

**Institutional Effectiveness  
2020-2021**

**Program:** Physics BS

**College and Department:** College of Arts & Science – Department of Physics

**Contact:** Stephen Robinson

**Mission:** The mission statement for the TTU Department of Physics is to promote the learning of physics through effective teaching, research, and public service. Such learning opportunities are provided to students of all disciplines, in support of the mission of the University.

The department addresses this mission through two programs:

1. a coherent program of study leading to a B.S. in Physics, and
2. a service program that provides courses in physics and astronomy that are requirements for other degree programs or are used by students to fulfill general education science requirements.

**Program Goals:**

PG 1: The Department will recruit and retain sufficient majors for a thriving educational program.

Increase majors at least one per year. Having sustained an average of at least 30 majors for several years, the current minimum acceptable threshold is that the average number of majors should not drop below 30.

PG 2: The Physics Department will contribute to the mission of the Millard Oakley Center for Teaching and Learning in Science, Technology, Engineering, and Mathematics (STEM).

The majority of faculty in the department will support the center by teaching at least one class using its facilities and/or facilitating activities in center outreach events.

Physics students will engage in at least three center outreach activities per year.

PG 3: Ensure the use of effective and innovative pedagogical methods within the classroom.

All faculty will report on changes/innovation in instruction in their annual reports, reflecting on their utility with regard to student learning and attitudes. Changes that result in improved student performance are expected to be adopted and will be shared with the department as a whole. As a minimum, faculty are expected to report on one such strategy per year.

PG 4: Provide opportunities for all physics majors to gain experience in authentic basic or applied research.

All faculty engaged in research in suitable fields will seek support to engage interested physics majors in their work. Opportunities at other institutions and in other fields will also be made known to physics majors. The targeted outcome is that all physics majors will have the opportunity to engage in such opportunities as many times as they wish during their TTU career. At a minimum, any interested student should engage in at least one such opportunity.

### **Student Learning Outcomes:**

SLO 1: Students completing calculus-based and algebra-based introductory physics courses will demonstrate increased understanding of foundational basic concepts in mechanics.

Students will achieve an average normalized gain score of at least 45% on a standard diagnostic test. For many years the targeted goal was a gain of 40%, but with recent improved performance, this year the target was raised to 45%. Currently, the minimum acceptable performance for any particular class section is a 30% gain, and any gain greater than 50% is regarded as exemplary.

SLO 2: Students graduating in physics will demonstrate an understanding of the basic principles and foundations of physics.

Graduating seniors will score, on average, at or above the 75<sup>th</sup> percentile on the ETS Major Field Test in Physics. The threshold of acceptability is to have all seniors score at or above the 50<sup>th</sup> percentile, thus maintaining a claim that TTU physics graduates are 'above average'.

SLO 3: Students graduating in physics will demonstrate the skills and techniques necessary to engage in authentic experimental investigation.

Students will demonstrate their ability to engage in experimental investigations by meeting or exceeding the minimum standards of the capstone Advanced Experimental Physics course (PHYS 4710 or PHYS 4711). The targeted outcome is that at least 75% of students should meet or exceed the minimum standards.

SLO 4: Students graduating in physics will demonstrate the ability to communicate their understanding orally in a presentation format.

Students will demonstrate their ability to effectively communicate their capstone Advanced Experimental Physics project (PHYS 4710 or PHYS 4711). The targeted outcome is that at least 75% of students should meet or exceed the minimum communication standards on the project rubric.

SLO 5: Students graduating in physics will have received an introduction to a range of common technological tools appropriate to physics and related disciplines.

All graduating physics majors and alumni report being adequately prepared to use technological tools appropriate to physics and related disciplines in their employment or graduate studies.

SLO 6: The TTU physics program will give students sufficient preparation in content and skills/techniques to continue to graduate school or obtain suitable employment.

All graduating seniors and alumni will report being well prepared to continue on to graduate school in physics (or a closely related discipline) or to enter immediate employment, whichever is relevant to their particular situation.

SLO 7: Students graduating in physics will demonstrate the skills and techniques needed to engage in planning and carrying out basic or applied research.

Students will demonstrate competency by completing a research project in PHYS 4730 (Research Planning) and PHYS 4740 (Research) courses taken as seniors. Students will meet or exceed the minimum standards of the research course (PHYS 4730 or PHYS 47140). The targeted outcome is that at least 75% of students should meet or exceed the minimum standards.

A departmentally developed curriculum map can be found in Appendix 1 that shows the connections between courses and student learning outcomes.

