II. <u>SUMMARY OF ASSESSMENT</u> *(suggested length of 1-2 pages)*

A. Program Learning Outcomes (PLO)

List all your PLO in this box. Indicate for each PLO its alignment with one or more institutional learning outcomes (ILO). For example: "PLO 1. Apply advanced computer science theory to computation problems (ILO 2 & 6)."

Physics B.A. Program Learning Objectives:

A. Describe the fundamental principles of Physics and be able to apply these core ideas to analyze physical processes; (ILO 1)

B. Use quantitative reasoning and critical thinking to solve problems, both theoretical and experimental in nature; (ILO 1)

C. Learn new technical subjects and skills; (ILO 1)

D. Construct, assess and troubleshoot experiments, quantitatively analyze the results using appropriate statistical procedures and tests of systematic errors, and draw meaningful conclusions; (ILO 1)

E. Effectively explain scientific ideas, both theoretical and experimental, to diverse audiences through written and oral presentations, both formal and informal; (ILO 2)

F. Work professionally, effectively, and inclusively as a member of diverse collaborations to solve problems. (ILO 4)

Physics B.S. Program Learning Objectives:

*A. **Explain** the fundamental principles of Physics and be able to apply these core ideas to analyze physical processes (ILO 1)*

*B. **Apply** quantitative reasoning and critical thinking to solve complex problems, both theoretical and experimental in nature; (ILO 1)*

*C. **Independently** learn new technical subjects and skills; (ILO 1)*

*D. **Design**, construct, assess and troubleshoot experiments, quantitatively analyze the results using appropriate statistical procedures and tests of systematic errors, and draw meaningful conclusions; (ILO 1)*

E. Effectively discuss scientific ideas, both theoretical and experimental, to diverse audiences through written and oral presentations, both formal and informal; (ILO 2)

F. Work professionally, effectively, and inclusively as a member of diverse collaborations to solve problems. (ILO 4)

The CSUEB Institutional Learning Outcome numbers referred to above correspond to the following:

(1) **Thinking and Reasoning:** think critically and creatively and apply analytical and quantitative reasoning to address complex challenges and everyday problems.

(2) **Communication:** communicate ideas, perspectives, and values clearly and persuasively while listening openly to others.

(3) **Diversity:** apply knowledge of diversity and multicultural competencies to promote equity and social justice in our communities.

(4) **Collaboration**: work collaboratively and respectfully as members and leaders of diverse teams and communities.

(5) **Sustainability**: act responsibly and sustainably at local, national, and global levels.

B. Program Learning Outcome(S) Assessed

List the PLO(s) assessed. Provide a brief background on your program's history of assessing the PLO(s) (e.g., annually, first time, part of other assessments, etc.)

The physics department has been assessing student learning for 4 years now, starting in 2014 with consistent measures in multiple courses each quarter. The specifics of which PLOs were tested in which class with what instrument are provide below.

Fall 2016

- PLO A and B: Physics 1001 Lecture - pre and post-instruction FCI
- PLO A and B: Physics 2004 Lecture - subset of questions from GRE-9277
- PLO A and B: Physics 2004 Lecture – Problem Set assessment (4th problem set in 2014)
- PLO E: Physics 1001 Lab – "measure g" experiment with presentation and notebook write-up assessment
- PLO E: Physics 2004 Lab – "measure g" experiment with presentation and notebook write-up assessment

Winter 2017

- PLO B: Physics 3302 QM II – Problem Set assessment (1st problem set in W 2014)

Spring 2017

- PLO A and B: Physics 1003 pre and post-instruction BEMA
- PLO A and B: Physics 4950 – Capstone – complete GRE-0177

C. **Summary of Assessment Process**

Summarize your assessment process briefly using the following sub-headings.

Instrument(s): *(include if new or old instrument, how developed, description of content)*
Sampling Procedure:
Sample Characteristics:
Data Collection: *(include when, who, and how collected)*
Data Analysis:

- PLO A and B
  - **Instrument(s):** Standardized tests (FCI/BEMA/GRE) and Homework Sets
  - **Sampling Procedure:** Pre and post course completion of standardized tests
  - **Sample Characteristics:** Limited sample due to small class size
  - **Data Collection:** Physics 1001, 4001, 2004, 4002, 4003, and 4950 (Professors Furniss and Smith in Fall 2016/Winter 2017 and Spring 2017)
  - **Data Analysis:** Percentage correct comparison of pre/post course tests, and comparison of raw homework score graded according to consistent rubric
- PLO D
  - **Instrument(s): Measuring "g" in lab**
  - **Sampling Procedure:** middle of quarter in both lower and upper division major courses
  - **Sample Characteristics:** Limited sample due to small class size
  - **Data Collection:** Physics 1001, 2004 (Professors Kimball and Smith in Fall 2016/Winter 2017 and Spring 2017)
  - **Data Analysis:** Labs graded according to consistent rubric and lower and upper division methods compared

D. **Summary of Assessment Results**

Summarize your assessment results briefly using the following sub-headings.

