GUSTAVUS

GUSTAVUS ADOLPHUS COLLEGE

Department of Physics

Physics Curriculum and Advising Guide

For current and prospective students:

- Learn about the department and its program
- Plan your course schedules
- Plan for study abroad
- Plan for pre-professional programs

Contents of this Document

This document began life in the 1990's as a two-page handout given annually to all physics majors (and prospective majors) at the beginning of each school year. It started as a simple grid showing the typical four-year course schedule of a physics major intending to go on to graduate study in physics or engineering. As our department has grown in size, and student advising questions have become more complex, the document has expanded to include details about a wider variety of topics. Some of these details will be relevant for some students, but not for others.

Most importantly, this document is not intended to be your advisor; it should only serve as a starting point for conversations with your actual advisor. No document can capture all of the subtleties and options that need to be considered in order for a student to make their best academic choices, whether in regard to course scheduling, preparation for graduate or pre-professional programs, or study aboard.

So, do use this document, but use it wisely. And, whatever choice you are confronting or considering with regard to your career, schedule a meeting to talk with your advisor!

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Introduction to the Department Curriculum

The Physics Department at Gustavus Adolphus College offers a comprehensive undergraduate major that is directed toward preparing students for graduate and professional degree work in physics, engineering, law, medicine, and a variety of related fields. The major is built upon courses that are designed to be taken in a specific sequence. These courses, together with others in mathematics and other laboratory sciences, will account for approximately one-third to one-half of the academic credit earned by students majoring in physics during their four years at the College. The purpose of this document is to expand upon the information in the College catalog, and to focus on the structure of the program taken by students with a variety of interests.

The physics major curriculum divides neatly along freshman-sophomore and junior-senior lines. During the first two years, students study the principles of Newtonian and non-Newtonian physics, using differential and integral calculus throughout. The four-course sequence of The Cosmic Universe, The Mechanical Universe, The Electromagnetic Universe, and The Quantum Universe constitutes an elementary yet quantitative and thorough introduction to the basic principles of astrophysics, classical mechanics, thermal physics, wave phenomena, optics, classical electromagnetism, DC and AC circuits, special relativity, quantum mechanics, condensed matter, atomic and nuclear physics. A required laboratory course in electronics and instrumentation in the fourth semester provides an introduction to analog and digital circuits and measurements, along with the necessary background for the more advanced laboratories to follow. Students will also take two co-requisite mathematics courses (Calculus I and II). Entering first-year students with demonstrated proficiency in calculus may be able to start with Calculus II, PHY250 (Applied Math for Scientists and Engineers), or another advanced math class if they so choose.

During the upper-class years, the student will see virtually all of the basic principles of physics extended in courses at a more advanced level of conceptual and mathematical sophistication. The student's experience with modern laboratory instrumentation and techniques is similarly extended through a required experimental modern physics laboratory, and elective courses in optics, condensed matter physics, astrophysics, and nuclear physics, and culminates with a capstone course project in physics.

The interdependence of the physics and mathematics courses in the curriculum for majors is no accident. It is a product both of the unity of the natural phenomena and the concepts that underlie our quantitative understanding of these phenomena. The sequential or stepping-stone character of the courses reflects this interdependence, as well as the need to match the level of the courses to the student's mathematical and conceptual sophistication. The prerequisites and co-requisites listed with each major course are the most obvious indicators of the background assumed for a student in a given course.

Because of the relatively small size of the department, and because of our commitment to offer courses for general education and for students majoring in other departments, the major courses are only offered once each year. For example, The Cosmic Universe is only offered in the fall semester. This fact, coupled with the sequential nature of the curriculum, places a heavy emphasis on good planning and accurate advising. This is especially critical for entering students who may be considering a physics major with advanced-degree or pre-professional goals.

It is often possible to fulfill the graduation requirements for a physics major in three-and-a-half or even three years. However, it will not be possible in three years for a student to take the full sequence of

courses that is recommended for graduate school in physics or electrical engineering. Waivers of specific course requirements for the major will be considered by petition to the physics department.

It is the **strong recommendation** of this department that any student considering a major in physics enroll in PHY-195/196 The Cosmic Universe & lab, and either MCS-121 Calculus I, MCS-122 Calculus II, (or, if appropriate, PHY-250, Applied Mathematics for Scientists and Engineers) in the fall of their first year.

Detailed plans of study for students wishing to major in physics while pursuing a wide range of long-term goals are shown beginning on page 10.

Review of Degree Requirements

The requirements for the B.A. degree with the major in physics are published in the College Catalog and are summarized below. In the following sections, we show how many of our majors pursue their studies through eight semesters, while keeping open a range of options for graduate and professional studies. Students wishing to pursue a pre-engineering emphasis or dual-degree program in engineering will follow essentially the same plan through at least the third year. The normal course load is 4.25 - 4.50 course credits per semester. (A maximum of 4.75 credits may be taken without payment of an overload fee, except for students who qualify under the Overload Guidelines in the College Catalog. This department will support overload fee waiver petitions from students with GPA 3.5 or better when students are earning credit for Honors in Physics, or for student-faculty or independent study research.)

