Engineering Physics - What is it, really?

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I. Introduction

The Physics Department at University of Wisconsin - Platteville (UWP) initiated its engineering physics program in 1996. During these past 5 years, the number one question heard from university administrators, prospective employers, and prospective students has been "What is Engineering Physics?". We have developed and refined an answer to that question based on our program at UWP, and that answer has seemed to satisfy most of the questioners. But as we prepared for our initial ABET inspection in fall 2000, we began to ask "What does Engineering Physics mean in other schools?" This paper is an attempt to answer that question.

Engineering physics (EP) has been around as an educational discipline in the United States for about 75 years. ABET began accrediting EP programs in 1949 with University of Maine and University of Oklahoma both achieving accreditation in that year.[1] The Physics and Engineering Physics Division of ASEE was started by Prof. Bennett who also started the program at University of Maine.[2] In 2000 there were 15 accredited and at least 32 non-accredited under-graduate programs across the country. The programs are located in all parts of the country and represent all types of colleges and universities. Appendix I lists all the EP programs identified from an Internet search. All the programs share the same title - Engineering Physics - and include at least some physics and some engineering, but that is about all they have in common. They differ in academic administration, relative amounts of physics and engineering, and both physics and engineering content. This paper looks at both the differences and the similarities in all the programs in an effort to better define what is meant by Engineering Physics.

Most of the information for this paper was taken from the EP program web pages. (Appendix I includes the URL's for the university home pages.) A total of 47 programs were identified. The web sites for 14 of the 15 accredited programs and 31 of the 32 non-accredited programs included curriculum information. The curriculum statistics below are based on these 45 programs. In addition a brief questionnaire (Appendix II) on enrollment numbers and course content was emailed to all the programs. About half (9 accredited, 14 non-accredited) responded, so the enrollment statistics are based on just these 23 programs.

II. Administration of EP Programs

The differences in programs begin with differences in academic identity. Most of the EP programs are offered as alternatives to traditional physics programs; however, 2 of the 23 respondents do not offer a traditional undergraduate physics major. A majority of the programs (38 out of 47) are administered by Physics Departments or the equivalent on campus. The remainder either have their own Engineering Physics Department separate from the Physics Department, are offered by a traditional engineering department, or are administered by interdisciplinary committees. About 20% of the EP programs, including one accredited program, are offered by Physics Departments at universities that do not offer any other engineering. The engineering content in these programs is taught by faculty in the Physics Departments. Figure 1 summarizes these statistics on EP administration.

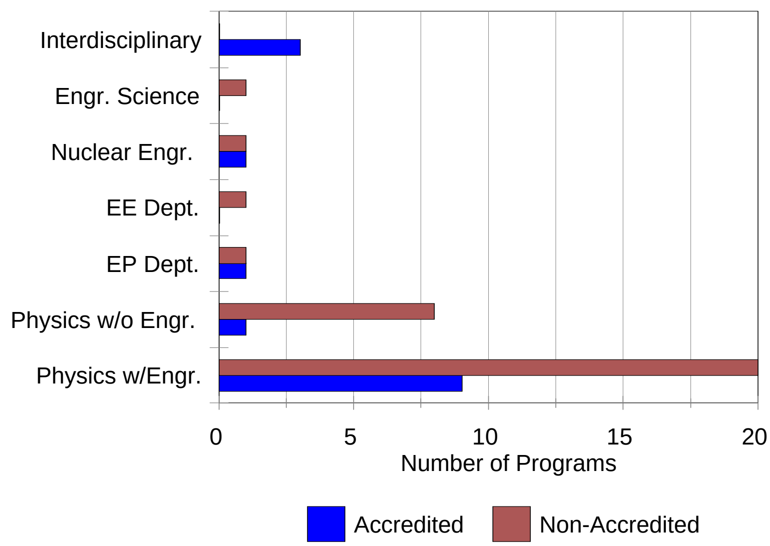

Figure 1: Administrative responsibility for engineering physics programs.

