Institutional Effectiveness Report

Name of Program/Department:	**Programs: Physics, Industrial Engineering, Mechanical Engineering** **Department: Physics and Engineering**
Year:	**2020-2021**
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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. Students continue to struggle with the assessment in PHYS 202, so we will develop and implement activities in both the lecture and lab portions of PHYS 202 to attempt to clarify these concepts. In the past, students in PHYS 202 Lab have also struggled with the assessment of experimental skills, but this year students did much better at that assessment – with 70% of students demonstrating mastery of this experimental skill, as opposed to 22% last year. We attribute this to the fact that this year – due to the pandemic – every student purchased their own lab kit which they used throughout the semester; so we plan to continue to require students to purchase and use their own lab kits next fall.

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; and the Computational Physics (CP) majors a direct assessment of their CP-specific knowledge.

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 all 7 of the SLOs.

The Mechanical Engineering (ME) program just began in Spring 2020 and will seek ABET accreditation after it becomes eligible. (ABET requires a program to have graduated students prior to review.) Current ME students were assessed in several courses, and most of the SLOs were met. One of the SLOs was not met, but this is likely due to the fact that the first cohort of students has not yet completed the full curriculum.

For the General Education courses, the students' experimental skills and their interpretation of experimental results was assessed. In each category, the students either met the benchmark of 70%, or were very close to meeting the benchmark. For the two categories where the benchmark was not met, this was likely due to the shortening and modification of the labs due to the pandemic.

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 (from Fall 2019): 65%, 18%, 26%, 38%, 15%, 94%
- 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 (from Spring 2020): 70%, 25%, 50%
- 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 newly-developed assessment that covers the content of all of the upper-level CP courses (Appendix D).

- Baseline post-test scores for HP (from Spring 2020): 3 out of the 4 students scored at least 70%. This HP assessment was new in Spring 2020, so we only had post-test scores; we did not have pre-test scores for the students who graduated in 2020.
- Baseline post-test scores for CP: N/A – Spring 2021 is the first time administering this assessment.
- 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 four 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.
- 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.
- 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 as both a written report and an oral presentation. (Appendix G includes the rubrics used for assessing both the written reports and 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.
- 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 four 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.
- 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 four 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.
- Benchmark & Target: 90% of graduates will indicate that they feel either very competent or fairly competent with regard to their computational skills.

Direct: Two Physics majors graduated with a concentration in Computational Physics in Spring 2021, and they completed a computational project (Appendix H) that was delivered to them electronically at the end of their final exams. These submissions were separately scored by two faculty.

- Baseline (Spring 2019): Average score was 47%. (Not delivered in Spring 2020.)
- 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 four 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.
- 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 four 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.
- 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 2021, N = 45 students took the pre-test, and N = 41 students took the post-test. (Appendix B) On all three questions, students showed significant pre/post gains. On all three questions, students also improved from their baseline (2020) results. For Question 1 (understanding acceleration), the number of students who correctly indicated that acceleration includes both speeding up *and* slowing down increased from 58% (pre) to 80.5% (post), which does meet the benchmark of 70%. For Question 2 (understanding Newton's 1st Law), the number of correct responses increased from 2% (pre) to 32% (post), but was still well short of the 70% benchmark. For Question 3, the number of students who were able to correctly apply Newton's 3rd Law increased from 29% (pre) to 61% (post), showing a large gain, but not quite reaching the 70% benchmark.

PHYS 202 Results: In Fall 2020, N=30 students took the pre-test, and N=29 students took the post-test. (Appendix A) The pre-test averages for each of the six questions were 10%, 10%, 10%, 3.3%, 20%, 40%; and the post-test averages for each of the six questions were 31%, 14%, 24%, 21%, 24%, 66%. For each of these questions, there was a significant pre/post gain, but this group was short of the 70% benchmark; and these post-test scores were lower than the baseline (for all but Question #5). These results are discussed in the "Action Items" on Page 9.

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 50%, and the average score on the post-test was 63%, with both students showing pre/post gains.

For Computational Physics, we administered a newly-developed assessment that covers the content of all of the upper-level CP courses (Appendix D). Two graduating seniors took this assessment and achieved an average score of 82.4%. These two students did not take the pre-test (since it was new). We did also administer the assessment to the three CP students who were part way through the upper-level curriculum, who have taken some – but not all – of the upper-level courses. These students achieved an average score of 62.7%. (In future years, we will have a more true "pre-test" group, who will take the test before taking the upper-level courses.)