Summary of Requirements for the Physics Major:

1. specific courses in physics and pre/co-requisite courses in mathematics (see the College catalog);
2. a minimum of 10.25 course credits in physics, with none graded below C-;
3. PHY-365, Course Project in Physics, which may be fulfilled by concurrent registration in any of the following courses: PHY-320, PHY-340, or PHY-360.

The general education courses for students who follow either the Liberal Arts Perspectives Curriculum or the Three Crowns Curriculum will be taken in parallel with major and elective courses, and should be largely completed by the end of the junior year. Students completing MCS-121 or MCS-122 (Calculus I or II) will automatically satisfy the general-education requirement in Mathematical and Logical Reasoning (MATHL). Since none of the physics courses that are designed for the major also satisfy the Liberal-Arts -Perspectives natural-science (NASP) requirements, majors must take such a course from another department. General Chemistry (CHE-107) is often the course recommended for physics majors (unless they enter with AP credit in chemistry), but other courses are also possible (Our Planet, GEO-111; Principles of Biology, BIO-101; etc.). Students should choose this non-physics laboratory science course based on their interests and long range plans. Two of the three College-required, writing-across-the-curriculum courses will be satisfied by completing FTS-100, a First-Term Seminar (or, for Three-Crowns -Curriculum students, CUR-100, Historical Perspective I) and PHY-305 Experimental Modern Physics Lab.

The on-line registration system requires concurrent registration in labs for courses with required laboratory components. In the introductory and intermediate courses, the lab receives separate credit and grade; while in the advanced courses, the course and lab credit and grade are integrated, even though, at times, the laboratory has its own course number and meeting times.

The Department recommends that all students who plan to pursue graduate study in physics or engineering acquire a working knowledge of a high-level computer language such as C++, Java, Python, or Fortran before graduation. C++ and Java are currently the most commonly required courses for students in engineering programs. Fortran remains a high-level language in Physics. The Department occasionally offers PHY-210, Scientific Programming for the Physical Sciences, on a January schedule that complements MCS-273, Introduction to C++.

The Mathematics and Computer Science Department also offers a number of other courses that may be of interest to physics majors. These include:

MCS-177 Introduction to Computer Science I
MCS-253 Differential Equations
MCS-321 Elementary Theory of Complex Variables (spring semester)
MCS-355 Scientific Computing and Numerical Analysis (spring semester, even years)
MCS-357 Discrete Dynamical Systems (fall semester, odd years)
MCS-358 Mathematical Model Building (January term, even years)

Students are encouraged to consult with their advisor and the course instructor to determine which courses from this list, or others in the catalog, might best fit their interests and degree plans. The plans of study outlined below cannot take the place of regular and meaningful faculty-student advising.

Honors In Physics

The Physics Department established an honors program in physics with the intention of promoting individual excellence in physics through directed research and demonstration of significant knowledge of the discipline. The requirements are:

1. Completion of a physics major, including PHY-300, PHY-350, PHY-380 and PHY-390
2. A minimum GPA in physics courses of 3.25
3. Completion of at least 1.0 course in research in physics (PHY-291 or PHY-391)
4. Completion of the Graduate Record Exam in Physics
5. Completion and successful defense of a senior thesis based on student's research

<u>Applications for honors in physics must be received by the department chair and accepted before the beginning of the student's last semester. Application forms are available from the department chair</u>.

The senior thesis must be based on the student's research and is prepared in consultation with a Gustavus physics faculty member. Copies of the thesis must be submitted to each member of the department at least two weeks before the end of the spring semester. The faculty will read and return the thesis with comments. A formal defense takes place no later than the last week of the semester.

Academic Advising in Physics and Pre-Engineering

All of the faculty members in physics place a high priority on student advising and enjoy the opportunity to get to know each advisee. However, academic advising is a two-way street. The system will work only if the student keeps his or her advisor informed of that student's progress, evolving interests and immediate or potential problems. The following sections describe the goals of the departmental advising program and outline the expectations for both members of the advising partnership.

First-Year Student Registration and Advising

First-year students normally register for classes in late June with the help of a faculty member from one of the departments in which the student has expressed some interest. Thus, the first semester schedule is already in place at the time of freshman orientation. However, the College assigns faculty advisors to first-year students based on one of two criteria: (1) enrollment in First-Term Seminar (Liberal Arts Perspective Curriculum); or (2) enrollment in the Three Crowns Curriculum. Although the first-year advisor will review the fall course schedule with the student during orientation, this is generally not a time for major changes in the course schedule worked out during the summer registration. This is particularly important for students who enter with a fairly clear idea of majoring in a science. New students should be wary of advice about curriculum matters from siblings and other relatives, Collegiate Fellows, and others who are not majoring in the student's prospective field of study. Well-prepared students are sometimes counseled by well-meaning individuals to take a light load (fewer than four courses) their first semester, or to avoid a certain combination of science and math classes. Unless specifically advised by an academic advisor to take a lighter load for good reason, the beginning student should enroll for 4 - 4.5 course credits.