III. EP Graduates

The largest programs responding to the survey graduate about 25 EP majors per year. Most of the programs are much smaller than that. The average number of graduates for the programs responding was 7 per year. In some schools the number of EP graduates was greater than the number of Physics graduates; in other schools it was less. The "employment" of EP graduates is also quite varied, although probably not much more than the "employment" of Physics graduates. From the responses to the survey about 50% of the EP graduates go directly into industry with another 8% going to government labs or other types of employment. Approximately 40% go directly to graduate school, about equally split between physics and engineering. These data are summarized in Figure 2.

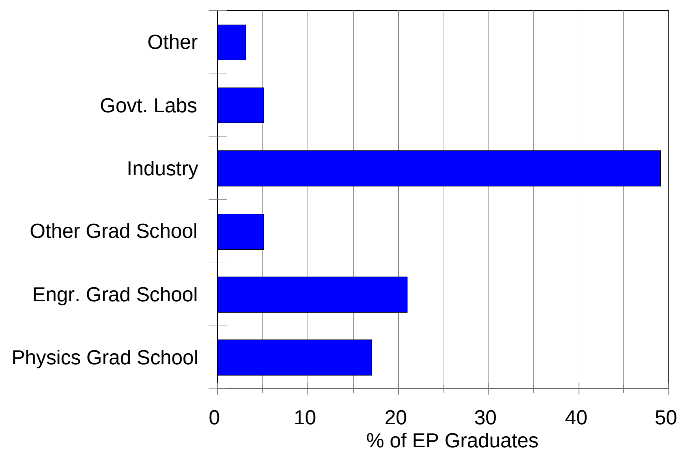

Figure 2: "Employment" of EP Graduates

IV. Curriculum Mix

All the EP programs combine engineering and physics in some proportion, but the relative amounts of each vary dramatically. Figure 3 shows the number of semester credits required by each accredited program in physics and engineering plus a separate listing of credits that could be taken from either engineering or physics. The physics credits do not include the two-semester sequence in general physics which is taken by almost all engineers. Physics includes Modern Physics, Theoretical Mechanics, Thermal Physics, Electricity and Magnetism, Optics, Quantum Mechanics (including Atomic and Nuclear Physics), Advanced Physics Lab, and other courses commonly identified with physics. Mathematical Physics courses were not included because they usually cover subjects included in math courses at other schools. Electronics and Design Project courses were counted as engineering credits even if offered by Physics Departments. The engineering credits do not include Introduction to Engineering or Graphics credits. The horizontal line at 48 credits represents the minimum amount of engineering science and design required for accreditation. The combined physics and engineering credits of all the accredited programs in Figure 3 obviously exceed this level. For comparison a traditional 36-credit physics major would probably include 25-28 physics credits as identified in this graph.

The amount of required engineering in the accredited EP curricula ranges from 76% of the total physics/engineering credits down to 17%. The required credits in the accredited programs average 23 $\pm$ 5 in physics and 36 $\pm$ 8 in engineering. All but 3 of the accredited programs fall within these standard deviations. Programs 16 and 44 (see Appendix I for identities) include enough required engineering credits to achieve accreditation without the physics credits. The rest of the programs must count at least some of their physics credits as engineering. Program 11, with only 10 credits of engineering, is housed in an EP department which offers most of the required course work for the EP major. It was impossible to distinguish between physics and engineering in many of the courses.