All students 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 four students indicated that they felt very competent in their acquired laboratory skills, which did meet the benchmark for this SLO. This result is slightly better than our baseline: Last year 80% felt very competent, and 20% felt fairly competent.

Direct: N=27 students completed the assessment in PHYS 202 Lab. All 27 students completed Part 1 correctly, and 19 students (70.4%) completed Part 2 correctly. This result is far better than we have achieved in the past (as compared with 22% last year), and has met the benchmark of 70%. This is discussed in the "Action Items" on page 9.

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

Direct: There were N = 8 students who completed the assessment in PHYS 419 (Appendix G). They received an average score of 65% on their written reports and an average score of 86% on their oral presentations. 87.5% of the students (7 out of 8) scored better than 80% on their oral presentations, which is slightly below our benchmark that 90% of the students will receive a score greater than 80% based on a faculty assessment of their oral presentations. These results are similar to our benchmark from last year.

Indirect: In an exit survey (Appendix E) that was completed by the four physics majors who graduated this year, 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. This did meet our benchmark of 90% of graduates feeling at least fairly competent in these skills. These results are similar to our benchmark 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 four physics majors who graduated this year, 100% of the respondents indicated that they felt either very competent (75%) or fairly competent (25%) with regard to their computational skills. This did meet our benchmark of 90% of graduates feeling at least fairly competent in these skills, and this was an improvement compared to last year's baseline.

Direct: Two Physics majors graduated with a concentration in Computational Physics in Spring 2021, and they completed a computational project (Appendix H) that was delivered to them electronically at the end of their final exams. These submissions were separately scored by two faculty. The two students averaged 69% on the measured criteria, which was just short of the benchmark of 70%, but was a significant improvement from our baseline of 47%. These results are discussed in the "Action Items" on page 9.

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 four physics majors who graduated this year (www.colorado.edu/sei/class), and the percentage of 'expert-like' responses was 76.4% which did meet the benchmark for this assessment of 70%. This result was similar to the baseline of 78% from last year. For reference, this assessment was also administered in Physics 200 (to N=20 underclass students) who had 47.5% '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 four physics majors who graduated this year, 100% of the respondents indicated that they felt either very well prepared for a career or future studies (75%) or fairly well prepared (25%). This did meet our benchmark of 90% of students feeling at least fairly well prepared, and this is an improvement over our baseline: Last year 80% of students felt 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, and we had hoped to include new activities to attempt to clarify these concepts; however the pandemic did not allow implementation of group activities and additional lab activities. Next year, we plan to implement new activities to help clarify these concepts. We will also explore the possibility of adjusting the assessment to more precisely identify the source of student confusion. (Currently, some of the assessment questions pack several concepts into a single question, making it difficult to know what part is causing the students' difficulty.)

SLO #3: Students will be able to use modern laboratory techniques to measure and analyze experimental data.

On an exit survey, all of the graduating physics majors indicated that they felt competent in their laboratory skills; and at the introductory level, most students were able to pass our assessment of experimental skills (Appendix E). Due to the pandemic, this year every student purchased their own lab kit which they used throughout the semester, and these students did far better on this assessment than the students in past semesters (70% this year, compared to 22% last year), so we plan to continue to require students to purchase their own lab kits in the future.

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, especially for the written reports. We have formed a committee to propose changes to PHYS 419, and that committee is meeting this summer.

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

On the computational project (Appendix H) the two students averaged 69% on the measured criteria, but almost all of the deductions occurred on Task 6, to "test and verify the numerical accuracy of your simulation". The students completely skipped this step and got 93% on the other tasks, so we will stress the importance of this task (to "test and verify") in our courses.

General Action Items:

Currently, for each SLO our Target is the same as our Benchmark. We will discuss our desires for future outcomes to decide whether or not we want to identify new Targets that differ from the Benchmarks.

Currently, 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" – is not well aligned with the SLOs that we assess. We will discuss this lack of alignment and adjust accordingly for next year.

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 PLOs. Also seen in the last column of the table, each PLO is supported by at least three SLOs.

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

			Student Learning Outcomes							
			1	2	3	4	5	6	7	Total
Program Learning Objectives	*Obtain an advanced degree*	a	X					X	X	3
	Lead a corporate project or research initiative	b	X	X	X	X	X	X		6
	Organize or support structured community outreach/education efforts	c		X	X	X	X			4
	Acquire skills/knowledge in other areas	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.