#### **Assessment Methods:**

*PG 1: The Department will recruit and retain sufficient majors for a thriving educational program.*

*Department Records:* At the beginning of each fall semester a count is made of the number of the total number of enrolled students who have Physics declared as a major. Because of the small numbers involved, trends are tracked using an average of the current year plus the previous four years. The department keeps a record of student participation in the research of department faculty members and in specialized summer research programs for undergraduates at other institutions. (Note: since almost all such experiences must necessarily take place during the summer it is impossible to ensure that all students will take advantage of such opportunities. However, the department will encourage such participation as actively as possible.) At the end of each academic year, a count is made of the number of actual or proposed projects, programs, and outreach events in which members of the Physics faculty and physics undergraduates were jointly involved with the Millard Oakley Center for Teaching and Learning in Science, Technology, Engineering, and Mathematics (STEM).

*PG 2: The Physics Department will contribute to the mission of the Millard Oakley Center for Teaching and Learning in Science, Technology, Engineering, and Mathematics (STEM).*

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*PG 3: Ensure the use of effective and innovative pedagogical methods within the classroom.*

*Annual Faculty Reports:* In their annual reports, faculty members will be asked to comment on their awareness of new pedagogical developments and whether they have tried to implement them in their own teaching.

*PG 4: Provide opportunities for all physics majors to gain experience in authentic basic or applied research.*

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*SLO 1: Students completing calculus-based and algebra-based introductory physics courses will demonstrate increased understanding of foundational basic concepts in mechanics.*

*Force Concept Inventory:* The Force Concept Inventory is a nationally recognized diagnostic test of basic conceptual understanding and is administered to all students at the beginning of both PHYS 2010 and PHYS 2110 courses, and then again after the relevant material has been covered. The normalized gain score, used to judge improvement in understanding, is a measure of the actual improvement in performance after instruction, versus the maximum possible improvement.

*SLO 2: Students graduating in physics will demonstrate an understanding of the basic principles and foundations of physics.*

*Major Field Test:* The ETS Major Field Test in Physics is a 70-item multiple-choice test that covers: Classical Mechanics and Relativity; Electromagnetism; Optics and Wave, Thermodynamics and Statistical Mechanics; Quantum Mechanics and Atomic Physics; and other Special Topics. All physics graduates will take the ETS Major Field Test in Physics during their final semester at TTU. Due to a low number of students, only two sub-scores are provided with the Exit exam results.

*SLO 3: Students graduating in physics will demonstrate the skills and techniques necessary to engage in authentic experimental investigation.*

*PHYS 4710/4711 Capstone Course:* All physics majors take a senior lab course, either PHYS 4710 (4 cr) or PHYS 4711 (2 cr). To be successful in this course students must synthesize many skills learned in their academic careers to date. They must engage in scientific investigation by planning and carrying out experiments, and they must use their physics knowledge to guide them and to interpret their results. They must also submit written reports of all their investigations and make a public oral presentation of one project at the end of the semester. Faculty present at these presentations will submit a report on them. A written summary of these reports, together with an assessment as to whether a particular student has met this outcome, will be compiled by the faculty member teaching the course, and placed in the student's file.

*SLO 4: Students graduating in physics will demonstrate the ability to communicate their understanding orally in a presentation format.*

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*SLO 5: Students graduating in physics will have received an introduction to a range of common technological tools appropriate to physics and related disciplines.*

*Exit Interviews:* Exit Interview with students who are getting ready to graduate from the program. While these students do not have the benefit of post-program experience, they do have a fresher recollection of their TTU experiences and so can provide valuable feedback on some elements of the program. The department chair already conducts a confidential exit interview with each graduating physics major. These interviews explicitly address how well prepared each student feels for their next career step, including their preparation in the use of technological tools and development of research skills.

*Alumni Surveys:* Because of the low number of physics graduates, the alumni surveys are administered to department alumni on an approximate 5-year cycle. Among the questions asked are how well graduates felt the TTU physics program prepared them for their chosen career path, and how effectively they were introduced to appropriate technological tools. (The most recent results available are from the survey conducted in Fall 2019 in conjunction with the department's scheduled academic audit.)

*SLO 6: The TTU physics program will give students sufficient preparation in content and skills/techniques to continue to graduate school or obtain suitable employment.*

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*SLO 7: Students graduating in physics will demonstrate the skills and techniques needed to engage in planning and carrying out basic or applied research.*

*PHYS 4730 (Research Planning) and PHYS 4740 (Research) Capstone:* All physics majors must take these two senior level research courses. To be successful in these courses, students must create a detailed research plan and present it both in written and oral formats (PHYS 4730). They must then conduct the planned research and again present the results in written and oral formats (PHYS 4740). Each year the department will judge students' competence in planning and conducting research and communication.