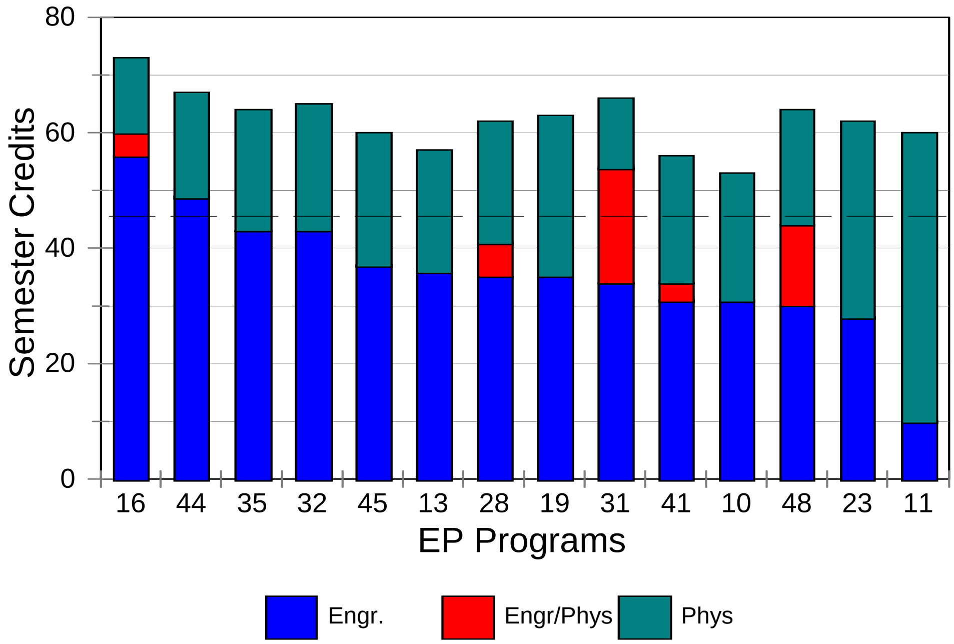

Figure 3: Engineering and Physics credits in Accredited Engineering Physics Programs. The horizontal line represents the ABET minimum for engineering science and design**.** The numbers identify the EP programs in Appendix I.

Figure 4 presents the same statistics for the non-accredited programs. As expected the credit distribution here varies more than in the accredited programs. In the survey only 4 of the 14 non-accredited respondents indicated an intent to seek accreditation in the next few years. Therefore, most of the non-accredited programs are not designed to meet ABET standards. In fact the total physics and engineering credits in 14 of the 32 programs fall short of the ABET minimum. Most of the programs are weighted more toward physics than their accredited counterparts. The required engineering credits for 22 of the 32 non-accredited programs fall below the 1σ level for the accredited programs (28 credits of engineering), although 6 of those do have enough physics/engineering electives to make up the difference. At least a third of these programs are basically physics majors with minimal engineering.

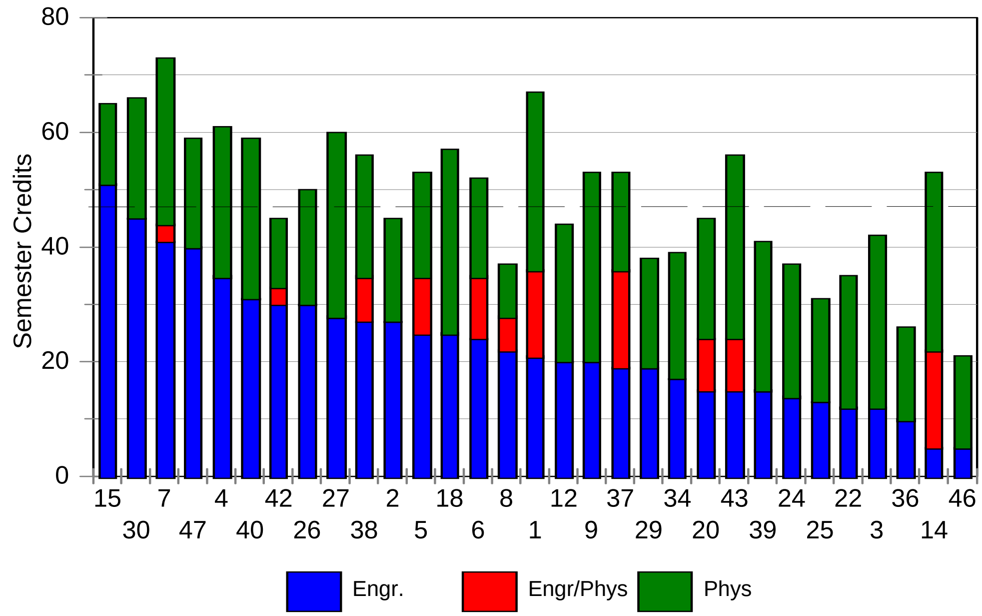

Figure 4: Engineering and Physics credits in Non-Accredited Engineering Physics Programs. The horizontal line represents the ABET minimum. The numbers identify the EP programs in Appendix I.

On the other extreme only 6 of these programs require less physics than the 1σ level in the accredited programs. A couple of these are programs with very low total credits so the physics requirement is still over half the total. The other 4 also have low total credits but they are weighted more to engineering. The average number of required physics credits in the non-accredited programs was the same as the average in the accredited programs, 23 ± 6.

