CRITERION 3. STUDENT OUTCOMES

A. Student Outcomes

List the student outcomes for the program and indicate where the student outcomes are documented. If the student outcomes are stated differently than those listed in Criterion 3, provide a mapping of the program's student outcomes to the student outcomes (a) through (k) listed in Criterion 3.

EP Program Outcomes

The *Engineering Physics (EP)* program utilizes the resources of five different programs: *Physics*, *Aerospace Engineering, Chemical Engineering*, *Electrical Engineering* and *Mechanical Engineering*, which are hosted in four different departments. All above engineering programs, including EP, are currently *ABET* accredited and are preparing for re-accreditation. Each of the programs has a common set of *Program Outcomes (a)-(k),* as required by *ABET*.

While other engineering programs at NMSU typically have additional program-specific outcomes as well, this is not the case for the EP program. Each of the other engineering programs at the *College of Engineering* have their own established *Program Outcomes & Assessment Procedures* to assess *Program Outcomes (a)-(k)* through their courses. Obviously, the EP program has essentially no influence on the other engineering program's current procedures, which the relevant engineering departments formulated such that they were deemed adequate for their own majors. Therefore, the EP program formulated their own *Program Outcomes & Assessment Procedure* using courses and other measures under full control of the *Department of Physics*.

It should be noted, however, that curricular changes (e.g. course sequence, delivery and content) in participating engineering departments may affect the EP program as well. This is another reason why representatives of participating engineering departments are members the *EP Program Committee*. If needed, these engineering representatives will disseminate and discuss the internal findings, assessment results and proposed course actions. In addition, these representatives help develop and change the *EP Program Outcomes & Assessment Procedure*, as appropriate. The separate assessment responsibilities of courses taught in *Physics* or *Engineering* courses provides the benefit of multiple independent and complementary measurements for each *Program Outcome*.

After consultation with faculty members from the *College of Engineering*, the *Department of Physics*, the *EP External Advisory Board (EPEAB)*, industry representatives, and current students and graduates, it was concluded that the current *Program Outcomes (a)-(k)* would continue suffice to ensure the quality of our EP program. An additional advantage is that these outcomes are common to the all the engineering programs, making the cross-departmental and cross-college EP assessment more straightforward. Subsequently, we continue to adopt the *ABET 2000 Program Outcomes (a)-(k)*, with some minor addition in the *Program Outcomes (e)*, *(h)* and *(k)*, where we included 'physics' specifically. The EP Program Student Outcomes are listed in Table 3.1., and each of the *Program Outcomes* was named with an identifying acronym for future reference.

Table 3.1. *Engineering Physics (EP) Program Outcomes.*

Scientific Expertise: an ability to apply knowledge of mathematics, science, and engineering.
Experimental Training: an ability to design and conduct experiments, as well as to analyze and interpret data.
Design Abilities: an ability to design a system, component, or process to meet desired needs with realistic constraints such as economic, environmental, social, political, ethical, health & safety, manufacturability, and sustainability.
Teamwork: an ability to function on multi-disciplinary teams.
Problem Solving: an ability to identify, formulate, and solve engineering and physics problems.
Professional Responsibility: an understanding of professional and ethical responsibility.
Communication Skills: an ability to communicate effectively.
Societal Impact: the broad education necessary to understand the impact of engineering and physics solutions in a global, economic, environmental, and societal context.
Life-long Learning: a recognition of the need for and an ability to engage in life-long learning.
Contemporary Issues: a knowledge of contemporary issues.
Technical Know-How: an ability to use the techniques, skills, and modern engineering tools necessary for engineering physics practice.

Like the other engineering programs, *EP Program Outcomes* assessment is mostly done *via* measurements in individual courses. The *EP Program Committee* has assigned outcomes measures to every course. Prior to the course, each instructor is informed about which of the *Program Outcomes* he/she is supposed to measure. While the *EP Program Committee* provides guidance to assigned instructors on how certain *Program Outcomes* may be measured, it is left up to the instructor to develop adequate quantitative assessment tools themselves. In most cases, instructors will utilize previously established assessment tools. The *Course Assessment Matrix for Physics Courses* has undergone changes in the past years by adding a few more courses that measure outcomes h, i and j. This occurred when some of the EP Concentrations removed certain elective courses. This left a gap in measurement for these outcomes and the gap was filled by adding measurement of outcomes h, i and j to a few of the core Physics courses.The current *Course Assessment Matrix for Physics Courses* is provided in Table 3.2.a