Methods (Industrial Engineering)

The industrial engineering program evaluates student performance using the seven outcomes required by the Accreditation Board for Engineering and Technology (ABET). These outcomes are measured at least twice throughout the academic year and 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	

The evaluations used to assess the SLOs are **direct assessments**. Faculty members 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), such as homework, specific content in a project, select quiz questions, or select questions from exams. Each selected work evaluation is graded using a qualitative scale of *excellent, acceptable, or unacceptable.* Table 3 presents the definition used for the qualitative scale, which serves as a guide for faculty members to assess the work from students.

Table 3. Definition of Scale Used for Direct Assessments of SLOs.

Scale	Definition
Excellent	Well above average/expected performance, great quality, stands out.
Acceptable	Average/expected performance, adequate quality.
Unacceptable	Below average/expected performance, poor quality of work.

Benchmarks, Baselines, and Targets

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 **benchmark** 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. The program uses the data from the previous year as a **baseline**. This allows faculty to be reactive if a SLO appears to be underperforming. The **target** for the near future is that all SLOs is to remain at above the benchmark of 70%. With the growth of the engineering programs, this target may change, but this change has not been implemented yet.

Assessment Results for 2020-2021 (Industrial Engineering)

The summary of the data gathered for the academic year 2020-2021 is shown in Figure 1. As the figure depicts, none of the outcomes reflected to be below the benchmark measure of 70%. This is consistent with the outcomes obtained in the 2019-2020 academic year, also portrayed in Figure 1. Based on these results, no immediate action will be taken to improve instruction in the courses where the outcomes were measured.

As a continuous improvement method, the faculty of the program met to evaluate the student outcomes and where they are currently being measured and make changes as needed to the map previously shown in Table 2. The faculty agreed that the outcome assessment will remain as mapped and will be evaluated again in 2022.

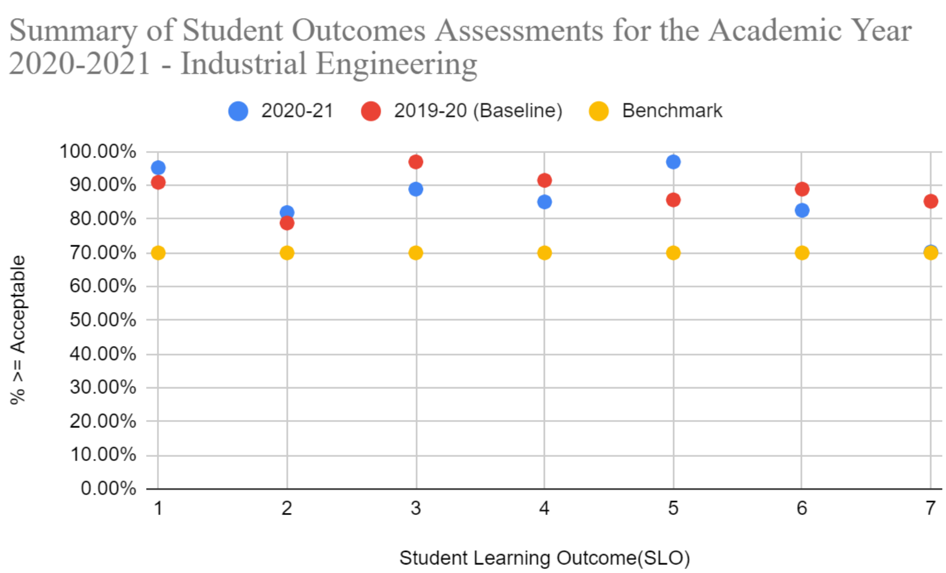


Figure 1. Summary of Student Outcomes Assessments by Outcome

Table 4 provides a detailed view of the results by outcome for the Academic Year 2020-2021, specifying the courses in which they were measured. This table allows faculty to take action (when 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. For the courses in which the % greater or equal to acceptable, the actions items are detailed below.

Table 4. Summary of Student Outcomes Assessment by Course for Academic Year 2020-2021

Semester	Course	Outcomes Measured	Excellent	Acceptable	Unacceptable	% >= Acceptable
Fall	*ENGR301*	1	2	4	1	85.71%
		4	0	6	1	85.71%
	ENGR320	3	*Measures not available*			
		6				
	ENGR350	5	0	2	1	66.67%
		6	0	1	2	33.33%
		7	0	1	2	33.33%
	ENGR420	2	7	2	2	81.82%
		4	8	2	1	90.91%
		5	7	4	0	100.00%
	ENGR467	1	*Measures not available*			
Spring	*ENGR101*	3	1	2	2	60.00%
		4	1	0	4	20.00%
		5				
	ENGR201	2	7	3	2	83.33%
		7	5	3	4	66.67%
	ENGR220	2	3	4	3	70.00%
	ENGR330	4	0	3	1	75.00%
	ENGR355	6	1	2	1	75.00%
	ENGR356	6	*Not offered this term*			
	ENGR373	1	1	2	0	100.00%
		3	3	0	0	100.00%
	ENGR470	2	7	2	1	90.00%
	ENGR480	1	10	0	0	100.00%
		2	8	2	0	100.00%
		3	6	4	0	100.00%
		4	8	2	0	100.00%
		5	8	2	0	100.00%
		6	8	2	0	100.00%
		7	6	4	0	100.00%

