These questions test the students' understanding of three concepts that are both fundamental to the study of physics and very conceptually difficult. N = 40 students took the pretest, and N = 26 students took the posttest. Results are provided below each question.

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.

Selecting both A & B demonstrates an understanding that the term "acceleration" includes both speeding up and slowing down. On the pretest, 13 out of 40 students (33%) answered both A & B; on the posttest 24 out of 26 students (92%) answered both A & B. Selecting A, B, *and* D, demonstrates an understanding of the vector nature of acceleration. On the pretest, 2 out of 40 students (5%) answered A, B, *and* D; on the posttest, 15 out of 26 students (58%) answered A, B, *and* D.

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

The correct answer is E, which demonstrates an understanding of Newton's first law of motion. On the pretest, 6 out of 40 students (15%) answered E; on the posttest, 25 out of 26 students (96%) correctly answered E. (The students explained their answer in problem #5 of the final exam.)

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.

The correct answer is that the forces were the same, which demonstrates an understanding of Newton's 3rd law. On the pretest, 10 out of 40 students (25%) answered this question correctly; on the posttest, 22 out of 26 students (85%) answered correctly.

Appendix C: Upper-Level Health Physics Assessment (Page 1 of 6)

B-3 For a radionuclide with a decay constant of 0.1 per min, all the following relationships are correct except:

a. the half-life is 6.93 minutes.
b. the mean-life is 10 minutes.
c. the tenth-life is 23 minutes
d. in one hour, the activity will be reduced to 0.025 of its initial activity.
e. the activity will decay to 0.1 of its initial activity every minute.

B-4 The Q-value of a reaction is defined as the:

a. energy equivalence of the decrease in rest mass.
b. excess kinetic and radiant energy of reactants over products.
c. excess binding energy of reactants over products.
d. minimum energy that can be exhibited by radiation emitted from the product.
e. energy required to "make the reaction go".

B-5 All of the following are sometimes emitted from the product nucleus or product atom following the disintegration of a parent nucleus except:

a. gamma rays of discrete energy by the product nucleus.
b. conversion electrons of discrete energy by the product atom.
c. a continuous spectrum of x-rays by the product atom.
d. Auger electrons of discrete energy by the product atom.
e. beta particles of varying energy by the product nucleus.

B-8 In simple radioactive decay, the number of radioactive atoms at any time, t, is given by $N_t = N_0$ e-λt. All of the following are correct except:

a. the factor $e^{-\lambda t}$ is the fraction of the original atoms remaining at time t and is termed the decay factor.
b. the quantity $(1 - e^{-\lambda t})$ equals the fraction of the original number of atoms decaying in time t.
c. the decay constant, λ, is the instantaneous fraction of atoms decaying per unit time.
d. the activity at any time is given by the product λN_t
e. the equation always predicts the actual number of atoms remaining.

B-14 For a radioactive nuclide with a disintegration constant of 0.693 min-1, the fraction of atoms that decays in one minute is expected to be:

a. 0.24.
b. 0.37.
c. 0.50.
d. 0.63.
e. 0.76.

B-16 A researcher desires to have 10 mCi of I-131 which has an 8-day half-life. If it takes 16 days for the shipment to reach its destination then the activity which must be shipped is:

a. 14 mCi.
b. 20 mCi.
c. 40 mCi.
d. 60 mCi.
e. 74 mCi.

C-3 For water in the photon energy region from 0.1 to 2.5 MeV the total energy mass absorption coefficient is accounted for almost entirely by:

a. photoelectric interactions.
b. Compton interactions.
c. pair production interactions.
d. Raleigh scattering.
e. Thompson scattering.

C-7 The linear stopping power for charged particles , (dE/dx):

a. includes both collision and radiation losses by the particle.
b. only includes ionization energy losses.
c. always equals LET.
d. is independent of the charge and velocity of the particle.
e. is independent of the atomic number of the medium.

C-17 The highest to lowest relative penetration of 1 MeV alpha, beta and gamma rays is:

a. alpha, beta, gamma.
b. beta, gamma, alpha.
c. gamma, alpha, beta.
d. gamma, beta, alpha.
e. beta, alpha, gamma.