The last row in the table indicates how often each *Program Outcome* is expected to be measured for any EP throughout completion of the program. Note, that some of the rows contain two courses, both of which will measure the same program outcomes. In some cases, the two courses may be alternative options (e.g. *PHYS 213* or *PHYS 215G*). In other cases, however, the two courses may both be required and will be taken in sequence (e.g. *PHYS 454* and *455*, or *PHYS 461* and *462*), thus providing two independent measures of particular *Program Outcomes*. The curriculum of our EP program and the content of the courses have been designed such that there are multiple independent measures for achievement of our *Program Outcomes (a)-(k)*.

Table 3.2.a. *Physics Course Assessment Matrix for Program Outcomes (a)-(k)*

Required Courses											
Physics 213 or 215G Mechanics	X										
Physics 213L or 215GL Mechanics Lab		X									
Physics 214 or 216G Electricity & Magnetism	X										
Physics 214L or 216L Electricity and Magnetism Lab		X									
Physics 217 Heat, Light, & Sound	X										
Physics 217L Heat, Light, & Sound Lab		X	X	X							
Physics 315 Modern Physics	X					X		X	X	X	
Physics 315L Modern Physics Lab		X	X	X			X				X
Physics 395 Math Methods											X
Physics 454 Intermediate Modern Physics I					X						
Physics 455 Intermediate Modern Physics II					X						
Capstone							X				X
Number of times an outcome is measured in required courses	*4*	*4*	*2*	*2*	*2*	*1*	*2*	*1*	*1*	*1*	*3*
Required Courses for some EP Concentrations											
Physics 461 Int. Electricity & Magnetism I					X	X		X	X	X	
Physics 462 Int. Electricity & Magnetism II					X	X		X	X	X	
Physics 480 Thermodynamics					X	a		a	a	a	
Physics 451 Intermediate Mechanics					X	X		X	X	X	
Number of times an outcome for any EP student					*2-3*	*1-3*		*1-3*	*1-3*	*1-3*	
Physics Course Electives											
Advanced Physics Lab		X	X	X			X				X
Physics 476 Computational Physics			X								X
Physics 495 Math. Methods of Physics											X

Physics 488 Solid State Physics						X		X	X	X	
Physics 489 Modern Materials						X		X	X	X	
Other Physics Electives			a	a		a		a	a	a	a
Number of times an outcome for any EP student		*0-1*	*0-1*	*0-1*		*0-1*	*0-1*	*0-1*	*0-1*	*0-1*	*0-1*
Non-Course Assessment Tools											
Senior-Exit Interviews	X	X	X	X	X	X	X	X	X	X	X
MFT Test	X				X			X			
Number of times an outcome for any EP student	***2***	*1*	*1*	*1*	***2***	*1*	*1*	*2*	*1*	*1*	*1*

a: whether this Program Outcome is measured depends on the individual instructor and/or the topic of the course.

Several faculty members in the *Department of Physics* have occasionally complained about an obvious flaw of the current assessment matrix, namely that some courses are required to measure multiple *Program Outcomes*, while other course are required to measure just one. Subsequently, instructors of those courses carry a higher burden in the assessment effort. Although the *EP Program Committee* did entertain some discussion on how course assessment could be distributed more uniformly, it was decided to postpone a re-distribution for now, given that *ABET* is expected to change its *Program Outcomes* definitions in the very near future.

Similarly, the participating engineering departments have published their own *Course Program Assessment Matrices*, see Tables 3.2.b-e.