V. Curriculum Content

In addition to the differences in the respective amounts of physics and engineering required in the curriculum, EP programs also differ in the physics and engineering content. Figure 5 shows the number of programs (percentages of the 14 accredited programs and 31 non-accredited programs) requiring at least one semester in each of several physics disciplines. Every one of the programs require Electricity and Magnetism. Over 2/3 of both accredited and non-accredited programs also require at least one semester of Modern Physics, Newtonian Mechanics, Quantum Mechanics, and Advanced Physics Lab. Courses in atomic physics have been included with the quantum physics count. The non-accredited programs also require Thermal Physics. The above subjects are also required by most traditional physics programs. Only about 1/3 of the EP programs require a course in Optics, and very few require Solid State Physics. These courses are available as electives in some of the programs; others don't offer them, don't require them, or substitute engineering courses. Optics would be required by a larger percentage of traditional physics programs; Solid State is usually an elective, if it is even available. Other physics courses are required or accepted as electives by a few EP programs, but nothing else is consistent throughout a significant number of programs.

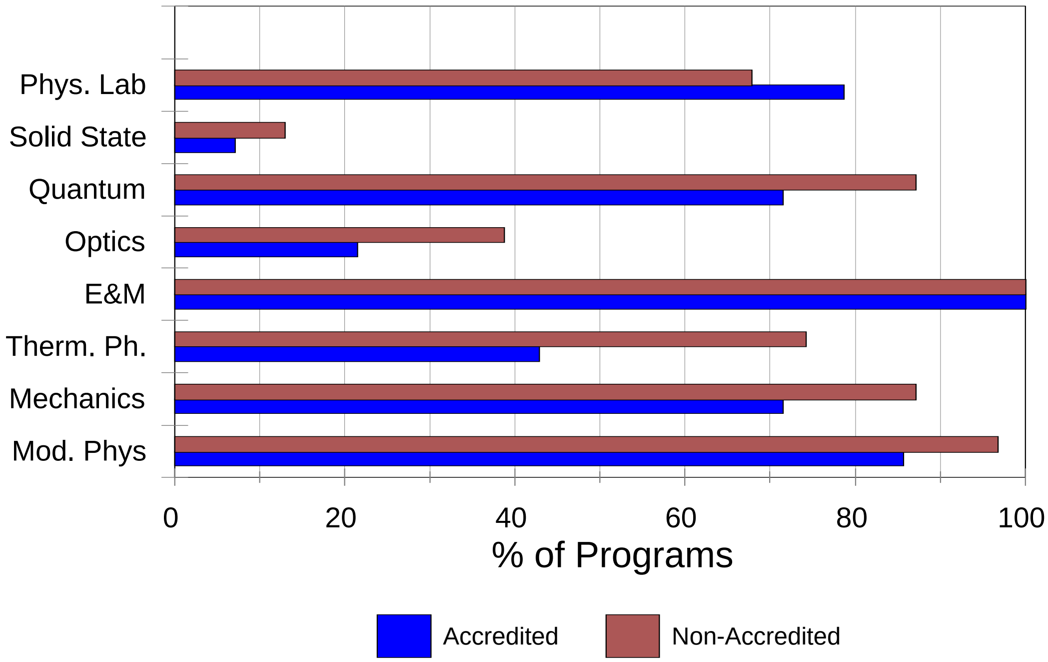

Figure 5: Required Physics Courses in Accredited and Non-Accredited EP Programs.

EP programs also vary in their approach to the required physics courses. In order to bring physics and engineering together into a single discipline, many of the programs have altered their approach to some or all of their "physics" courses. In response to the questionnaire, 5 of the 9 accredited programs and 5 of the 14 non-accredited programs indicated that they introduce engineering topics and/or applications into their physics courses. The larger percentage for the accredited programs reflects the ABET requirement for adequate engineering science and design in the curriculum.

The engineering content in EP programs is much more varied. Figure 6 shows the statistics for several basic engineering areas. The only engineering subject required by 2/3 of all programs is circuits, and even there the number of credits varies significantly (3 -8). A large majority of the accredited programs also require some type of capstone design course, most are one semester but a few are two semester sequences. Not surprisingly, a capstone design course is required in less than a third of the non-accredited programs. Requirements in the other engineering subjects vary widely. The engineering mechanics and engineering thermodynamics requirements tend to complement the physics requirements in mechanics and thermal physics, respectively, although a number of programs require both physics mechanics and engineering statics. Only a few require both mechanics and engineering dynamics. Most of the engineering subjects are required by more accredited programs than non-accredited ones.