C-24 An interaction of neutrons with an energy of 1 Mev important because of its contribution to the total absorbed dose and because of its importance in many neutron shields is the:

a. (n,p) reaction on nitrogen.
b. (n,d) reaction on boron.
c. elastic scattering reaction with hydrogen.
d. inelastic scattering reaction with hydrogen.
e. (n,γ) reaction with sodium.

C-32 The threshold for pair production in the coulomb field of a target nucleus is about:

a. 0.51 MeV.
b. 1.02 MeV.
c. 1.53 MeV.
d. 2.04 MeV.
e. 2.56 MeV.

C-69 Annihilation radiation originates in which of the following sources?

a. electron atomic transitions.
b. positron-electron pairs.
c. nucleus of an atom.
d. radar transmissions.
e. radiant energy lost by charged particles.

J-3 If a person has been exposed to 450 roentgens of radiation:

a. his chances for survival are approximately 50-50.
b. no valid conclusions can be drawn, since the duration of exposure and the extent to which the body has been irradiated are not known.
c. he will be violently ill and will have many undesirable after-effects.
d. he has received LD-50.
e. he has received a lethal exposure.

J-12 If the brain (mass 1500 g) and the kidney (mass 350 g) both receive an acute dose of 500 rad from a high energy x-ray machine, the observed physiological effect on the brain would be less than on the kidney because...
a. it has greater mass.
b. the brain does not process bodily fluids.
c. the brain has a higher cell mitotic rate.
d. the brain has a lower cell mitotic rate.
e. the skull is very thick and dense.

J-19 At what level of acute whole body radiation would you expect to begin to see some significant physiological effects in a population?
a. 0.17 rem.
b. 0.5 rem.
c. 170 rem.
d. 500 rem.
e. 1,700 rem.

J-20 The effect on an individual being exposed to a gamma source continuously 100 rad/hr for 7 hours relative to another exposed to 100 mrad/hr for 7000 hours would be:
a. less.
b. greater.
c. same.
d. dependent on the type of radiation.
e. dependent on the weights of the persons exposed.

J-23 Chronic radiation exposures are those:
a. involving continuous or repeated exposures over a relatively long time interval.
b. involving a definite increased risk of cancer.
c. involving no significant or somatic injury.
d. that are acceptable to the exposed individual.
e. that may have some small risk to the exposed individual.

J-24 Acute radiation exposures are those:
a. occurring under critical conditions.
b. occurring as a result of an accident.
c. involving relatively large doses in a relatively short time.
d. requiring medical attention.
e. requiring notification of the NRC.

Appendix C: Upper-Level Health Physics Assessment (Page 5 of 6)

D-1 The quality factor, Q, ranked from highest to lowest for alpha, beta, and recoil atom is:
- a. alpha, beta, recoil atom.
- b. beta, alpha, recoil atom.
- c. beta, recoil atom, alpha.
- d. recoil atom, beta, alpha.
- e. recoil atom and alpha, beta.

D-8 The absorbed dose...
- a. has the unit 1 rad = 1 joule/g.
- b. is the energy imparted by radiation divided by the mass of the interacting volume.
- c. is a function of directly ionizing radiation only.
- d. applies to the ionization produced by X or gamma radiation only.
- e. is defined as being measured in tissue.

D-12 The dose equivalent is the:
- a. activity in curies in the organ of reference.
- b. dose in rads.
- c. energy deposited per gram times the quality factor and other appropriate modifying factors.
- d. dose in rads times the quality factor times the distribution factor or other modifying factors.
- e. amount of X or gamma radiation interaction in air.

K-12 Which of the following radiations presents the most severe external radiation hazard ?
- a. alpha particles.
- b. gamma photons.
- c. fast neutrons.
- d. beta particles.
- e. conversion electrons

P-1 The basic physical methods applied to protection against internal radiation hazards are:
- a. film badges, dosimeters, ion chambers, survey meters.
- b. respirators, ventilation, air cleaning equipment, decontamination, time limitation, protective clothing, glove boxes.
- c. time, distance, shielding.
- d. bio-assay, whole body counting, nose wipes.
- e. standards, regulations, procedures.