Action Items (Industrial Engineering)

Actions from 2019-2020 assessments:

From last year's assessment, the student outcomes assessment by course reflected that outcomes 2 and 7 were under the target level in the courses ENGR 201 and 220. After discussion, faculty believed that the sudden transition to online instruction affected these student outcomes. No changes will be implemented to course instruction, as this is believed to be a direct effect of the COVID-19 pandemic.

Opportunities and resolutions from 2020-2021 assessment results:

- In the course ENGR 101, outcomes 3 and 4 showed less than 70% of students performing at a level less than acceptable. After discussion, the faculty attributed these outcomes to a weaker- performing IE cohort, as the entire class -which includes mechanical engineering students- did perform at a level above 70%.
    - Resolution: The faculty agreed that no changes are needed for assessment methods or instruction at this time. However, faculty will make sure to look at these outcomes at the end of the academic year 2021-2022.
- For the course ENGR 101, outcome 5 was not measured. This outcome, as detailed above, deals with students' ability to function effectively on teams. Because of current COVID-19 policies, the instructor of the course did not find an appropriate method of measurement for this outcome.
    - Resolution: With the policies becoming less and less restrictive, it is sought that the Spring 2022 will be a more "normal" year and this outcome can be measured appropriately.
- In the course ENGR 201, outcome 7 showed less than 70% of students performing at a level less than acceptable. This outcome, as detailed previously, deals with students' ability to acquire and apply new knowledge as needed. After discussion, the faculty attributed this result to a new assessment method used.
    - Resolution: The next time this course is offered (Spring 2022) other assessment methods will be used that will afford a better assessment of this outcome.
- In the course ENGR 350, outcomes 5, 6, and 7 showed less than 70% of students performing at a level less than acceptable. After discussion, the faculty attributed these outcomes to a weaker- performing IE cohort.
    - Resolution: The faculty agreed that no changes are needed for assessment methods or instruction at this time. However, faculty will make sure to look at these outcomes at the end of the academic year 2021-2022.

- The course ENGR 356 was not offered in the Spring of 2021. Outcome 6, which was supposed to be measured in this course was then not measured. However, outcome 6 was measured in four other courses throughout the year.
    - Resolution: The course is expected to be taught in Spring of 2022, where the outcome will be measured.
- The outcomes for ENGR 320 and 467 were not obtained due to faculty member not entering before leaving FMU. This affected outcomes 1, 3, and 6. However, these outcomes were also measured in other courses during this year.
    - Resolution: Faculty will assess the student outcomes for these courses in the Fall of 2021.

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 2021 at the FMU ME Advisory Board Annual Meeting, board members reviewed the PEOs and provided feedback. FMU faculty reviewed the feedback and updated PEOs as follows. This process (of receiving and incorporating feedback from the ME advisory board) is in compliance with the program's continuous improvement plans.

1. **Apply engineering skills to solve complex technical and mechanical problems, and make decisions based on objective analyses.**
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-2021-2022/#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 5**.

Table 5: SLO to PLO Mapping for Mechanical Engineering

		Student Learning Outcomes						
		1	2	3	4	5	6	7
Program Learning Objectives	Apply engineering skills to solve technical problems	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 6** provides information regarding previous year's data which serves as a baseline. **Table 7** illustrates the mapping of all Student Outcomes to mechanical engineering courses.

Table 6: Baseline and Benchmarks for each SLO

SLOs	2019-2020 Baseline	2020-2021 Benchmark
1	100%	70%
2	86%	70%
3	N/A	70%
4	N/A	70%
5	N/A	70%
6	N/A	70%
7	68%	70%

Table 7: 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 8: Summary of End of Semester Student Outcomes for Academic Year 2020-2021 (by Course) – Mechanical Engineering

Fall 2020				
Course number	**SLO**	**% students who received "Excellent"**	**% students who received "Acceptable"**	**% students who received "Unacceptable"**
ENGR301	Outcome 1	12.50%	87.50%	0.00%
	Outcome 4	0.00%	62.50%	37.50%
ENGR350	Outcome 5	100.00%	0.00%	0.00%
	Outcome 6	33.33%	50.00%	16.67%
	Outcome 7	66.67%	33.33%	0.00%