All first-year students who indicate an interest in physics and who are enrolled in The Cosmic Universe and The Mechanical Universe receive information about the physics program in class, and will be invited to establish an early informal advising relationship with one of the instructors of these courses or with another member of the department. Prospective majors with questions should meet with this informal advisor before fall and/or spring registration periods to review their plan of study as part of the exploration of the major or pre-professional program.

Students who have indicated an interest in a pre-professional program (such as engineering, law, or medicine) or in a second major are encouraged to meet at an early date with the designated advisor for that program and/or with a member of the second department. (Please read the caution about double majors at the end of this document.) This will provide the student the opportunity to make sure that she or he is taking the necessary introductory courses in the fields that support a later choice of major or pre-professional program.

Choosing the Major Advisor

During the second semester of the first year the student will be encouraged to obtain a faculty advisor from the student's major department. Most first-year students who are considering a physics major will be enrolled in PHY-205/206 The Mechanical Universe. They will have had classroom experience with two or three faculty members from the department, and ideally with one of these as an informal advisor. It would be natural for the student to approach one of these teachers about their becoming the student's formal faculty advisor. In order to equalize the advising loads and to accommodate student interest in

particular specialties or professional programs, the department may encourage the student to sign up with one of the other faculty members from whom the student will be taking courses in the sophomore year. In any case, a member of the physics faculty would then become the student's advisor of record by signing the appropriate form. Students with pre-engineering plans should have been meeting with the pre-engineering advisor within the physics department (your course instructor should be able to inform you who this person is).

We encourage students to become familiar with the major curriculum and opportunities for other activities carried out by the department as soon as possible. As emphasized previously, the sequential nature of the core courses and the limited number of sections and offerings make it absolutely essential that the student obtain accurate advice about course selection.

Class announcements, e-mail messages, meetings with your physics advisor, Society of Physics Students meetings, and departmental bulletin boards are the principal avenues for information of importance to majors and prospective majors. Examples of this sort of information include visiting and student speakers, summer research and internship opportunities, student employment in the department, new courses to be offered, and other curricular matters.

The Advising Calendar

By becoming an advisee, the student agrees to meet with the faculty advisor for academic and career planning, not only for a signature at registration times. For returning students, the first meeting of the year should occur sometime before the end of the second week of the fall semester. The purpose of this meeting is to review the student's course program and discuss the overall plan for the year. The faculty advisor will sometimes post a sign-up sheet for appointments. Of course, if the student finds it necessary to drop or add courses that bear on the major or pre-professional programs, then he or she should discuss these issues with the departmental advisor as soon as the problem arises. <u>It is an essential part of the compact between student and departmental advisor that all substantive changes to the student's course schedule be discussed with the academic advisor in advance of such changes</u>.

The regular meeting in each semester occurs as the student prepares to register for the following semester's courses. January Term and spring semester registration both take place in November. Normally, the student will have worked up a preliminary schedule that the faculty advisor can review. The advisor will check progress toward graduation requirements, as well as discuss the student's plans beyond Gustavus. When the proposed schedule is complete the advisor will electronically approve the registration.

There is a natural evolution in the advising relationship as the student moves into the upper class years. Informal advising goes on all the time, and the small size of most physics courses and the frequent development of mentoring relationships through research and independent studies make this almost inevitable. It is one of the benefits of going to a place such as Gustavus.

Double Majors

In general, we do not encourage students to complete the formal graduation requirements for double majors. This usually results in two "minimal majors", and requires the skipping of courses recommended for admission to graduate school in the chosen field. Schedule conflicts between required courses in the two departments are virtually guaranteed. Graduate admissions committees in physics and engineering departments expect all applicants to have strong supporting course work in mathematics, and some background in chemistry and computer science. Of course, students planning inter-disciplinary graduate work in such fields as biophysics, geophysics, materials science, law, or medicine will need to take particular heed of the recommended preparation from the graduate departments or professional schools they expect to apply to. Usually a minor or equivalent course work in the second department is more than sufficient for admission to such interdisciplinary specialties.

Those students who pursue or declare two majors have the responsibility of establishing an advising relationship with a faculty member from <u>each</u> department. The physics department requires that all students declaring a major in physics establish an advising relationship with a physics faculty member. The signatures of both the physics advisor and the department chair are required on graduation applications.