Appendix C: Upper-Level Health Physics Assessment (Page 6 of 6)

P-19 Which of the following is <u>not</u> a major objective of a radiological protection program.

a. Minimize external exposure to individuals.
b. Minimize internal exposure to individuals.
c. Minimize collective exposure.
d. Ensure economical operation while meeting the basic requirements.
e. Minimize contamination of areas, personnel, and equipment.

P-32 A technician is allowed 100 mrem to complete a job. He spends 15 minutes in a 100 mrem/hr field, 30 minutes in a 40 mrem/hr field, and 4 minutes in a 300 mrem/hr field. How many more minutes can he remain in the 300 mrem/hr field?

a. 0.1 minute.
b. 7 minutes.
c. 11 minutes.
d. 12 minutes.
e. 15 minutes.

Q-16 For radiation protection purposes, which of the following organs has been selected as the critical organ in children for exposure to environmental iodine?

a. Gonads.
b. Thyroid.
c. Lungs.
d. Whole Body.
e. Bone marrow.

G-2 The ALI or Annual Limit on Intake as used in ICRP Publication 30 for a radionuclide for occupational exposure is:

a. determined from the maximum permissible uptake rate by Reference Man for an occupational exposure of 50 years.
b. the quantity which if taken into the body alone during a year will cause one of the ICRP dose limits to be exceeded.
c. the annual amount in an organ of reference which will cause one of the ICRP dose limits to be exceeded
d. that quantity in the total body such that the critical organ is irradiated at the maximum permissible dose equivalent rate.
e. determined by first establishing the derived air concentration based on metabolic models for intakes over a 50 year period.

Appendix D: Upper-Level Computational Physics Assessment (Page 1 of 12)

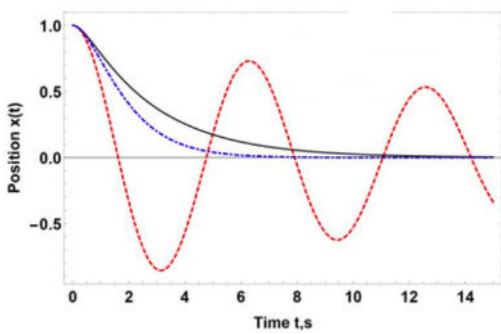
1. Which of the following statements is not true about non-inertial frames of reference?
    b. The frame of reference is accelerating relative to an inertial frame of reference.
    c. Fictitious forces are needed to fully explain the motion of objects.
    d. Newton's laws of motion hold true with no alteration.
    e. The Earth is an example of a non-inertial frame of reference.

2. Seen below is the form for the Lagrange equations of motion. The Lagrangian (L) is equal to what?

$$\frac{\partial L}{\partial x_i} - \frac{d}{dt}\frac{\partial L}{\partial \dot{x}_i} = 0, i = 1,2,3, \ldots$$

    a. L = T + U
    b. L = T - U
    c. L = U - T
    d. L = T*U

3. The graph below shows the curves for an undamped oscillator, a critically damped oscillator, and an overdamped oscillator. Identify which curve represents each type of oscillator. Label in order of black (solid line) curve, blue (dash-dot line) curve, and red (dash line) curve.



    a. Underdamped, critically damped, overdamped
    b. Underdamped, overdamped, critically damped
    c. Overdamped, critically damped, underdamped
    d. Overdamped, underdamped, critically damped
    e. Critically damped, underdamped, overdamped
    f. Critically damped, overdamped, underdamped

4. Conservation laws in physics, such as the law of conservation of energy or liner momentum, state that a certain physical property does what?
    a. The physical property does not change in the course of time within an isolated physical system.
    b. The physical property does change in the course of time within an isolated physical system.
    c. The physical property does not ever change in the course of time.
    d. None of the above.