Spring 2021				
Course number	**SLO**	**% students who received "Excellent"**	**% students who received "Acceptable"**	**% students who received "Unacceptable"**
ENGR101	Outcome 3	66.67%	16.67%	16.67%
	Outcome 4	66.67%	8.33%	25.00%
ENGR201	Outcome 2	47.62%	19.05%	33.33%
	Outcome 7	52.38%	14.29%	33.33%
ENGR220	Outcome 2	14.29%	71.43%	14.29%
ENGR250	Outcome 1	0.00%	77.78%	22.22%
	Outcome 7	0.00%	55.56%	44.44%
ENGR330	Outcome 4	66.67%	33.33%	0.00%
ENGR370	Outcome 1	33.33%	50.00%	16.67%
	Outcome 4	16.67%	66.67%	16.67%

Table 9: Summary of SLOs for Academic Year 2020-2021 (by Outcomes) – Mechanical Engineering

SLO	% students who received "Excellent"	% students who received "Acceptable"	% students who received "Unacceptable"
1	20.00%	70.00%	10.00%
2	34.78%	44.93%	20.29%
3	66.67%	16.67%	16.67%
4	39.02%	41.46%	19.51%
5	40.00%	60.00%	0.00%
6	33.33%	50.00%	16.67%
7	39.34%	29.51%	31.15%

Action Items (Mechanical Engineering)

Table 8 shows assessment results for the ME program by course, and **Table 9** 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 4, 2021. 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 opportunity to change program declaration. Many students in first three semesters are still determining which program is best suited to them.

1. SLO 1:
   - Benchmark achieved. No action items.
2. SLO 2:
   - ENGR201: Outcome 2 - ME students did not do well. Work on a final project was used to assess this student outcome. Students showed signs of being on track to complete "Excellent" work, however they submitted incomplete work. It is hypothesized that time management while performing work on the assessment instrument, was an issue. In the future, time management must be emphasized and perhaps, more time must be allowed for completion of the work.
3. SLO 3:
   - Benchmark achieved. No action items.
4. SLO 4:
   - ENGR301: Outcome 4 – The faculty hypothesize that this was a cohort-specific issue, not an instructional issue. Therefore, no changes are needed.
5. SLO 5:
   - Outcome 5 was not measured by Dr. Renu due to COVID safety restrictions.
   - Dr. Kanaparthi measured outcomes only at the start of the semester. This was due to miscommunication of ABET evaluation expectations. Requirement of end of semester evaluations was emphasized during the meeting.
   - Based on this, not data was available to assess Outcome 5 for ENGR101. The faculty will pay special attention to SLO 5 in the forthcoming academic year.
6. SLO 6:
   - Benchmark achieved. No action items.

7. SLO 7:
    - ENGR201: Outcome 7 – Homework which required students to research CAD tools and apply their findings, was not used this year. This might have made students too dependent on classroom instruction. Faculty need to consider going back to open-ended assignments for the students to research and apply new knowledge.
    - ENGR250: Outcome 7 - Inability of students to transfer theoretical knowledge to practical applications was noted. Assessment method may have contributed to the outcome. Resolution will be to have supplemental instructional methods. It may also help to find another assessment method that can better represent this outcome.
    - Faculty are going to wait until next year to take any further action this because there are three other ME courses that should measure SLO 7 that have not been taught yet.
8. Other action items:
    - **Indirect assessments:** Currently no indirect assessments were conducted. The engineering faculty will develop indirect assessment methods for the forthcoming academic year.
    - **Rubric for assessments:** The engineering faculty have determined that there is a need to define “excellent”, “acceptable”, and “unacceptable”. This will improve consistency of assessment across faculty. This will be included as an appendix in next year’s report.

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=133)	Post-Test Results (N=133)
1. Identify all testable variables that might affect desired property (cart's acceleration, pendulum's time period) **Gen Ed goal: #5**	7.3	7.6
2. Design experimental tests to eliminate (rule out) variables that do not affect the desired property. **Gen Ed goals: #4, #5**	5.2	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**	6.1	7.5
4. Demonstrate proficiency in the data collection and analysis process; accurate measurements and computations. **Gen Ed goals: #4, #5**	7.5	7.5
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**	4.8	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**	5.7	7.0
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	7.5

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

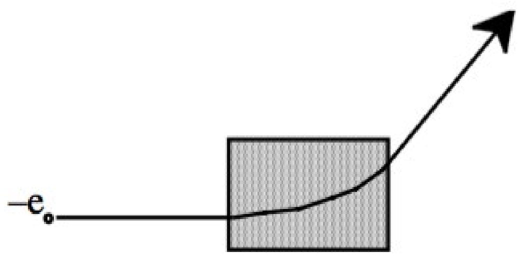
Benchmark: Students will score at least 7/10 (70%) on each of the seven measurable outcomes being assessed.