Typical Four-Year Course Schedule

For students considering technical employment or graduate study in physics or engineering (physics/engineering professional track):

First Semester of First Year
PHY-195 The Cosmic Universe (CU)
PHY-196 CU Lab (0.25)
MCS-121 Calculus I
General Education (CUR-100 or FTS-100)
General Education (CUR-140 or, possibly, CHE-107)

Second Semester of First Year
PHY-205 The Mechanical Universe (MU)
PHY-206 MU Lab (0.25)
MCS-122 Calculus II
General Education
General Education/Elective

First Semester Second Year
PHY-215 The Electromagnetic Universe (EU)
PHY-216 EU Lab (0.25)
PHY-250 Applied Mathematics
General Education/Lab Science
General Education/Elective

Second Semester Second Year
PHY-225 The Quantum Universe
PHY-270 Electronics
PHY-271 Electronics Lab (0.25)
General Education
General Education/Elective

January Term of First and Second Years
PHY-210 Scientific Programming for the Physical Sciences, MCS-273 Introduction to C++, or other course.

First Semester Third Year
PHY-300 Mechanics
PHY-305 Experimental Modern Physics
General Education/Elective
General Education/Elective

Second Semester Third Year
PHY-350 Electromagnetic Theory
PHY-370 Advanced Math Methods of Physics
General Ed./Elective/PHY-320*, 330*, 340* or 360 (along with PHY-365 Course Project in Physics)
Elective

First Semester Fourth Year
PHY-380 Thermal and Stat. Physics (0.75)
PHY-390 Intro. To Quantum Mechanics
PHY-399 Seminar
General Education/Elective
Elective

Second Semester Fourth Year
PHY-360 Optics with lab
PHY-320 Astrophysics*, PHY-330*, or PHY-340* (along with PHY-365 Course Project in Physics)
General Education/Elective
Elective

January Term of Third or Fourth Year
PHY-330 Nuclear Physics*, PHY-340 Condensed Matter Physics*, PHY210 Fortran and C++ for the Physical Sciences, MCS-273 Introduction to C++, PHY-391 Research, or other course or experience.
*These courses are offered on a rotating schedule.

Note: It is possible to complete a physics major in three years, by following the first three years of the above schedule grid. However, this will leave some gaps in the student's preparation for graduate study in either physics or engineering.

Planning for Study Abroad

While study away experiences may be extremely valuable (indeed life changing) and are encouraged by the physics department, it should be realized that, as is often the case in life, choices must be made. If substitute courses at a study away location cannot be found, the student may have to acquire some background/prerequisite course information on their own, during summer course work, or receive permission of the department to take later courses (which will be decided on a case by case basis and may or may not be granted), or may just have to miss out on some later classes. Early planning may help minimize the impact on your Gustavus course of study.

The suggestions on the following pages are examples of ways in which it is possible to incorporate study aboard into the physics major. You should carefully explore all of your available options with the Gustavus Center for International and Cultural Education (CICE) and your physics academic advisor.

The Gustavus physics department has established working relationships with physics departments at two, very different, foreign institutions. One is the School of Physics at Universiti Sains Malaysia (The Science University of Malaysia) in Penang, Malaysia. The other is the Physics Department at the University of Wollongong in Australia. While both of these places provide a comprehensive set of physics courses, all taught in English, they obviously represent very different choices for a study-abroad experience.

The following pages present sample plans of study for students considering technical employment or graduate study in physics or engineering and who wish to study away for a full semester. They also contain information about study-abroad opportunities at foreign intuitions at which the Gustavus Physics Department has established relationships.

Sample Course Schedules Incorporating Study Abroad

Study Away During Spring Semester

Please note that while the department fully supports our students choosing a study away experience, this choice will necessarily impact your course of study at Gustavus, and as such, compromises will generally need to be made. Planning early may help minimize these.

First Semester of First Year
PHY-195 The Cosmic Universe (CU)
PHY-196 CU Lab (0.25)
MCS-121 Calculus I
General Education (CUR-100 or FTS-100)
General Education (CUR-140 or, possibly, CHE-107)

Second Semester of First Year
PHY-205 The Mechanical Universe (MU)
PHY-206 MU Lab (0.25)
MCS-122 Calculus II
General Education
General Education/Elective

First Semester Second Year
PHY-215 The Electromagnetic Universe
PHY-216 EU Lab (0.25)
PHY-250 Applied Mathematics
General Education/Lab Science
General Education/Elective

Second Semester Second Year
PHY-225 The Quantum Universe
PHY-270 Electronics
PHY-271 Electronics Lab (0.25)
General Education
General Education/Elective

January Term of First and Second Years
PHY-210 Fortran and C++ for the Physical Sciences, MCS-273 Introduction to C++, or other course.

First Semester Third Year
PHY-300 Mechanics
PHY-305 Experimental Modern Physics
General Education/Elective
General Education/Elective

Second Semester Third Year
Study away semester
(Students should try to take substitute courses for E&M or Advanced Math Methods, if possible. The math is prerequisite for Quantum Mechanics).