Main Findings:

<u>RESULTS</u>

<u>Pre- and post-instruction tests/surveys</u>: (SLOs: A,B,C for both BA and BS)

These exams give us a snapshot of the students' working knowledge in physics, conceptual understanding, and ability to efficiently solve problems. These exams are a core part of our assessment of our first three SLOs. Since the tests are nationally normed they enable us to make quantitative comparisons of our students' performance to that of students from other institutions.

A subset of the exams are given before and after instruction (at the beginning of the course and at the conclusion of the course) to provide a quantitative measure of student improvement during the course. The gain is calculated as the difference between pre- and post-instruction scores divided by the number of incorrect answers on the pre-test.

1. Physics 1001 (Force Concept Inventory, FCI, a nationally normed assessment tool)

The Force Concept Inventory (FCI) instrument is designed to assess student understanding of the most basic concepts in Newtonian physics. This forced-choice instrument has 30 questions and looks at six areas of understanding: kinematics, Newton's First, Second, and Third Laws, the superposition principle, and types of forces (such as gravitation, friction). Each question offers only one correct Newtonian solution, with common-sense distractors (incorrect possible answers) that are based upon student's misconceptions about that topic, gained from interviews.

	2016	2015	2014	2013	2012	2011
Gain between post- and pre-test:		45	56	27	30	31
Overall post-test score:		59	66	47	52	48

Studies have shown that in a traditional, well-taught lecture class, the FCI gain is measured to be around 20% while in a class employing a wide range of active engagement and peer-to-peer instruction techniques, the FCI gain can approach close to 50%.

For the overall post-test FCI score, the generally acknowledged threshold for understanding the material is an average of about 60%.

In 2015, the General Physics students were able to achieve an FCI gain of 45% and a post-test average 59%, indicating successful learning compared to national averages. Some relevant factors that have persisted between the relatively successful 2014 and 2015 versions of the course may have been the frequent use of peer-to-peer instruction activities (such as think-pair-share), implementation of weekly quizzes and reviews, and a reduction of material covered in order to focus more classroom time on core subjects.

2. Physics 1003 (Brief E&M Assessment, BEMA, a nationally normed assessment tool)

The Brief Electricity and Magnetism Assessment (BEMA) assesses what students know about the most basic and central concepts of the calculus-based introductory E&M course. It is comprehensive, covering topics from the Coulomb force law to magnetic induction, but omitting radiation because it is very common for the introductory course not to get that far. It has been used by various instructors in various settings and has been judged an appropriate and fair assessment of introductory E&M by physicists experienced in teaching E&M at various levels. It is not aimed at any particular curriculum but contains only those elements common to all calculus-based introductory courses.

	2016	2015	2014	2013

Gain between post- and pre-test:	20	22	14	29
Overall post-test score:	44	42	37	47

Studies have shown that in a traditional, well-taught lecture class, the BEMA gain is measured to be around 20% while in a class employing a wide range of active engagement and peer-to-peer instruction techniques, the gain can be above 30%.

For the overall post-test BEMA score, the generally acknowledged threshold for understanding the material is an average of about 60%.

Of significant concern is that our students are not meeting these thresholds. As part of our new curriculum, we have converted our 1 quarter electromagnetism course (PHYS 1003) into a 1 semester course (PHYS 136), covering the same material but with an extended time to include more active learning, peer-to-peer activities, and review and assessment throughout the course.

3. <u>Physics 4001-4003 (Brief E&M Assessment, BEMA, a nationally normed assessment tool)</u>

The BEMA was also used to assess upper division students' knowledge of electromagnetism in Physics 4001-4003. The exam was administered at the beginning of PHYS 4001 and again at the conclusion of PHYS 4003 with the results listed below:

	4001-4003 (3rd/4th yr)	1003 (1st yr)
Gain between post- and pre-test:	35	20
Overall post-test score:	48	44

Of significant concern, we did not observe significant gains between the lower and upper division performance. The Department has discussed this at length and continues to debate the best path forward. The introduction of the new PHYS 230 (Physical Reasoning) is intended to offer further review and reinforcement of basic concepts in electromagnetism and other subjects in Physics.

4. <u>Physics 2004 (Physics GRE-based assessment, Physics GRE-9277, nationally normed for students applying to graduate school)</u>

The Physics Graduate Record Exam (GRE) test consists of approximately 100 five-choice questions, some of which are grouped in sets and based on such materials as diagrams, graphs, experimental data and descriptions of physical situations. The aim of the test is to determine the extent of the examinees' grasp of fundamental principles and their ability to apply these principles in the solution of problems. Most test questions can be answered on the basis of a mastery of the first three years of undergraduate physics.

In Physics 2004, we use a subset of questions from the GRE test centered around topics that students should have familiarity with through the General Physics sequence (including Modern Physics, PHYS 2004).