Commentary and Action Items for General Education

The benchmark (70%) was met for five of the seven outcomes. For outcomes #2 and #5, the benchmark was almost met (68% and 66%), but these percentages represent a decrease from last year. Due to the pandemic, the lab periods were shortened in order to have only half of the students in the room at a time, and the lab activities were modified in order to fit into this shorter time. This likely contributed to these lower scores, so the faculty who teach Physical Science labs will discuss how the shortened lab activities relate to outcomes #2 and #5 in order to make sure that these outcomes are adequately addressed next year.

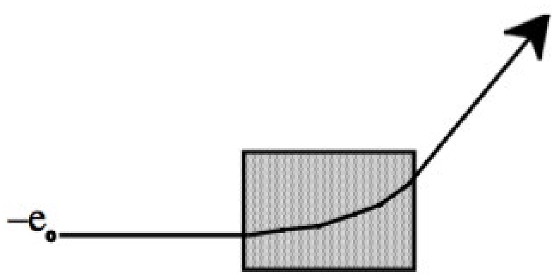
Appendix A: Physics 202 Pre/Post Instruction Survey

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

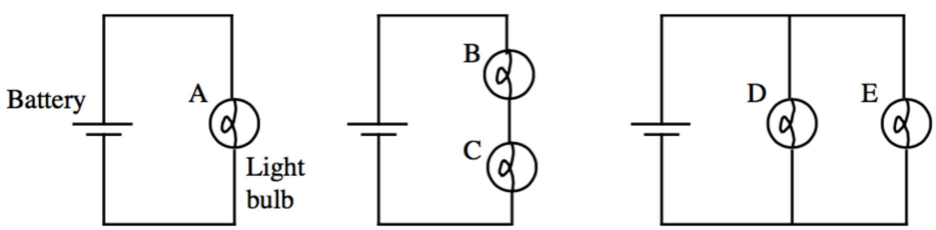
Question 2:
A moving electron travels along the path shown. It passes through a region of magnetic field (shown as the gray rectangle). There are no other charges and no other electric fields. In what direction is the magnetic field in the gray region?



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.

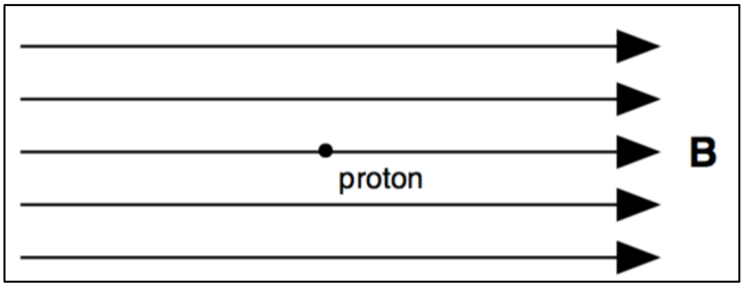


Q11 Rank all 5 light bulbs (A, B, C, D, E) in order of brightness from brightest to dimmest.

(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

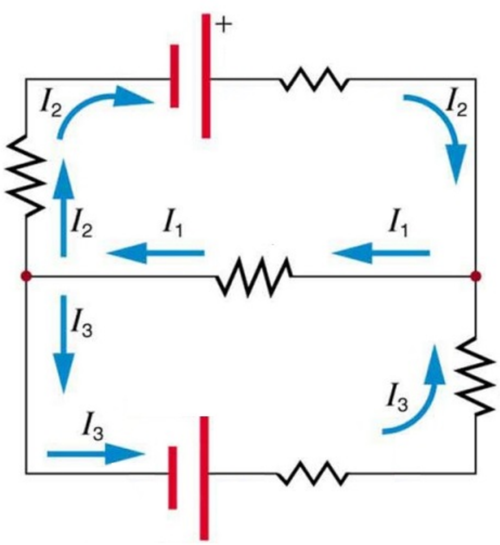
Question 5:

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

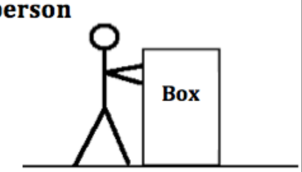
Appendix B: Physics 201 Pre/Post Instruction Survey

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 = 24 students took the pretest, and N = 20 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, 8 out of 24 students (33%) answered both A & B; on the posttest 14 out of 20 students (70%) answered both A & B. Selecting A, B, *and* D, demonstrates an understanding of the vector nature of acceleration. On the pretest, 4 out of 24 students (17%) answered A, B, *and* D; on the posttest, 5 out of 20 students (25%) 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, 1 out of 24 students (4%) answered E; on the posttest, 5 out of 20 students (25%) 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, 3 out of 24 students (13%) answered this question correctly; on the posttest, 10 out of 20 students (50%) 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.