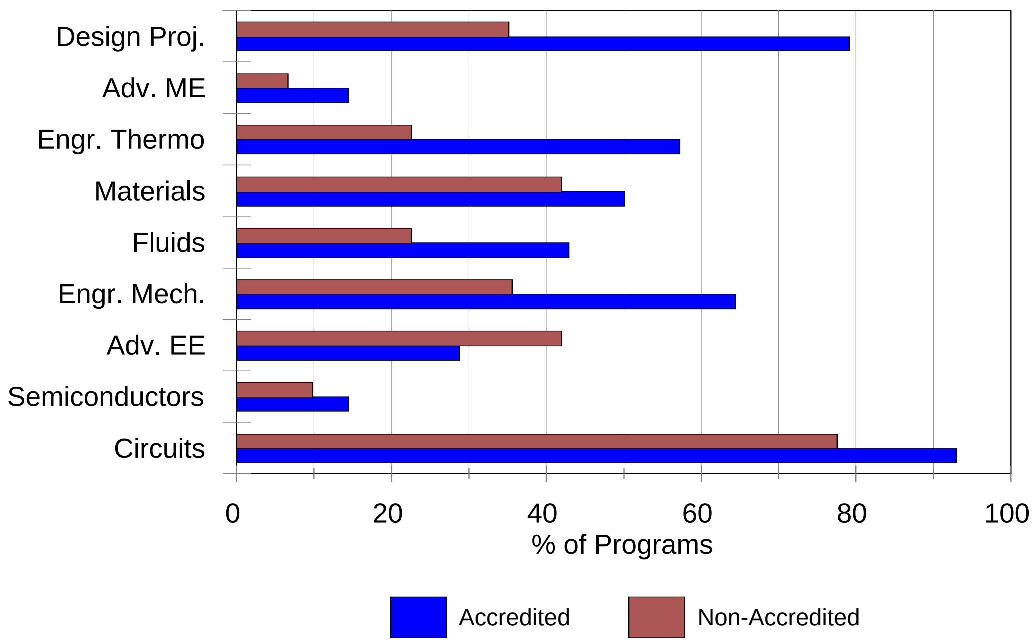

Figure 6: Required Engineering Courses in Accredited and Non-Accredited EP Programs.

Missing from the picture presented by Figures 5 and 6 are the electives, which play a larger role in the engineering coverage than in physics. Most of the programs (39 out of 45; all the accredited) include some electives in their curriculum. Many of these are true electives; others are dictated by a student's choice of emphasis. Either way the large number of electives is consistent with a broad definition of engineering physics.

Figure 7 summarizes the elective requirements of the programs. Accredited programs allow for an average of 20 $\pm$ 9 credits of electives within the required curriculum; for non-accredited programs the number is 14 $\pm$ 10. These elective credits allow EP majors to tailor the curriculum to their interests. Most programs allow for a broad range of choices in the electives so different students end up with very different emphases within the EP major. Some programs allow students to choose their electives from any other engineering major, others restrict the choices to a designated few engineering majors, and still others restrict the electives to a sub-discipline (such as solid state electronics). Physics electives are also allowed in many programs, so students are able to develop an applied physics emphasis within engineering physics. Table I summarizes the types of engineering emphases available in the different programs. This breadth of emphases seems to be one of the defining characteristics of engineering physics. Within a single academic discipline - EP - students can focus on areas as diverse as digital electronics and civil engineering. In many programs these students will be together in all their physics and capstone design classes providing for truly multi-disciplinary experiences right in the EP program.