First Semester Fourth Year
PHY-380 Thermal and Stat. Physics (0.75)
PHY-390 Intro. to Quantum Mechanics**
PHY-399 Physics Seminar (0.25)
General Education/Elective
Elective

Second Semester Fourth Year
PHY-350 Electromagnetic Theory and/or
PHY-370 Advanced Math Methods of Physics
PHY-320*, 330*, 340* or 360
(along with PHY-365 Course Project in Physics)
Elective

January Term of Third or Fourth Year
PHY-330 Nuclear Physics*, PHY-340 Condensed Matter Physics*, PHY210 Fortran and C++ for the Physical Sciences, MCS-273 Introduction to C++, PHY-391 Research, or other course or experience.

* These courses are offered on a rotating schedule.
** May possibly be taken with permission of the department if prerequisites not satisfied.

Study Away During Fall Semester

Please note that while the department fully supports our students choosing a study away experience, this choice will necessarily impact your course of study at Gustavus, and as such, compromises will generally need to be made. Planning early may help minimize these.

First Semester of First Year
PHY-195 The Cosmic Universe (CU)
PHY-196 CU Lab (0.25)
MCS-121 Calculus I
General Education (CUR-100 or FTS-100)
General Education (CUR-140 or, possibly, CHE-107)

Second Semester of First Year
PHY-205 The Mechanical Universe (MU)
PHY-206 MU Lab (0.25)
MCS-122 Calculus II
General Education
General Education/Elective

First Semester Second Year
PHY-215 The Electromagnetic Universe
PHY-216 EU Lab (0.25)
PHY-250 Applied Mathematics
General Education/Lab Science
General Education/Elective

Second Semester Second Year
PHY-225 The Quantum Universe
PHY-270 Electronics
PHY-271 Electronics Lab (0.25)
General Education
General Education/Elective

January Term of First and Second Years
PHY-210 Fortran and C++ for the Physical Sciences, MCS-273 Introduction to C++, or other course.

First Semester Third Year
Study away semester
(Students should try to take substitute courses for Mechanics and/or Expt'l Modern Physics, if possible)

Second Semester Third Year
PHY-350 Electromagnetic Theory (with permission
PHY-370 Advanced Math Methods of Physics
General Ed./Elective/PHY-320*, 330*, 340* or 360 (along with PHY-365 Course Project in Physics)
Elective

First Semester Fourth Year
PHY-300 Mechanics
PHY-305 Experimental Modern Physics
PHY-399 Physics Seminar (0.25)
General Education/Elective
Elective

Second Semester Fourth Year
PHY-360 Optics with lab
PHY-320 Astrophysics*, PHY-330*, or PHY-340* (along with PHY-365 Course Project in Physics)
General Education/Elective
Elective

January Term of Third or Fourth Year
PHY-330 Nuclear Physics*, PHY-340 Condensed Matter Physics*, PHY210 Fortran and C++ for the Physical Sciences, MCS-273 Introduction to C++, PHY-391 Research, or other course or experience.

* These courses are offered on a rotating schedule.

Study Abroad on the Gustavus - Universiti Sains Malaysia Exchange

One option for study abroad is the individual student exchange agreement between Gustavus and Universiti Sains Malaysia (USM), located in Penang, Malaysia. (This is the same institution that hosts the biennial Gustavus Semester in Malaysia – Living Diversity., held spring semester in odd-numbered years)

Gustavus Courses	USM Equivalent Courses (**Boldfaced indicates a correct semester fit)**
Second Year Fall	
PHY215,216 The Electromagnetic Universe	ZCT 102/4(II) + ZCT 192/2(II) (lecture) (lab)
PHY250 Mathematical Methods for Physics	**ZCT110/4(I)** + ZCT112/3(II) (linear algebra)+ (multivariable calc)
Second Year Spring	
PHY225 The Quantum Universe	**ZCT 104/3(II)**
PHY270,271 Electronics and Instrumentation	**ZCT 106/3(II)** + ZCT206/3(I) (analog) + (digital)
Third Year Fall	
PHY300 Mechanics	ZCE 208/3(II)
PHY305 Experimental Modern Physics	**ZCT 293/2(I)** or ZCT 294/2(II)
Third Year Spring	
PHY350 Electromagnetic Theory	**ZCT 304/3(II)**
PHY370 Advanced Mathematical Methods for Physics	ZCT210/4(I), **ZCT218/4(II)** (Complex, ODE), (Transforms, Spec. Func.,PDEs)
Fourth Year Fall	
PHY380 Statistical and Thermal Physics	**ZCT 212/3(I)**, **ZCT 312/3(I)** (Thermo) (Stat. Mech.)
PHY390 Quantum Mechanics	ZCT 205/3(II)
Fourth Year Spring	
PHY340 Condensed Matter Physics	ZCT 307/3(I)
PHY360 Optics	ZCT 213/3(I)

Study Abroad in Wollongong, NSW, Australia

Wollongong is a large city located about 80 km south of Sydney on the coast. In less than 25 years, the University of Wollongong has grown from only 900 students to well over 30,000 and has become home to world class research facilities. Most international students will be housed at Campus East, which although 3 km from the main campus is a short walk from Fairy Meadow Beach. Free shuttle busses provide easy access to Uni campus as well as the central business district. Travel to Sydney is an easy and quick (usually less than 90 minutes) ride on the South Coast train line.