Subject area breakdown:

Subject	2016 results	2015 results	2014 results	2013 results	National Average
Classical mechanics:	--	27	29	25	52
Electromagnetism:	--	15	11	18	48
Optics:	--	28	30	25	40
Thermodynamics:	--	19	18	19	52
Quantum:	--	22	25	18	45
Special relativity:	--	23	24	22	39
Laboratory methods:	--	22	23	19	39
Special topics:	--	24	9	38	39

Although in past years we have found that results are largely consistent from year-to-year, we have not collected this data in 2015 or 2016. We have already coordinated to ensure that this same data is taken in the 2017 year.

5. <u>Physics 4950 (Physics GRE-0177, nationally normed for students applying to graduate school)</u>

The Physics Graduate Record Exam (GRE) test consists of approximately 100 five-choice questions, some of which are grouped in sets and based on such materials as diagrams, graphs, experimental data and descriptions of physical situations. The aim of the test is to determine the extent of the examinees' grasp of fundamental principles and their ability to apply these principles in the solution of problems. Most test questions can be answered on the basis of a mastery of the first three years of undergraduate physics.

In Physics 4950, our Capstone class, we use a complete GRE test covering all subjects in Physics. For 2015, the results are based on a single student. These results are unavailable for 2016.

Subject area breakdown:

Subject	2016 results	2015 results	2014 results	2013 results	National average
Classical mechanics:	--	22	20	24	51.6
Electromagnetism:	--	24	21	27	48.2
Optics:	--	18	15	20	39.8
Thermodynamics:	--	18	15	21	51.9
Quantum:	--	18	25	11	45.4
Atomic:	--	18	29	29	52.1
Special relativity:	--	5	0	9	38.8
Laboratory methods:	--	36	33	39	38.5
Special topics:	--	20	20	20	38.8

6. Comparison of Physics 2004 (2nd year) to Physics 4950 (4th year) results from 2015:

Subject	Physics 2004 (avg)	Physics 4950 (avg)
Classical mechanics:	27	22
Electromagnetism:	15	24
Optics:	28	18
Thermodynamics:	19	18
Quantum:	22	18
Special relativity:	23	5
Laboratory methods:	22	36
Special topics:	24	20

These data are from 2015Of concern, here too we did not observe significant gains between the lower and upper division performance.

Recommendations for Program Improvement: *(changes in course content, course sequence, student advising)*

(1) Basic physics knowledge taught in the General Physics sequence (PHYS 1001-1003, PHYS 2004) would continue to be emphasized throughout the upper-division curriculum by additional "basic" problems added on to homework assignments to give students extra practice at the basic concepts. This will be done, to as great a degree as possible, without sacrificing the advanced instruction that is part of the present curriculum.

(2) Weekly quizzes without notes and more in-class, peer-to-peer activities are a useful tool for reinforcing basic knowledge and problem-solving skills that can be used in upper division as well as lower division courses.

(3) We will continue to increase use of in-class presentations of problem solutions and peer-to-peer learning strategies in upper division classes to further emphasize and practice accessing the fund of physics knowledge.

(4) We will emphasize throughout lower and upper division the "Prepare-Solve-Assess" strategy of problem solving.

(5) We will expand use of peer evaluation to help teach students how to evaluate their own work.

Next Step(s) for Closing the Loop: *(recommendations to address findings, how & when)*

When converting to semesters, we are planning to offer three semesters of General Physics and a writing class, *PHYS 230: Physical Reasoning*, to further emphasize and review fundamental knowledge and problem solving skills.

Other Reflections:

A Department goal is for our students to achieve at least the national average on all nationally normed exams. (This goal, in the case of the GRE exam, may be aspirational as we are comparing all our students to a subset of students who applied to graduate school in Physics.)

There are certainly some bright spots as we have achieved or have come close to achieving that goal for the Physics 1000 series, indicating that our General Physics instruction is successful and our teaching strategies are working.

However, the performance of our upper division students falls short of our goals, and in fact the performance of the 3rd and 4th-year students shows little improvement compared to the 1st and 2nd-year students. On the other hand, one should be careful about reading too much into the results as relatively few students (around 10) have taken the exams each year.

The Department held many meetings of the tenure-track faculty throughout the year to "close the loop" and strategize on what improvements might be made to curriculum and teaching methods.

It was the continued opinion of the faculty that based on these results, physics majors overall were suffering from a lack of a fund of knowledge about physics and had significant weaknesses in conceptual understanding and problem solving skills that needed to be addressed.

E. Assessment Plans for Next Year

Summarize your assessment plans for the next year, including the PLO(s) you plan to assess, any revisions to the program assessment plan presented in your last five-year plan self-study, and any other relevant information.

Academic Year 2017-18

Fall 2018

- Physics 135 Lecture - pre and post-instruction FCI
- Physics 137 Lecture - subset of questions from GRE-9277
- Physics 137 Lecture – Problem Set assessment (4th problem set in 2014)
- Physics 135 Lab – "measure g" experiment with presentation and notebook write-up assessment
- Physics 137 Lab – "measure g" experiment with presentation and notebook write-up assessment

- Physics 3302 QM II – Problem Set assessment (1st problem set in W 2014)

Spring 2019

- Physics 136 pre and post-instruction BEMA
- Physics 230 – complete GRE-0177