**Results:**

*PG 1: The Department will recruit and retain sufficient majors for a thriving educational program.*

The number of declared physics majors at the start of the Fall 2020 semester was 28. Though this was an increase of 5 on last year, the 5-year average remains at 28, below the minimum acceptable threshold. Last year we proposed several initiatives to improve recruitment and retention. Unfortunately, we were not able to implement all of these due to the COVID-19 pandemic. However, increased efforts at personal contact and involving current students in recruitment have resulted in a significant increase in the number of applications and admissions for the Fall 2021 semester.

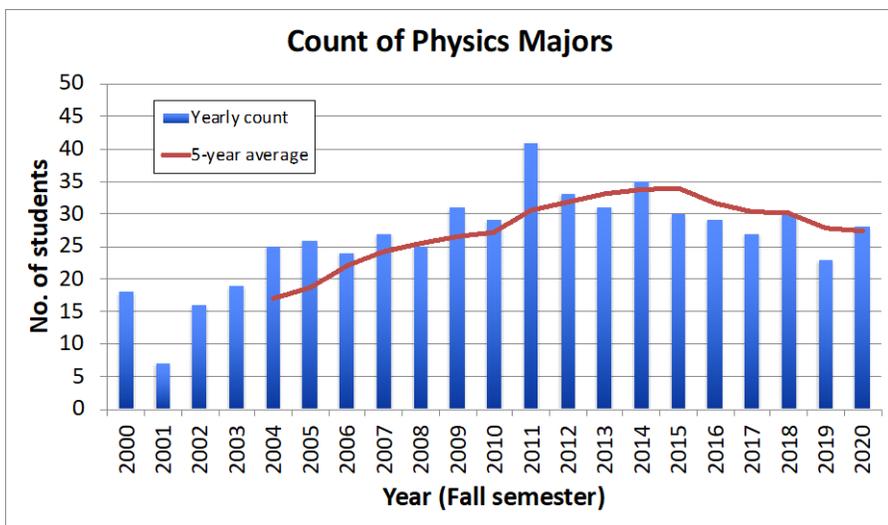


Fig 1. Number of students declaring a physics major at the start of each academic year.

PG 2: *The Physics Department will contribute to the mission of the Millard Oakley Center for Teaching and Learning in Science, Technology, Engineering, and Mathematics (STEM).*

Physics faculty involvement in projects and programs associated with the Millard Oakley STEM Center (MOSC) continued at a high level despite the COVID-19 pandemic. Six faculty members made use of the MOSC facilities for at least one of their courses. Two of these faculty members were also PIs on separate grants administered by MOSC. Because of the pandemic, MOSC only offered limited online outreach, and only one faculty member (and no students) was involved in these. This does meet the target for involvement of faculty, but not for students. However, given the circumstances, this is understandable.

PG 3: *Ensure the use of effective and innovative pedagogical methods within the classroom.*

All faculty reported that they tried at least one different strategy in their classes this year. Although much of this was as a result of the restrictions imposed by the COVID-19 pandemic, some have said that various strategies proved to be so useful that they will continue to employ them in their 'in-person' classes. Such strategies include:

- Holding virtual help sessions over Zoom.
- In active-learning classes, having students record their thinking in shared Google documents that are then posted on the course iLearn site.
- Using on-line whiteboards to annotate and share diagrams.
- Posting recordings of class discussion for later review.
- Assigning specific roles for group work in class.

PG 4: *Provide opportunities for all physics majors to gain experience in authentic basic or applied research.*

During this year a total of twenty individual undergraduate students participated in research activities of various types with department faculty members. This is a remarkable achievement, given the restrictions imposed by the COVID-19 pandemic. In addition, one graduate student in the College of Education was mentored by two physics faculty members. All physics majors who desired such an experience were accommodated, thus achieving the target for this goal.