Course Work:

One of the great advantages of studying at the University of Wollongong is the ability to continue with physics courses uninterrupted. Whether you choose to study abroad as a sophomore or junior, spring or fall semester, there are courses that match what Gustavus offers. Owing to its modest beginnings, teaching is of highest priority at Wollongong and our students generally do quite well. Courses are generally taught in a modified British system, which means most of a student's grade will be determined by the results of the final exam. However, mid-term exams are offered for most courses, and in some retakes are allowed to encourage students to earn the best grades. Students will also find that grading scales are more liberal.

Research Opportunities:

The University of Wollongong has become one of the premier research universities in Australia in recent years. Hundreds of millions of dollars have been spent in developing the Innovation Campus, which houses cutting edge research in a wide variety of physics, chemistry, and related fields. It is also home to think tanks and start-up companies that are pushing the envelope in battery research, photovoltaics, polymers, and bionics. The majority of the research work done on the main campus within physics falls into one of two categories, medical physics and terahertz radiation.

Professor Antoloy Rozenfeld is director of the medical physics research program, which focuses on the development of electronic devices which may be used to monitor health. For example they are currently working with existing electronics to produce implantable dosimeters to monitor radiation during oncological therapies.

Professor Roger Lewis is director of the terahertz radiation program which has developed new sources of radiation in the region of the electromagnetic spectrum between infrared and radio, as well as new uses for this radiation. In addition to developing sources and optics for light in this region of the spectrum, they have used it for a broad range of applications from analyzing semiconductors to dirt.

Professor Alexy Pan heads up the thin film technology research program, which has its roots in the physics department, but takes advantage of the vast resources at the Innovation Campus. This group works on high temperature superconductors produced using thin film technology, as well as spintronics and magnetic properties of materials (mainly thin films).

There are a number of ways a student can become involved in research while studying at the University of Wollongong. Researchers in the physics department and at the Innovation Campus are excited to have good undergraduate students join their groups, even for a short time. A student can be involved in a casual way, like we often do on the Gustavus campus, committing to a few hours per week without compensation or course credit, to paid "summer" internships. The Physics Department has money to support junior level students who wish to learn more about research by staying on campus during the summer holiday (10 weeks beginning after session ends in November) and working with one of the research groups. This program is open to Gustavus students, providing an opportunity to do research in the middle of our academic year.

Dual-Degree 3/2 Pre-Engineering Program

The physics department offers a dual degree engineering program with the University of Minnesota and Minnesota State University, Mankato. In this program the student attends Gustavus Adolphus College for three years, completing all of the general education requirements and required courses for the physics major. The student then transfers to the dual-degree institution and completes the required sequence of engineering courses in roughly two years. On completion of these requirements, the student receives a bachelors degree in physics from Gustavus, and a bachelors degree in Engineering from the University. This 3/2 dual-degree program is particularly valuable in engineering disciplines where an undergraduate engineering degree is important for professional licensure.

Please contact an advisor in the physics department as soon as possible to develop a three-year plan. In developing this three-year plan, there are several important considerations:

- It is essential that all Gustavus graduation requirements are met before leaving Gustavus. This would include all general education requirements, IEX, language requirements, etc.

- To complete the Gustauvs physics major, insure completion of all required physics courses; in particular PHY-305 (Experimental Modern Physics) and PHY-365 (Project in Physics) should be taken at Gustavus.

- The math requirement for most University of Minnesota engineering program can be completed by taking PHY-250 (Applied Math Methods) and PHY-370 (Advanced Math Methods). An alternate math track would involve MCS-221 (Linear Algebra), MCS-222 (Multivariable Calculus) and MCS-253 (Differential Equations).

- Many of the engineering tracks require a programming class focused on a language such as C/C++. The physics department regularly offers a Scientific Programming course during January that will fulfill this programming requirement. It is highly recommended that this is taken at the first possible opportunity.

- In addition to physics and math courses, the transfer plans listed below may require courses in math, chemistry, biology, or other departments.

- Listed below are the minimal set of courses for transfer to the University of Minnesota dual degree program. This list does not include all of the physics courses required for a physics major at Gustavus. As noted above, it is highly recommended that all students complete both PHY-305 and PHY -365 before leaving Gustavus.

Further details can be found at: https://gustavus.edu/engineering/

The information bon the following pages is based on the August 29, 2014 revision of the Transfer Course Plan. Interested students are strongly advised to visit the University of Minnesota Dual Degree website at

http://cse.umn.edu/admissions/transferadm/dualdegree/index.php

to view the official version of the Transfer Course Plan and Technical Course Equivalencies, and to obtain additional information about the program and application process.