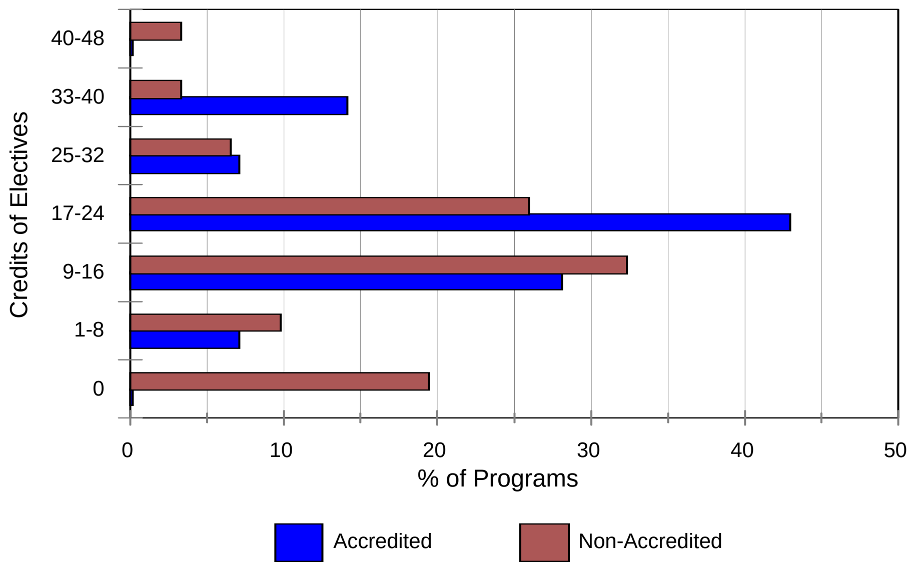

Figure 7: Elective Credits in Accredited and Non-Accredited EP Programs.

Table I: Emphases in EP Programs

Aerospace Engineering	Electro-mechanical
Applied Physics	Industrial Engineering
Chemical Engineering	Mechanical Engineering
Civil Engineering	Nuclear Engineering
Computer Science	Optics
Electrical Engineering	Solid State Electronics/Materials

VI. Conclusion

The above statistics provide a picture of what engineering physics represents in different schools. Although the programs are very diverse, there are some consistencies which define engineering physics. Most of the programs, both accredited and non-accredited, require a comparable amount and content of physics. 27 of the 47 programs require between 18 and 28 credits of physics. The percentage is even higher for the accredited programs - 11/14. Most of the programs include Newtonian Mechanics, Electricity and Magnetism, Modern Physics, Quantum Mechanics, and Advanced Physics Lab in these required credits. From this we can conclude that engineering physics includes a solid foundation in physics.

In contrast to the physics requirements, the engineering requirements in the engineering physics programs is very inconsistent, both in amount and content. The accredited programs were somewhat consistent, dictated by the ABET requirements. 12 of the 14 programs required more than 30 credits of engineering. The non-accredited programs varied from 5 to 51 credits of engineering. Only 8 of the 31 non-accredited programs require more than 30 credits of engineering. These programs are basically indistinguishable from the accredited programs. Most of the remaining 23 programs require only a small amount of engineering to complement a standard physics major. These programs are basically a physics major with an engineering minor, or less. 13 programs require less than 20 credits of engineering. Graduates of these programs are physics majors with some exposure to engineering. From these statistics we can conclude that at least accredited engineering physics includes a solid background in engineering. Other programs which call themselves engineering physics fall short in engineering, and maybe are more applied physics than engineering physics.

The engineering content in the different programs also varies considerably, much more than the physics content. Most of the programs require some electronics, but this is true of most physics programs as well. A majority of accredited programs also require engineering mechanics and engineering thermodynamics. The engineering mechanics tends to be a supplement to theoretical mechanics, usually just statics. The engineering thermodynamics is a complement to the thermal physics; almost all the programs required either thermal physics or engineering thermodynamics. The only other subject required by a majority of the accredited programs was design, to fulfill the ABET requirement for a capstone design experience. Only the electronics was required by a majority of the non-accredited programs. From this we can conclude that engineering physics includes some electronics, some type of thermodynamics, and, for accreditation, design. Beyond that the engineering content varies dramatically from school to school.

What *is* characteristic of the engineering requirements throughout the programs is diversity and choice. Many of the programs develop engineering emphases within their curriculum, although the nature of these emphases vary from school to school. Also, 35 of the 47 programs (12 of 14 accredited) allow for 12 or more credits of choice in the major. Most of these choices are engineering credits. These choices within the same program allow students to develop their own concentrations or emphases, which may vary from student to student. If nothing else, engineering physics is multi-disciplinary.