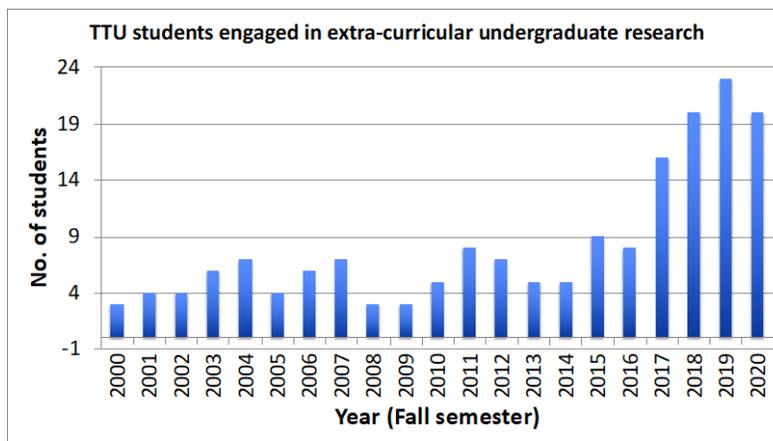


Fig 2. Number of undergraduate students engaged in extra-curricular research.

*SLO 1: Student Learning Outcome 1 - Students completing calculus-based and algebra-based introductory physics courses will demonstrate increased understanding of foundational basic concepts in mechanics.*

In the Fall 2020 all PHYS 2110 sections were delivered using a variety of hybrid or online formats. Unfortunately, only one of these sections (the one designated as officially ‘online’) achieved the goal of a normalized gain of 45%. The low performance of the other sections is likely attributable to both faculty and student discomfort with the delivery formats employed. For the Spring 2021 semester we used appropriate classroom spaces to revert to ‘socially-distanced’ in-person instruction for four sections, a fifth again being designated as ‘online’. Three of the five sections surpassed the goal, with the lowest gain of 33% being attained by the online section. Folding in these results, the rolling 5-semester average gain now stands at 46%, surpassing the goal of 45% set only two years ago! Unfortunately, the disruption caused by the COVID-19 pandemic has meant that often significantly less than half the students in these classes completed the post test, so we will wait to make decisions on any changes until the situation gets back to normal.

Turning to PHYS 2010, all sections were taught using an online format in both semesters. Interestingly, the average gain for the fall sections taught using the guided-inquiry LEAP curriculum was 50%, whereas for the spring it was only 28%. On reflection, we attribute this drop off mainly to certain concepts not being addressed due to time constraints. Reluctantly, we continued to offer one section of PHYS 2010 in the more traditional manner. This because of i) the need to accommodate students who cannot fit the LEAP format into their schedule, and ii) not enough faculty who are comfortable teaching in the LEAP format. Low registration in this section meant that no meaningful data could be collected in either semester, but past history indicates that gains of less than 20% are typical. We hope that an expected opportunity to hire a new faculty member in the near future will help to address this issue.