5. The Hamiltonian function (H) of a system is written in terms of generalized coordinates (q) and generalized momentum (p). What are Hamilton's equations of motions that correspond to the Hamiltonian function (H)?

$$q_k = \frac{\partial H}{\partial p_k};\ -p_k = \frac{\partial H}{\partial q_k}$$

$$-\dot{q}_k = \frac{\partial H}{\partial p_k};\ \dot{p}_k = \frac{\partial H}{\partial q_k}$$

$$\dot{q}_k = \frac{\partial H}{\partial p_k};\ -\dot{p}_k = \frac{\partial H}{\partial q_k}$$

$$-q_k = \frac{\partial H}{\partial p_k};\ p_k = \frac{\partial H}{\partial q_k}$$

6. What is the relationship between potential energy and conservative force?

$$\vec{F} = -\int U d\vec{r}$$

$$\vec{F} = \int U d\vec{r}$$

$$\vec{F} = \vec{\nabla} U$$

$$\vec{F} = -\vec{\nabla} U$$

7. Which is true about an ideal conductor - check all that apply

	True	Not True
It always has a neutral net charge	☐	☐
Any excess charge is evenly distributed throughout the volume	☐	☐
Any Excess charge only exists on the surface	☐	☐
The electric field inside is always radially outward	☐	☐
The electric field inside is always zero	☐	☐
The electric field on the surface is always parallel to the surface	☐	☐
The electric field on the surface is always perpindicular to the surface	☐	☐
The electric field on the surface is always zero	☐	☐

8. Which of the following conclusions can be drawn from Maxwell's Equations?

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

	Indicated by Maxwell's Equations	Not Ture/Not indicated by Maxwell's Equations
Magnetic field lines have no beginning or end/they only exist in loops	☐	☐
There are no magnetic monopoles	☐	☐
There are no electric monopoles	☐	☐
Magnetic fields curl around currents	☐	☐
Electric fields curl around currents	☐	☐
A changing magnetic field can induce an electric field	☐	☐
A changing electric field can induce a magnetic field	☐	☐
Electric field lines point away from positive charges.	☐	☐
Positive charges feel a force in the same direction as an electric field	☐	☐
Positive charges feel a force in the same direction as a magnetic field	☐	☐
Charges only feel a force from the magnetic field if they are in motion	☐	☐
Light is a wave of oscillating electric and magnetic fields	☐	☐

9. A solid sphere has a charge density proportional to the distance from the origin, ρ=kr. Which law would be the easiest to use to determine the electric field?

Ampere's Law

$$\oint \vec{B} \bullet \vec{dl} = \mu_0 I_{encl}$$

Biot-Savart's Law

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{I} \times \hat{\Re}}{\Re^2} dl$$

Gauss's Law

$$\oint \vec{E} \bullet \vec{da} = \frac{Q_{encl}}{\epsilon_0}$$

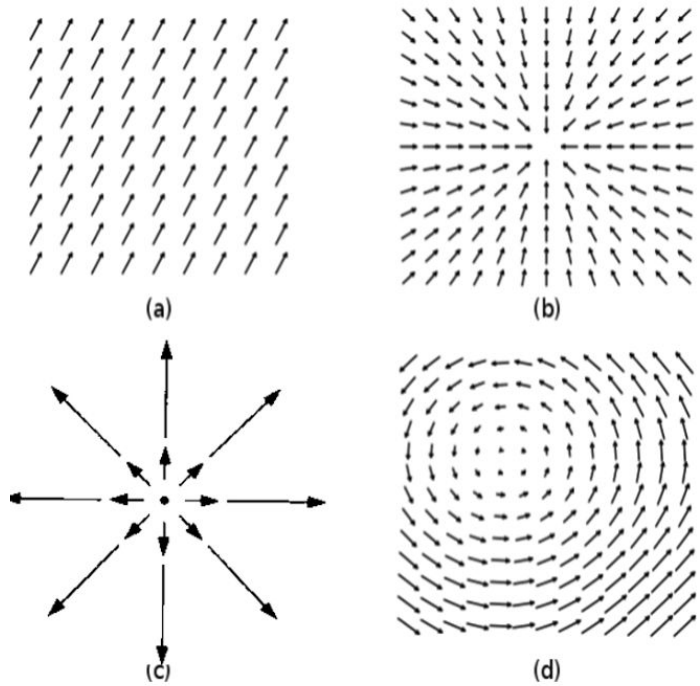
Coulomb's Law

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \int \frac{\rho}{\Re^2} \hat{\Re} d\tau$$