Appendix C: Upper-Level Health Physics Assessment (Page 4 of 6)

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.

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.

P-19 Which of the following is not 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)

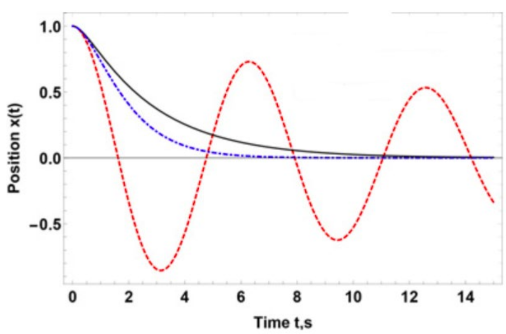
1. Which of the following statements is not true about non-inertial frames of reference?
   b. The frame of reference is accelerating relative to an inertial frame of reference.
   c. Fictitious forces are needed to fully explain the motion of objects.
   d. Newton's laws of motion hold true with no 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, $\rho=kr$. 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

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

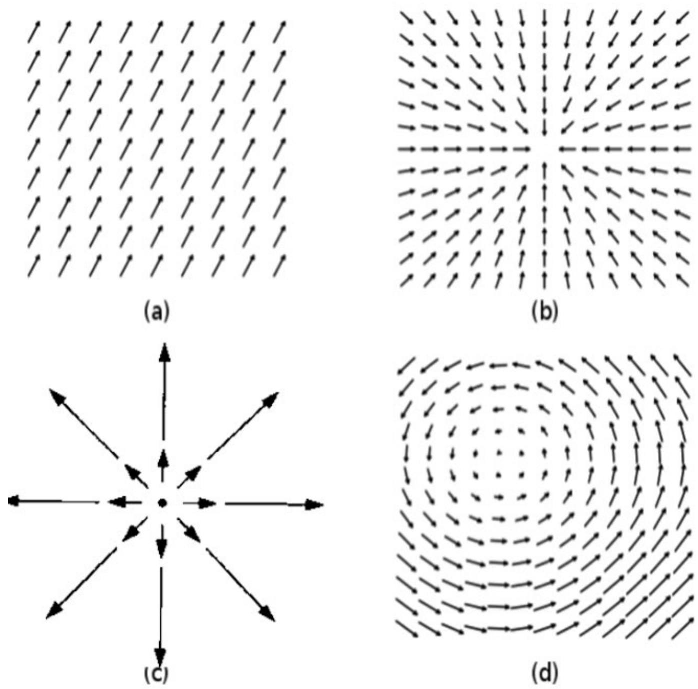
Coulomb's Law

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

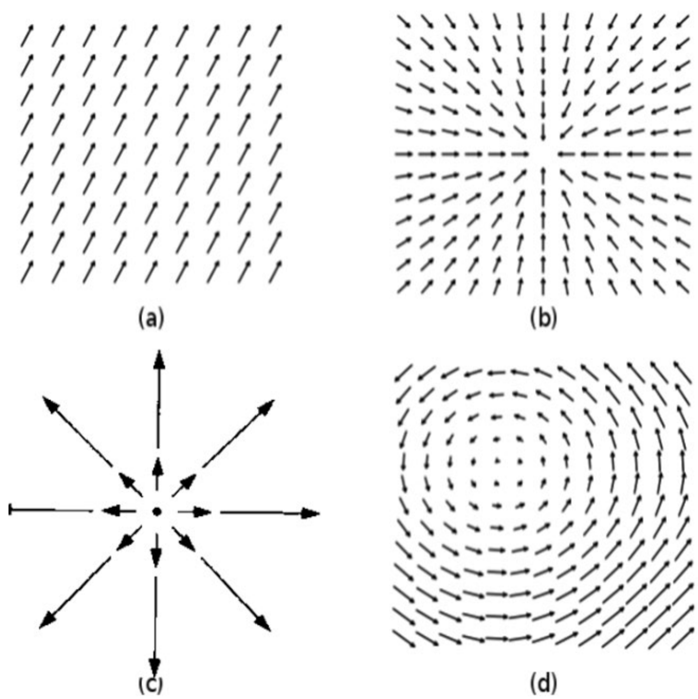
10. Bound charges must be considered when dealing with which of the following situations?