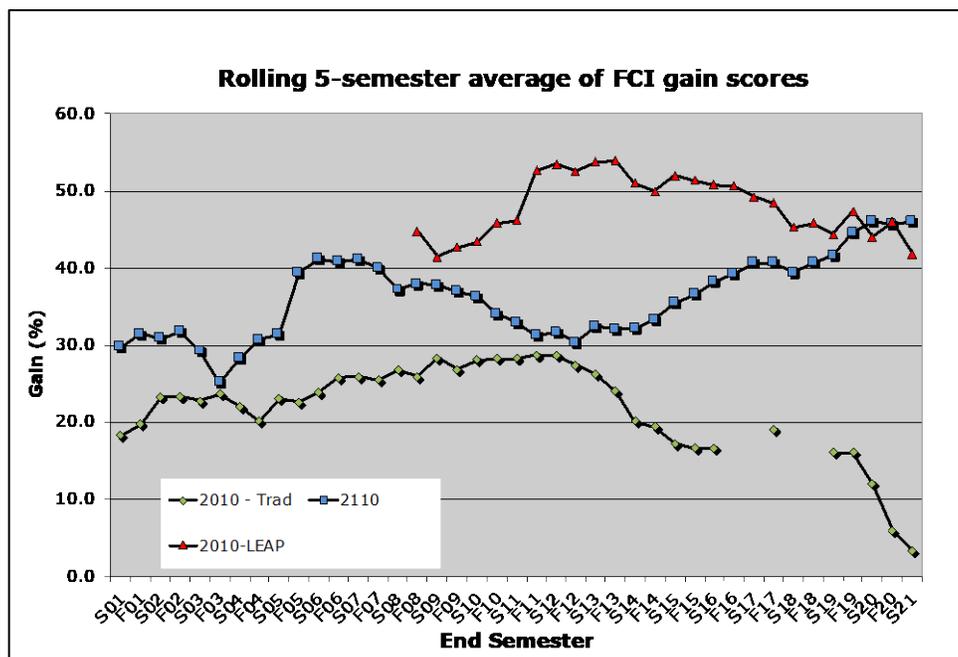
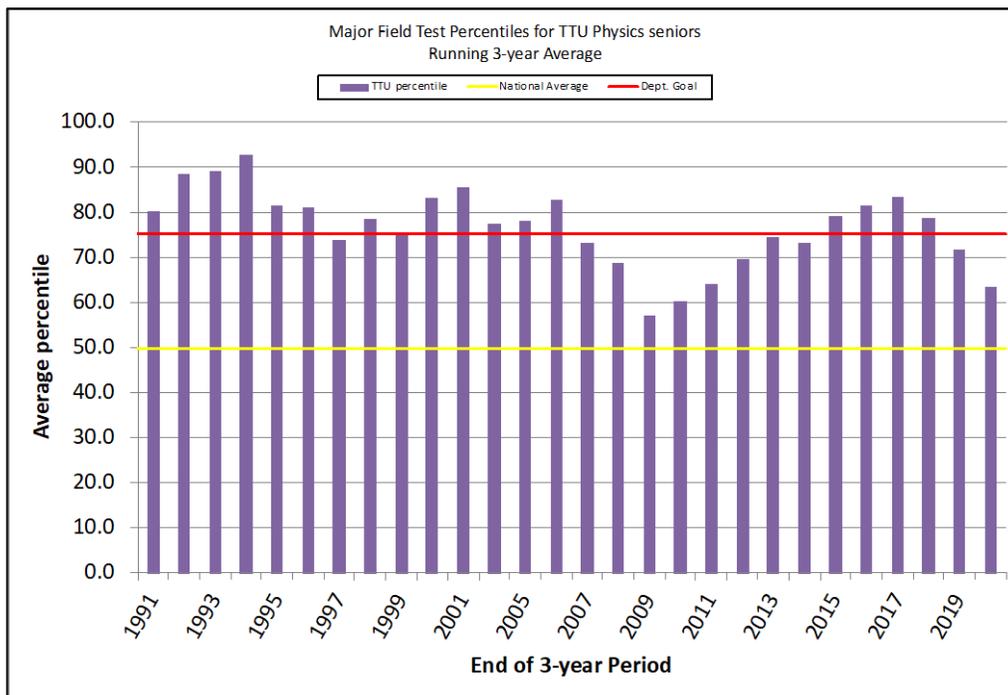


Fig 3. Rolling 5-semester average of FCI gain scores.

*SLO 2: Student Learning Outcome 2 - Students graduating in physics will demonstrate an understanding of the basic principles and foundations of physics.*



*Fig 4. Rolling 3-year average of physics majors' Major Field Test percentiles.*

Major Field Test: Two graduating seniors took the Major Field Test this year, placing (on average) at the 48<sup>th</sup> percentile. This is a disappointing result, falling below our minimum acceptable target, but should be tempered by the fact that these students' junior and senior years were severely affected by the pandemic situation, whereas the percentile rankings are determined using several years of national data. This brings our three-year average percentile ranking down to 64, but we will wait to propose any action until we see if the current downward trend continues as circumstances return to normal.

Alumni Survey: A full report of our most recent survey in Fall 2019 is attached, but significant results in the context of this SLO are:

- Alumni continue to be highly satisfied with the program and the overall level of preparation they receive for their future careers.
- The standard of preparation in Classical Mechanics and Thermodynamics is consistently rated as somewhat weaker than that in other topics.

*SLO 3: Student Learning Outcome 3 - Students graduating in physics will demonstrate the skills and techniques necessary to engage in authentic experimental investigation.*

Two physics majors took the PHYS 4710 course this year. Both met the minimal expectations. Thus, the target for this goal was attained. However, the small number of students involved in these courses means we will have to wait several years to get the general picture.

*SLO 4: Student Learning Outcome 4 - Students graduating in physics will demonstrate the ability to communicate their understanding orally in a presentation format.*

Two physics majors took the PHYS 4710 course this year. Both were judged by the faculty to have made acceptable oral presentations, attaining the target for this goal.

*SLO 5: Student Learning Outcome 5 - Students graduating in physics will have received an introduction to a range of common technological tools appropriate to physics and related disciplines.*

Exit Interview: Exit interviews were conducted with two graduating seniors this year. Both expressed satisfaction at their exposure to relevant commercial software and opportunities to practice their own coding in a physics context.