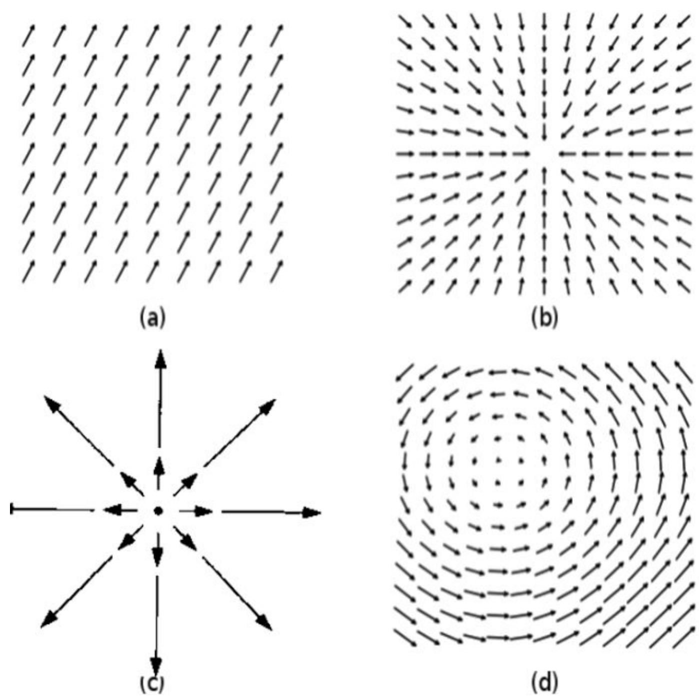
10. Bound charges must be considered when dealing with which of the following situations?

   a. calculating the magnetic field in the presence of a conductor
   b. calculating the electric field in the presence of a conductor
   c. calculating the magnetic field in the presence of a polarized object
   d. calculating the electric field in the presence of a polarized object
   e. calculating the magnetic field in the presence of a magnetized object
   f. calculating the electric field in the presence of a magnetized object

11. Which of the following vector fields has a positive divergence?



12. Which of the following vector fields has a non-zero curl?



13. An "adiabatic" process is one that…

   a. Happens quickly, so the temperature stays constant.
   b. Happens slowly, so the temperature stays constant.
   c. Happens quickly, so there is no heat transfer.
   d. Happens slowly, so there is no heat transfer.

14. An "isothermal" process is one that…

   a. Happens quickly, so the temperature stays constant.
   b. Happens slowly, so the temperature stays constant.
   c. Happens quickly, so there is no heat transfer.
   d. Happens slowly, so there is no heat transfer.

15. What are the typical speeds of the molecules in the air at room temperature?

   a. Much slower than 1 meter/second
   b. A few meters/second
   c. A few hundred meters/second
   d. A few million meters/second

16. According to the "equipartition theorem," the average energy of each microscopic degree of freedom is equal to…

   $\frac{1}{2}kT$

   $\frac{1}{2}mv^2$

   mgy

   $\frac{GMm}{r}$

17. The act of "throttling" in a refrigerator is when…
   a. Heat is transferred out from the refrigerator through the coils in the back.
   b. The fan turns on inside of the refrigerator in order to move the air.
   c. The refrigerant is pushed through a small hole and expands
   d. The compressor turns on in the bottom of the refrigerator.

18. The ideal gas law can be written "PV = NkT". What is the definition of both the "N" and the "k" in this equation?
   a. N: Number of moles; k: Thermal conductivity
   b. N: Number of moles; k: Boltzmann's constant
   c. N: Number of molecules; k: Thermal conductivity
   d. N: Number of molecules; k: Boltzmann's constant

19. The probability of a system being in a state of energy E at temperature T is given by…

$$P = \frac{n(E)}{n(T)}$$

$$P = \frac{1}{Z}e^{-E/kT}$$

$$P = \frac{kT}{E!}$$

$$P = \int_0^\infty \frac{E^2}{T} dE$$

20. Entropy is defined as...

$$S = k\ln(\Omega)$$

$$S = nRT$$

$$S = \int_0^\infty E^2 dt$$

$$S = q\vec{v} \times \vec{B}$$

21. There are two quantum distribution functions that are listed below. What type of particle is described by each of these two functions?