Transfer Plan to Institute of Technology, University of Minnesota

These are the "technical" courses that are suggested students complete before applying for transfer. Applications may be made before completing all the courses. If not Dual Degree, see:
www.admissions.tc.umn.edu/cle
for information concerning liberal education course requirements.

Dual Degree students will take the courses suggested below plus additional courses required for their major. All liberal arts courses will transfer for credit; the liberal arts requirement at the U of M is satisfied by the requirements at Gustavus Adolphus College.

Engineering Majors

Aerospace Engineering
CHE 107(1061/1065, 1062/1066)
MCS 121(1271), 122(1272)
PHY 195/196(2503, 205/206(1301), 210(CSCI 1113), 215/216(1302), 250(MATH 2263), 270/271(may substitute for EE 3005/3006), 300(AEM 2012), 370(MATH 2243)

Biomedical Engineering
BIO 101(in lieu of BIOL 1009), 102(Tr.), 201(Tr.), 202(Tr.), 373(in lieu of BMEN 2501)
CHE 107(1061/1065, 1062/1066), 141(2301), 371(4501 in lieu of BMEN 2101)
MCS 121(1271), 122(1272)
PHY 195/196(Transfers), 205/206(1301), 210(in lieu of BMEN 2401), 215/216(1302), 225 (2303), 250(MATH 2263), 370(MATH 2243)

Bioproducts and Biosystems Engineering
BIO 101(in lieu of BIOL 1009)
CHE 107(1061/1065, 1062/1066)
MCS 121(1271), 122(1272)
PHY 195/196(Transfers), 205/206(1301), 215/216(1302), 250(MATH 2263), 370(MATH 2243)
Courses for a particular emphasis:

- Bioproducts Engineering Emphasis
  - CHE 141(2301), 251(2302, 2311)*
- Bioprocessing & Food Engineering Emphasis
  - CHE 141(2301), 251(2302, 2311)*
  - MCS 142(STAT 3021)
- Environmental & Ecological Engineering Emphasis
  - MCS 142(STAT 3021)

* Indicates classes that might be counted at technical electives.

(continued on the next page)

Chemical Engineering
CHE 107(1061/1065, 1062/1066), 141(2301), 251(2302, 2311), 270 + 380(in lieu of 2121), 371 (4501), 372(4502, 4511)
MCS 121(1271), 122(1272)
PHY 195/196(Transfers), 205/206(1301), 215/216(1302), 250(MATH 2263), 370(MATH 2243)
CHEN 2001 - Material and Energy Balances is now only a fall semester class (no longer offered in the summer) and it is a prerequisite class for the junior sequence.
- If a student transfers to the U of M after the freshman year, they will take the same classes as sophomores in Chemical Engineering and the student should graduate in three years.
- A student transferring after two years will take Physical Chemistry, CHEN 2001, and perhaps a few other classes. It will take the student three years to graduate.
- A student who competes three years at Gustavus Adolphus College (completing ALL of the above classes) may be admitted as a pre-chemical engineering major. The first semester they will take CHEN 2001 and MATS 3011. Those two grades will determine admission to the major. If admitted, it will take a total of three years at the University of Minnesota to graduate.

Civil Engineering
CHE 107(1061/1065, 1062/1066)
MCS 121(1271), 122(1272), 142(STAT 3021 in lieu of CEGE 3102)
PHY 195/196(Transfers), 205/206(1301), 215/216(1302), 250(MATH 2263), 300(AEM 2012), 370(MATH 2243)

Computer Engineering
MCS 121(1271), 122(1272), 177(CSCI 1901), 178(CSCI 1933), 236(CSCI 2011), 375(CSCI 4041), 378(CSCI 4061)
PHY 195/196(Transfers), 205/206(1301), 215/216(1302), 250(MATH 2263), 270(EE 2001), 271(EE 2002), 370(MATH 2243)

Electrical Engineering
CHE 107(1061/1065)
MCS 121(1271), 122(1272)
PHY 195/196(2503), 205/206(1301), 210(in lieu of EE 1301), 215/216(1302), 250(MATH 2263), 270(EE 2001), 271(EE 2002), 370(MATH 2243)

Environmental Engineering
BIO 101(in lieu of BIOL 1009)
CHE 107(1061/1065, 1062/1066), 141(2301)
GE 111(ESCI 1001)
MCS 121(1271), 122(1272), 142(STAT 3021 in lieu of CEGE 3102)
PHY 195/196(Transfers), 205/206(1301), 215/216(1302), 250(MATH 2263), 370(MATH 2243)

(continued on the next page)

Geoengineering
CHE 107(1061/1065, 1062/1066)
GE 111(ESCI 1001), 250(ESCI 4501), 271(ESCI 2301), 372(ESCI 2302)
MCS 121(1271), 122(1272), 142(STAT 3021 in lieu of CEGE 3102)
PHY 195/196(Transfers), 205/206(1301), 215/216(1302), 250(MATH 2263), 300(AEM 2012), 370(MATH 2243)

Industrial & Systems Engineering
General Biology strongly recommended
CHE 107(1061/1065)
E/M 102(in lieu of ECON 1101), 260(in lieu of MKTG 3001)
MCS 121(1271), 122(1272)
PHY 195/196(Transfers), 205/206(1301), 210(CSCI 1113), 215/216(1302), 250(MATH 2263), 370(MATH 2243)

Dual Degree students interested in Industrial & Systems Engineering will be considered on a case-by-case basis to take the sophomore and junior classes concurrently. Successful completion of the classes would allow graduation in two years.