   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 $V(x) = \frac{1}{2}m\omega^2x^2$ 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

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

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:

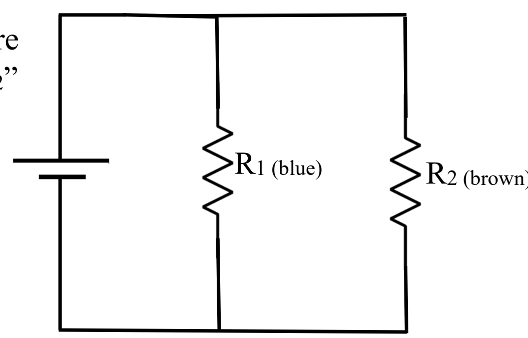
- One battery, in a battery holder.
- The two resistors that have the smaller diameter. (Do not use the large diameter resistor.)
- Several small wires with alligators clips at both ends. (Take all of them out from your kit to make sure that you have plenty.)
- Your DMM, with the two leads connected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

Part 1:

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.

Part 2:

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 both Written & Oral Communication of Technical Material (Page 1 of 2)

<u>Assessment rubric for written literature review</u>:

PHYS 419 - Fall 2019

Criteria	Outstanding (12 – 15 pts)	Good (8 - 11 pts)	Fair (4 – 7 pts)	Unacceptable (0 – 3 pts)	Points Earned
Content (max of 15 Points)	• Information provided is pertinent to the topic • Information provided is logical & supported by evidence	• Information provided is pertinent to the topic • Information provided is fairly logical & reasonably supported	• Information provided is consistently pertinent • Information provided is logical or supported by evidence	• Information provided is not pertinent • Information provided is rarely logical & supported by evidence	
Mechanics (max of 15 Points)	• Proper citations are used • Grammar and Spelling have been checked • Hook statement is clearly provided in the opening of the Introduction	• Proper citations are used • Grammar and Spelling issues are minimal • Hook statement is provided in the opening of the Introduction	• Citations are used properly in most cases • Grammar and Spelling issues are apparent • Hook statement is not very clear in the Introduction	• Citations are not properly used • Grammar and Spelling has not been checked • Hook statement is missing from the Introduction	
				Total Points for the Scientific Literature Review Article: (maximum 75 Points)	

SLR Format: Throughout the semester the student has been building their SLR to include the sections listed below. Students researching a topic that did not have a scientific theory were asked to write a Methodology section instead that described how data for a particular population was collected. Some papers will also provide a Models section – especially if the topic involved numerical simulations. The SLR is written in the voice of a reporter. The only section where the author's voice may appear is in the Discussion section. This author voice can address shortcomings of the research work. Each student was asked to visit the Writing Center once they had a full draft of the paper.

Sections that are to be included in the final paper:

Abstract; Introduction; Theory (or Methodology); Experiments (or Models); Results; Discussion; Conclusion, References

Citations: The PHYS 419 class was directed to use APA parenthetical citations instead of ordered numbers. The reference section is therefore to be in alphabetical order by last name of authors.

Assessment Rubric for Presentation

Student Name: ____

The Presentation is 100 points toward the final grade.

100 - 90 points = Demonstrates excellent understanding of the topic and presented a clear and easy to follow summary of their research.

89 - 75 points = Demonstrates good understanding of the topic and presented a somewhat clear and easy to follow summary of their research.

75 - 0 points = Demonstrates incorrect or insufficient understanding of the topic and presented a hard to follow summary of their research.

Criteria	Points Earned
Organization (15 Points) • Speaker provided outline of presentation • Speaker provided content in a logical sequence	
Content (45 Points) • Technical terms are defined for the audience • Material presented is relevant to the topic • Sufficient material is presented • Obvious conclusion summarizing the presentation is made • Graphs and Figures were relevant to the presentation	
Presentation (40 Points) • Speaker used a clear, audible voice • Speaker maintained eye contact with audience • Presentation completed in the allotted time period • Information was well communicated • Speaker was dressed appropriately for the presentation	
Total Points for the Conclusion and Abstract Sections: (maximum 100 Points)	

Evaluator Comments:

Assignment developed based on the Workshops from "Lessons for a Scientific Literature Review." By R. Schmidt, M. Smyth, & V. Kowalski (2008) Libraries Unlimited.

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.

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.