$$1. \quad \overline{n} = \frac{1}{e^x + 1} \qquad 2. \quad \overline{n} = \frac{1}{e^x - 1}$$

- ◯ Eq. 1 describes atoms, and Eq. 2 describes electrons.
- ◯ Eq. 1 describes electrons, and Eq. 2 describes atoms.
- ◯ Eq. 1 describes bosons, and Eq. 2 describes fermions.
- ◯ Eq. 1 describes fermions, and Eq. 2 describes bosons.

22.

The expectation value of an observable quantity can be interpreted as...

- ◯ The most likely value of the quantity over many measurements
- ◯ The average value of the quantity over many measurements
- ◯ The maximum value of the quantity over many measurements
- ◯ The variance of the quantity over many measurements

23.

Solving the equation $\frac{-\hbar^2}{2m}\frac{d^2}{dx^2}\psi(x) + V(x)\psi(x) = E\psi(x)$ gives solutions $\psi_n(x)$.
These solutions ***always*** have definite (i.e., fixed)...

- ◯ position
- ◯ time
- ◯ energy
- ◯ momentum

24.

The motion of electrons (i.e., the time evolution of their wave functions) confined in a potential usually happens over times on the scale of...

- ◯ femtoseconds
- ◯ nanoseconds
- ◯ microseconds
- ◯ picoseconds

25.

Consider a particle confined in the one-dimensional potential

$$V(x) = \begin{cases} 0 & 0 < x < L \\ \infty & \text{otherwise} \end{cases}$$

As $L \to \infty$, the difference between the energies of the stationary states...

- ◯ increases
- ◯ decreases
- ◯ remains constant

26.

Within the scope of PHYS 401, the energy of an electron in a hydrogen atom is determined by...

- ◯ The magnetic quantum number, m
- ◯ the principal quantum number, n
- ◯ the azimuthal quantum number, l
- ◯ More than one of the above

27.

Consider a particle confined in the harmonic potential $V(x) = \frac{1}{2}m\omega^2 x^2$ initially in the state $|\Psi\rangle = \frac{1}{\sqrt{11}}|\psi_0\rangle - \frac{3}{\sqrt{11}}|\psi_2\rangle + \frac{1}{\sqrt{11}}|\psi_4\rangle$. At t = 0, the probability of measuring its energy to be $\frac{5}{2}\hbar\omega$ is

- ◯ 1/11
- ◯ 3/11
- ◯ 3/sqrt(11)
- ◯ 9/11

28.

In PHYS410, which experimental skill was emphasized in every experiment that was performed?

- ◯ Keeping a detailed and accurate lab notebook
- ◯ Writing a complete and formal lab report
- ◯ Giving a clear and complete oral presentation
- ◯ Measuring extremely small motions
- ◯ Using electrical resistance to measure nature

Appendix D: Upper-Level Computational Physics Assessment (Page 11 of 12)

29.

In PHYS410, the Michelson Interferometer Apparatus used a 50/50 beam splitter to separate a 632 nm (red) laser beam into two beams with the same intensity. Mirrors were used to bring these two beams back together so that they overlapped. In modern experimental physics, what is the primary use for a Michelson Interferometer? In other words, what do interferometers do best?

- ◯ Demonstrate bands (fringes) of constructive and destructive interference
- ◯ Study the motion of forced harmonic oscillators
- ◯ Produce circular rings of constructive and destructive interference
- ◯ Perform careful tests of the Theory of Special Relativity
- ◯ Measure extremely small motions with great accuracy

30.

In PHYS410, a Fourier Spectrum Analyzer was used. Like a Digital Oscilloscope, the Fourier Spectrum Analyzer can show a plot of voltage versus time for a time-varying signal. However, the Fourier Spectrum Analyzer also performs a Fourier Transform on a time-varying signal. What important additional information does this allow a Fourier Spectrum Analyzer to provide?