All these characteristics are best summarized in a definition of EP found on the Wright State University web page. "This (EP) program merges a strong knowledge of physics with the knowledge of designing unique engineering systems, processes, and devices. An engineering physicist completes the link between the scientist and the engineer by applying theoretical approaches to practical problems."[3] This sums up the true essence of engineering physics. Programs that fulfill this definition are truly engineering physics programs. Those that don't are something else.

References

1. URL: http://www.abet.org/accredited_programs/EACWebsite.html.
2. Private communication with Professor Charles W. Smith, Department of Physics, University of Maine.
3. URL: http://www.wright.edu/academics/physics/programs/bsegphys.htm

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Appendix I: Undergraduate Engineering Physics Programs in the United States

School	Web Address	ABET accredited
1. University of Arizona	arizona.edu	
2. Arkansas Tech	atu.edu	
3. Binghamton University	binghamton.edu	
4. Bradley University	bradley.edu	
5. Univ. of California - Berkeley	coe.berkeley.edu	
6. Univ. of California - San Diego	ucsd.edu	
7. Case Western	cwru.edu	
8. Univ. of Central Oklahoma	ucok.edu	
9. Univeristy of Colorado	colorado.edu	
10. Colorado School of Mines	mines.edu	Yes
11. Cornell University	cornell.edu	Yes
12. Dartmouth College	dartmouth.edu	
13. Embry Riddle	db.erau.edu	Yes
14. University of Illinois	uiuc.edu	
15. Univ. of Illinois - Chicago	uic.edu	
16. University of Kansas	ukans.edu	Yes
18. Lehigh University	lehigh.edu	
19. University of Maine	umaine.edu	Yes
20. Univ. Massachusetts - Boston	umb.edu	
21. University of Michigan	umich.edu	
22. Morgan State	morgan.edu	
23. Murray State University	mursuky.edu	Yes
24. Northern Colorado University	unco.edu	
25. North Dakota State	ndsu.edu	
26. Univeristy of North Texas	unt.edu	
27. Ohio State University	ohio-state.edu	
28. University of Oklahoma	uo.edu	Yes
29. Oklahoma State	okstate.edu	
30. Oregon State	orst.edu	
31. University of Pacific	uop.edu	Yes
32. University of Pittsburgh	pitt.edu	Yes
33. Princeton University	princeton.edu	Yes
34. Purdue-Calamet University	calumet.purdue.edu	
35. RPI	rpi.edu	Yes
36. Samford	samford.edu	
37. Santa Clara University	scu.edu	
38. SE Missouri State	semo.edu	
39. University of South Carolina	sc.edu	
40. South Dakota State	sdstate.edu	
41. Stevens Institute of Technology	stevens-tech.edu	Yes
42. Tarleton State University	tarleton.edu	
43. University of Tennessee	utk.edu	
44. Texas Tech	ttu.edu	Yes
45. Tulsa University	utulsa.edu	Yes
46. Westmont College	westmont.edu	
47. University Wisconisn-Platteville	uwplatt.edu	
48. Wright State University	wright.edu	Yes

Appendix II: Questionnaire

The questions below refer to your Engineering Physics program, unless otherwise stated. I have included the answers for our program here at UWP as a guide. (note: our program is only 5 years old so we only have one full graduation class.) Your participation is greatly appreciated. Any responses prior to 20 December will be included in my statistics.

	UWP	Your program
1. How many years have you had an Engineering Physics program?	5	
2. What is the average number of EP graduates per year?	7	
3. On graduation what % of your EP graduates go on to		
Grad school in Physics ‘	10%	
Grad school in Engineering	0%	
Grad school, other	10%	
Govt. Labs (including NASA)	0%	
Industry	80%	
Other	0%	
4. In courses normally thought of as Physics classes (Mechanics, E&M, Thermal Physics, Quantum, Optics, etc) do you alter the approach to incorporate more engineering applications for the EP students?	Yes	
5. Is your program ABET accredited?	No	
If not, are you seeking accreditation?	Yes	
How soon (estimate)	2001	
6. Does your university also offer a regular physics major?	No	
7. If your answer to 6 is yes, what is the average number of physics graduates per year?	NA	