Table 3.2.b. *Aerospace-Engineering Course Assessment Matrix for Program Outcomes (a)-(k)*

Mapping of Aerospace Engineering Curriculum to Program Outcomes															
		Contribution to Program Outcomes											AE specific Program Criteria		
		ability to apply knowledge of mathematics, science, and engineering	ability to design and conduct experiments, as well as to analyze and interpret data	ability to design a system, component or process to meet desired needs within realistic constraints	ability to function on multidisciplinary teams	ability to identify, formulate, and solve engineering problems	understanding of professional and ethical responsibility	ability to communicate effectively	the broad education needed to understand the impact of engineering in a variety of contexts	recognition of the need for, and an ability to engage in lifelong learning	knowledge of contemporary issues	ability to use the techniques, skills and modern tools necessary for engineering practice	knowledge covering aeronautical or astronautical engineering areas	knowledge of some topics from area not emphasized	design competence
Curriculum Area	**Credits**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**AE1**	**AE2**	**AE3**
ME 261	3	**X**				X			Fulfilled by NMSU General Education Requirements			X			
AE 339	3	X	X	X		X							X	X	
AE 362	3	X				**X**						X	**X**	X	
AE 363	3	X				X						X	X	X	
AE 364	3	X				X						**X**	X	**X**	
AE 419	3	X				X						X	X	X	
AE 424	3			**X**	X			X					X	X	X
AE 428	3			X	**X**			X					X		**X**
AE 439	3	X				X						X	X		
AE 447	3	X	**X**			X		**X**					X	X	
ME 449	1						**X**	X		**X**	**X**				

X = courses assessed for outcome

Table 3.2.c-d. *to be provided by engineering programs.*

Table 3.2.e. *Mechanical-Engineering Course Assessment Matrix for Program Outcomes (a)-(k)*

Mapping of Mechanical Engineering Curriculum to Program Outcomes																
		Contribution to Program Outcomes											ME Specific Program Criteria			
		ability to apply knowledge of mathematics, science, and engineering	ability to design and conduct experiments, as well as to analyze and interpret data	ability to design a system, component or process to meet desired needs within realistic constraints	ability to function on multidisciplinary teams	ability to identify, formulate, and solve engineering problems	understanding of professional and ethical responsibility	ability to communicate effectively	the broad education needed to understand the impact of engineering in a variety of contexts	recognition of the need for, and an ability to engage in lifelong learning	knowledge of contemporary issues	ability to use the techniques, skills and modern tools necessary for engineering practice	knowledge of chemistry and calculus-based physics with depth in at least one	ability to apply advanced mathematics, multivariate calculus, and differential equations	familiarity with statistics and linear algebra	ability to work professionally in both thermal and mechanical systems areas
Curriculum Area	**Credits**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**ME1**	**ME2**	**ME3**	**ME4**
Required Mechanical Engineering Courses																
ME 159	2			X			X		Fulfilled by NMSU General Education Requirements			X	215, PHYS 216, CHEM 111, CHEM 112)			X
ME 222	3											X				X
ME 228		X	X	X		X								X		X
ME 236	3	X				X						X		X		
ME 234	3					X								X		
ME 240	3					X								X		X
ME 261	4	X				X						X		X	X	
ME 326	3			X	X		X				X			X		X
ME 328	3	X												X	X	
ME 338	3	X	X	X		X								X		X
ME 340	3					X								X		
ME 341	3	X				X								X		X
ME 345	3		X					X				X			X	
ME 425	3	X		X		X						X				X
ME 426/427	6			X	X			X								X
ME 445	3		X			X		X						X	X	X
ME 449	1						X	X		X	X					
X =course assessed for outcome																

Each faculty member is responsible for measuring the assigned *Program Outcomes*. These are documented in the instructors *Post Instructor Comment Form*, a copy of which is provided in the appendix. The completed *Post Course Instructor Comment Form* and other relevant materials for each course are electronically stored in an assigned folder. The *Department of Physics* performs annual reviews of achievement for each *Program Outcomes* and uses the data to determine whether program or course changes are needed. Program Outcomes Assessment and Reviews are collected and compiled electronically and in print in a separate folder.

Like Physics, the participating engineering programs have developed their own assessment matrices for their engineering courses, as shown in Table 3.2.b-e. For the engineering courses, assessment of the *Program Outcomes (a)-(k)* is done in the engineering department, which hosts that program for their majors, i.e. the *Department of Electrical & Computer Engineering* will assess *EE* courses, the *Department of Mechanical & Aerospace Engineering* will assess *AE* and *ME* courses, and the *Department of Chemical & Materials Engineering will* assess *ChME* courses. Since EP students do not have the same course requirements in their concentration compared to the majors in that engineering degree, the engineering assessment will not necessarily cover every single of those program outcomes independently (although it typically covers most of them) for every single EP student.