- ◯ A plot of time versus speed for the signal (the speed content of the signal)
- ◯ A plot of amplitude versus frequency for the signal (the frequency content of the signal)
- ◯ A plot of wavelength versus time for the signal (the time content of the signal)
- ◯ A plot of polarization versus speed for the signal (the polarization content of the signal)
- ◯ A plot of Fourier spectrum versus time for the signal (the amplitude content of the signal)

31.

In PHYS 410, a Lock-In Amplifier was used. What is the purpose of a Lock-In Amplifier?

- ◯ To pull a large signal out of a high noise environment
- ◯ To pull a small signal out of a high noise environment
- ◯ To pull a large signal out of a low noise environment
- ◯ To pull a small signal out of a low noise environment
- ◯ To eliminate all of the noise in an environment

Appendix D: Upper-Level Computational Physics Assessment (Page 12 of 12)

32.

In PHYS 410, Diode Laser Spectroscopy was performed on Rubidium atoms. In an absorption experiment, four atomic transitions were observed between allowed energy levels in Rubidium atoms. This was done by directing an infrared (780 nm) diode laser though a glass cell that was filled with Rubidium vapor. The transmitted laser light was measured with a photodiode detector. When the laser is exciting an atomic transition in an absorption experiment, each atomic transitions is detected as...

- ○ A constant (unchanging) light intensity striking the photodiode detector
- ○ An increase in the light intensity striking the photodiode detector
- ○ A zero light intensity striking the photodiode detector
- ○ A randomly oscillating light intensity striking the photodiode detector
- ○ A decrease in the light intensity striking the photodiode detector

Appendix E: Exit Survey Administered to Graduating Physics Majors

Provide an email address that you will continue to check after graduation. *
What is your major? *
When did you select this major? *
Why did you choose this major? *
Are you graduating with any minors? If so, what are they? *
Did you take any astronomy classes? If so, which ones?
How many semesters did you spend enrolled as a student at FMU? *
What is your current overall FMU GPA? *
How many summer internships did you complete? *
How many summer research experiences did you complete? *
If you completed a summer internship, please list your employer.
If you completed a summer research experience, please list where you performed this research.

Assess your level of content knowledge in your major. *

- Very knowledgeable
- Fairly knowledgeable
- Not very knowledgeable
- Not at all knowledgeable

Assess your level of competence with regard to laboratory skills. *

- Very competent
- Fairly competent
- Not very competent
- Not at all competent

Assess your level of competence with regard to computational skills. *

- Very competent
- Fairly competent
- Not very competent
- Not at all competent

Assess your level of competence with regard to technical writing. *

- Very competent
- Fairly competent
- Not very competent
- Not at all competent

Assess your level of competence with regard to giving a technical presentation. *

- Very competent
- Fairly competent
- Not very competent
- Not at all competent

Assess to what extent these skills and this content knowledge have improved as a result of the courses you have taken in your major. *

- Very large improvement
- Large improvement
- Some improvement
- No improvement

Assess the sense of community that you experienced within your major at FMU. *

Did you feel like the faculty/department cared about your academic and future success? Did you feel connected with fellow classmates in the department?

- Very good sense of community
- Fairly good sense of community
- Some small sense of community
- No sense of community

Discuss what things you think contributed (either positively or negatively) to your sense of community.

What do you plan to do after graduation? *

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? *

- Very well
- Fairly well

Not very well
Very poorly

Is there anything that you think could have been done to improve your experience (within your major) at FMU?

If you have any other comments that you would like to share about your experience (within your major) at FMU, please write them below.

Appendix F: Physics 202 Lab Assessment of Experimental Skills (Page 1 of 2)

Logistics:

The students were given this individual assessment of their experimental skills. Each student was provided a maximum of 7 minutes to complete the assessment. The students were asked not to talk with their classmates about the assessment. An aspect of this assessment that is new in 2020 is that every student owned his/her own (identical) lab kit, instead of being provided with the equipment at the start of the assessment.

The next page is what was given to the students.