Alumni Survey: A full report of our most recent survey in Fall 2019 is attached, but relevant to this SLO, alumni reported that preparation in terms of using software and coding was 'adequate' to 'good'.

*SLO 6: Student Learning Outcome 6 - The TTU physics program will give students sufficient preparation in content and skills/techniques to continue to graduate school or obtain suitable employment.*

Exit Interview: Exit Interviews were conducted with two graduating seniors this year. Both were intending to go to graduate school, and deemed their preparation for this to be good.

Alumni Survey: A full report of our most recent survey in Fall 2019 is attached, but relevant to this SLO, alumni continue to report being highly satisfied with the program and the overall level of preparation they receive for their future careers.

*SLO 7: Student Learning Outcome 7 - Students graduating in physics will demonstrate the skills and techniques needed to engage in planning and carrying out basic or applied research.*

PHYS 4730 (Research Planning) and PHYS 4740 (Research) courses: Two students completed these courses this year and met the minimal standards for success, thus demonstrating their attainment of the required skills and in planning and carrying out research.

Research Involvement: During this year a total of twenty individual undergraduate students participated in research activities of various types with department faculty members. This is a remarkable achievement, given the restrictions imposed by the COVID-19 pandemic. All physics majors who desired such an experience were accommodated.

Exit Interviews: Exit Interviews were conducted with two graduating seniors this year. Both were of the opinion that their research experience was extremely valuable.

Alumni Survey: A full report of our most recent survey in Fall 2019 is attached, but relevant to this SLO, alumni continue to report their research involvement as being one of their most valuable undergraduate experiences.

## **Modifications for Improvement:**

### *Program Goal 1*

The number of physics majors at TTU seems to have stabilized at a five-year average of around 30. In order to try to grow this number (Program Goal 1) we continue to try various approaches to improve recruitment and retention.

In an effort to raise the profile of the department, as well as make direct contact with prospective physics majors, we will continue to contact instructors of high school physics classes and offer faculty and student volunteers as visiting speakers who can give presentations on various topics, as well as advertise/recruit for our program. We will also continue to have a faculty and student presence at all university recruiting events.

### *Program Goal 1, Student Learning Outcome 6*

Until recently the physics program at TTU has been mainly geared toward those who wanted to pursue their studies into graduate school, with little emphasis on preparation for other careers. However, recently, through a newly established contact at Cookeville Regional Medical Center (CRMC), it has been brought to our attention that a program in Health Physics may offer an opportunity to help address a predicted shortage of practitioners in this field, as well as recruiting more students for the department. We had hoped to pursue this possibility during the past year (and proposed it as a modification in last year's report), but the COVID-19 situation made it impossible to do so. Therefore, during the coming year we will reassess as to whether it would be realistic to establish such a program by conducting a needs assessment and feasibility study.

### *Program Goal 4, Student Learning Outcome 7*

With the desire to grow the number of physics majors, and the emphasis on undergraduate research in the department, it is important to seek opportunities to expand the opportunities for such research experiences in the department. During the coming year we expect to conduct searches for one or two new faculty members and, with this in mind, we will ask candidates to submit a plan for involving undergraduates in their research.

## **Appendices**

1. Physics BS Curriculum Map

## Appendix 1: Physics BS Curriculum Map

*Support for core goals and learning outcomes in the program of study for a B.S. in Physics.*

Course	Title	Goals/Learning Outcomes					
		Physics knowledge	Analytical skills	Laboratory skills	Communication skills	Computer skills	Research experience
PHYS 1137	Frontiers of Physics	X					
PHYS 2110	Calculus-based Physics I w/lab.	X	X	X			
PHYS 2120	Calculus-based Physics II w/lab	X	X	X			
PHYS 2420	Modern Physics	X	X		X	X	
PHYS 2920	Mathematical Physics		X		X	X	
PHYS 3610	Classical Mechanics	X	X		X	X	
PHYS 4610	Classical Elec. & Mag. I	X	X		X	X	
PHYS 4620	Classical Elec. & Mag. II	X	X		X	X	
PHYS 3120	Statistical Thermal Physics	X	X		X	X	
PHYS 3810	Quantum Mechanics I	X	X		X	X	
PHYS 3820	Quantum Mechanics II	X	X		X	X	
PHYS 4710/ PHYS 4711	Advanced Experimental Physics	X	X	X	X	X	
PHYS 4130	Computational Physics		X		X	X	
PHYS 4130	Research Planning	X	X	X	X	X	X
PHYS 4140	Research	X	X	X	X	X	X