Course Program Outcomes Assessment

The *Department of Physics* has had a long history of monitoring student progress and learning (well before the introduction of the EP program) since *Physics Education* had been one of its research strength in the department going back to the early 1990s. While the then-developed assessment tools could be easily extended to measure some of the *ABET Program Outcomes*, particularly *Program Outcomes (a), (b)* and *(e)*, the instructors developed their own assessment tools for many of the other *Program Outcomes*, typically under the guidance of the *EP Program Committee*. In general, the *EP Program Outcomes & Assessment Procedure* is driven by the desire that each of the *Program Outcomes* should be measured by multiple courses and methods. Doing so, we made sure that the process is less dependent on individual courses, types of measurements, assessment methods or individual instructors. Below, we summarize some of the assessment approaches for the different *Program Outcomes*.

Nationally-normed tests

The *Department of Physics* commonly uses standardized national tests for measurements of achievement particularly for *Program Outcome (a) - Scientific Expertise* and *Program Outcome (e) - Problem Solving*.

For more than 20 years, the *Department of Physics* made use of *Graduate Record Exam (GRE)* questions to monitor student competitiveness at a national level. *GRE* questions are embedded in homework and/or exam problems, and the results can be taken as a direct measure of *Program Outcome (e) – Problem Solving*.

Similarly, we use the *Force Concept Inventory (FCI)* test, which can be taken as a direct measure of *Program Outcome (a) - Scientific Expertise*. The FCI test was first introduced by Hestenes, Wells and Swackhamer, *The Physics Teacher* 30, 1992, 141-158. The *FCI* measures the understanding of the basic concepts of Newtonian physics. For some courses, this test is given both at the beginning and end of the course to gauge the net student gain. Typically, the *FCI* test is used in freshman courses, but we have also given it as part of the upper-division physics mechanics course. Freshman students are typically below the *entry level* but should be past that at the end of their first year; graduating students should be at the *mastery level*.

In some cases, instructors used the national average of skill-builder questions in on-line homework programs, such as *Mastering Physics®* used in introductory courses, as additional measurement for *Program Outcome (a) - Scientific Expertise*.

Tests and probes previously developed by NMSU *Physics Education Research (PER)* group

The Department of Physics was very fortunate to have Dr. Steve Kanim as one of its faculty members. While Dr. Kanim is now retired, he still has ongoing research is in *Physics Education*

Research (PER). He helped developed many different (nationally recognized) exams and other probes to test student's conceptual understanding of physics.

As part of his research, he had also developed much of the material for the introductory physics laboratories, particularly for *PHYS 213L* and *PHYS215GL*, the introductory mechanics labs in physics. These labs allow that student performance can be evaluated at several levels, one of which provides a measurement for *Program Outcome (b) – Experimental Training*. Dr. Kanim also co-authored the *E&M TIPERs; Electricity & Magnetism Tasks* (ISBN-10: 0131854992), which is widely used nationally for the instruction of introductory electricity and magnetism, including our *PHYS 214L* and *PHYS216GL* labs.

Dr. Kanim also designed several standardized pre-requisite tests, which are given to students prior to the course. The purpose of the pre-requisite tests is to test whether students have been adequately prepared and remember the pre-req materials needed for taking a course. While most pre-requisite test are not *a priori* designed to measure ABET *Program Outcomes*, they test the level of student learning, therefore providing input on how to improve content delivery. One of his more commonly administered tests is the so-called *Mechanics & Electricity Assessment Test (MEAT)*, which does provide *Program Outcomes* measure.

Assessment tools developed by *Engineering Physics (EP) Program Committee*

The *EP Program Committee* designed a *Teamwork Evaluation Form* and an *Oral Report Evaluation Form* that can be used by individual instructors to assess *Program Outcome (d) – Teamwork* and *Program Outcome (g) Communication Skills*, respectively. Instructors are free to choose whether to make use of the provided forms for the evaluation of these two outcomes, and most of them do. These forms are provided in *Supplementary Information*.

Assessment tools developed by individual instructors

Program Outcomes (c) - Design Abilities, *(f) – Professional Responsibility*, *(h) – Societal Impact*, *(i) – Life-long Learning*, *(j) – Contemporary Issues* and *(k) – Technical Know-how*, are typically assessed using assessment tools designed by individual instructors.