Appendix F: Physics 202 Lab Assessment of Experimental Skills (Page 2 of 2)

Physics 202 - Assessment of Experimental Skills

Equipment:

Take out the following equipment from your lab kit which you will use below:

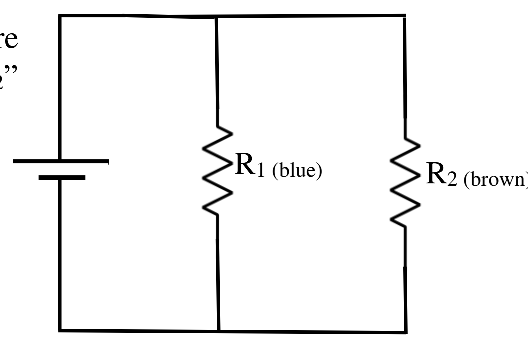
- One battery, in a battery holder.
- The two resistors that have the smaller diameter. (Do not use the large diameter resistor.)
- Several small wires with alligators clips at both ends. (Take all of them out from your kit to make sure that you have plenty.)
- Your DMM, with the two leads connected to COM and INPUT, and with the alligator clip extensions connected to the leads.

Please do not talk with your classmates about this assessment.

You will have up to 7 minutes to complete the two parts below. Please start the timer now.

<u>Part 1</u>:

Construct the circuit shown in the circuit diagram, where "R_1" represents the small blue (100 Ω) resistor, and "R_2" represents the small brown (47 Ohm) resistor.



Once you have completed setting up this circuit, pause your timer, and raise your hand to have your instructor come check your circuit.

<u>Part 2</u>:

Don't continue on to Part 2 until after your instructor has checked your circuit from Part 1.

Restart your timer. Then, using the same circuit that you constructed above, now also include your DMM to measure the current that flows through resistor R_2.

When you have completed your circuit, stop your timer, and let your instructor know that you are done.

Please do not talk with your classmates from the other lab section about this assessment.

Appendix G: Physics 419 (Senior Seminar) Rubrics for Assessing Oral Communication of Technical Material ()

Category 1 - Knowledge of the Subject (50 points)
Did the speaker demonstrate an appropriate level of understanding of the topic that was presented?

Category 2 - Clarity of the Presentation (25 points)
Did the speaker explain the topic in a clear and understandable manner, so that a scientifically literate person could follow it?
Did the speaker present the content in a logical order?

Category 3 - Presentation Skills (25 points)
Did the speaker use a clear, audible voice (and avoid the use of "um", "uh", etc....)?
Did the speaker maintain an appropriate level of eye contact with the audience (or simply read from the slides)?
Did the speaker show appropriate enthusiasm for the topic?

Appendix H: Comp. Physics Assessment of Computational Skills (Page 1 of 2)

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, potential and total energy at any time t.
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, potential, and total energy as a function of time.
5. Test and verify the numerical accuracy of your simulation. Describe the numerical tests you have chosen, and how your tests give you confidence that your numerical solution is accurate.
6. Do your results make sense physically (qualitatively and quantitatively)? List every way that you can think of to check whether or not your results are 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.	Correct implementation of Euler, 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 H: Comp. Physics Assessment of Computational Skills (Page 2 of 2)

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 d apart from each other. One particle is **fixed** (stationary), and then the other particle is released (free to move) at time t=0.

Goal: Find each object's position and velocity, and the system's kinetic and potential energy as a function of time, t.

Quantitative Details: Use $d = 10$ cm for the initial separation. Pick a value for the charge of each object, using units of μC (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:

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

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, potential, and total energy at any time t.
3. Produce and describe plots of the position and velocity for each object as a function of time. (Use whatever time scale turns out to be most interesting/insightful for the problem.)
4. Produce and describe a plot of the system's kinetic, potential, and total energy as a function of time. (Use whatever time scale turns out to be most interesting/insightful for the problem.)
5. Test and verify the numerical accuracy of your simulation. Describe the numerical tests you have chosen, and how your tests give you confidence that your numerical solution is accurate.
6. Do your results make sense physically (qualitatively and quantitatively)? List every way that you can think of to check whether or not your results are realistic.
7. **If time permits**: Modify your code so that *both* particles are free to move, and repeat the above analysis steps.