Program Outcome (c) and *(k)* are mostly technical in nature, and they are typically extracted from scores or partial scores of individual assignments or projects, such as a capstone design task.

Program Outcomes (f), *(h)*, *(i)* and *(j)* have been found to be the most difficult to determine. Instructors have used a variety of approaches to come up with quantitative measures for the *Program Outcome(s)*, such as sub-scores in essays, class attendance, specialized assignments, class participation or similar.

Other Program Outcomes Assessment

The *Department of Physics* uses a senior-level test from the *Educational Testing Service® (ETS) - the Physics Major Field Test*. This test is given annually at the end of an upper-level physics course, such as *PHYS 455 (Quantum Mechanics II*) or *PHYS 462 (Intermediate Electricity and Magnetism II)*, but it is open to all seniors in physics or EP. Students are encouraged to take the test in their senior year, and participation is fully paid for by the *Department of Physics.* While the *ETS* test is not mandatory, students participating in it can earn extra-credit points in above upper-division courses and thus every EP student will take the test at least once. The *ETS* test is a commercially-produced test that is widely used physics and engineering programs across the country. It provides a comparison with the national norm for general physics topics in mechanics, electricity & magnetism, thermodynamics, and modern physics. The *ETS* test allows the course instructor to use individual scores for the second part of the exam as part of the course grade, while using group scores for individual subjects to evaluate both *Program Outcome (a) - Scientific Expertise* and *Program Outcome (e) - Problem solving*.

EP students in their graduating semester are asked complete a *Senior Student Exit Interview (SSEI)*, which include questions about students' perceptions for achievement of each of the *Program Outcomes (a)-(k).*

More details of the *Program Assessment Tools* for each individual *Program Outcome* are presented in *Criterion 4 – Continuous Improvement*.

Documentation for Assessment of Program Outcomes

Every time after teaching a relevant course, the instructor is expected to file course and evaluation materials in the *'Maroon' Instructor Notebook* (it is called 'maroon' because of the color of the binder). The most important document in the *Instructor Notebook* is the completed *Post-Course Instructor Comment Form*, which summarizes class details, results of program outcome measurements and some general comments. A copy of the *Post-Course Instructor Comment Form* is provided in Supplementary Documentation. Other materials that instructors will file in the *Instructor Notebook* are listed below. In general, the *Maroon Instructor Notebooks* will contain information and a summary the course each semester it was taught. This provides important feedback to instructors of future course and ensures continuity. Its contents are listed below.

A complementary *'White' Course Notebooks* is prepared once every 6 years, just prior to *ABET* accreditation visit. The *Course Notebooks* contains a detailed summary and examples of student work for each assignment. Its contents are listed below.

Finally, there are separate *'Blue' Program Outcomes Notebooks*, which contains yearly reports for each of the program outcomes, among other documents (see detailed list below). Since 2010, each faculty member of the *Department of Physics* will be charged in summarizing the measurements of a program outcome. This ensures faculty involvement in the ABET assessment process. The *Program Outcomes Notebook* also contains the results of our yearly student progress reports, where progress of each student is reviewed individually. Its contents are listed below.

As a practical matter, we began keeping the notebooks online in 2008, and print them out for *ABET* assessment. Virtual notebooks are available to all faculty and are much more useful in that form. In summary, the notebooks contain the following:

'Maroon' Instructor's Notebooks (prepared at the end of each course)

- completed *Post-Course Instructor Comment Form*.
- supporting material for Outcomes Assessment *(a-k)* (questions, tests, etc.).
- syllabus and actual schedule followed
- copies of exams, quizzes and homework, or references thereto.
- copies of other class materials

'White' Course Notebooks (prepared for *ABET* review cycle)

- course outline and syllabus

- copies of all assignments, i.e. pre-req. test, exams/labs/quizzes/homeworks/projects
- copies of student work for each assignment (typically: high/medium/low)
- hand-outs and other material used
- summary of student evaluations

'Blue' Outcomes Notebooks (prepared for *ABET* review cycle)

- Part 1: separate notebooks for each of the *Program Outcomes (a)-(k)* containing annual summaries of all outcomes measures.
- Part 2: supplementary documents, such as
    - *Post-Course Instruction Forms* for courses taught during the reporting period
    - *Senior Student Exit Interview (SSEI)*
    - summaries of *ETS-MFT* tests
    - other outcomes measures