Materials Science Engineering
CHE 107(1061/1065, 1062/1066), 141(2301)
MCS 121(1271), 122(1272)
PHY 195/196(2503), 205/206(1301), 215/216(1302), 250(MATH 2263), 370(MATH 2243)

Mechanical Engineering
General Biology strongly recommended
CHE 107(1061/1065)
MCS 121(1271), 122(1272)
PHY 195/196(Transfers), 205/206(1301), 210(CSCI 1113), 215/216(1302), 225(for a science elective), 250(MATH 2263), 270/271(may substitute for EE 3005/3006), 300(AEM 2012), 370 (MATH 2243)

Preparing for Other Pre-Professional Programs

In addition to the many varieties of engineering offered in graduate school, it is possible to enter other professional schools (law, medicine, dentistry, etc.) having graduated from Gustavus with a physics major. Below are some examples.

Pre-Law

ample plan of study for students wishing to pursue a law school degree (**physics pre-law track**)

The program outlined below does not show the required Lifelong Fitness and Activity courses, nor does it show any fractional credits for musical or athletic activities.

First Semester of First Year
PHY-195 The Cosmic Universe (CU)
PHY-196 CU Lab (0.25)
MCS-121 Calculus I
General Education (CUR-100 or FTS-100)
General Education/Pre-law Elective**

Second Semester of First Year
PHY-205 The Mechanical Universe (MU)
PHY-206 MU Lab (0.25)
MCS-122 Calculus II
General Education
General Education/Pre-law Elective**

First Semester Second Year
PHY-215 The Electromagnetic Universe
PHY-216 EU Lab (0.25)
PHY-250 Applied Mathematics
General Education/Lab Science
General Education/Pre-law Elective**

Second Semester Second Year
PHY-225 The Quantum Universe
PHY-270 Electronics
PHY-271 Electronics Lab (0.25)
General Education/Pre-law Elective**
General Education/Pre-law Elective**

First Semester Third Year
PHY-300 Mechanics or Pre-law Elective
PHY-305 Experimental Modern Physics
General Education/Pre-law Elective**
Pre-law Elective**

Second Semester Third Year
Pre-law Elective**
Pre-law Elective**
Physics Elective (e.g. PHY-370 or PHY-320, 330, 340 or 360 along with PHY-365 Course Project in Physics)
General Education/Pre-law Elective**

First Semester Fourth Year
PHY-399 Physics Seminar (0.25)
General Education/Pre-law Elective**
Pre-law Elective**
Pre-law Elective**

Second Semester Fourth Year
Pre-law Elective**
Elective
Elective
Physics Elective as necessary

**See the next page for a sub-set of possible Pre-law electives.

The physics pre-law track offers students considerable freedom in their course of study. Students should work closely with their academic advisor to ensure that they satisfy all the requirements for the physics major. Students wishing to pursue patent law should consider including more physics/science courses in their plan of study than those indicated in the sample plan above.

All accredited American law schools require a four-year college degree or its equivalent. The American Bar Association and the National Association of Pre-Law Advisors suggest that students take courses that improve the following skills: analytical and problem solving, critical reading, writing, oral communication and listening, and general research. A choice of a particular major, especially at a liberal arts school, is far less significant than making wise course choices that foster these skills. Doing very well in one's chosen major is critical, for grade point average is a key component of the admission criteria for law schools.

Thus, the general advice from pre-law advisors and law schools is that students should seek a broad liberal arts education --- a wide range of courses across subject areas. Since law school is not dependent upon the substantive knowledge gained at the undergraduate level (as opposed to medical school, for example), preparing for law school doesn't necessarily entail taking any particular set of courses. With that said, a set of undergraduate courses (in no particular sequence) can be helpful in law school and in the practice of law include:

COM-120 Public Discourse
COM-260 Argumentation and Debate
POL-110 U.S. Government and Politics
E/M-101 Macroeconomics
PSY-100 General Psychology
PHI-236 Formal Logic
LAT-101 and LAT-102 Latin
HIS-130 and HIS-140 U.S. History

These are a suggested set of courses referred to above as "Pre-law Electives". This is not an exhaustive list.

Gustavus also has some law-related courses in several departments. Students thinking of law school should **not** take these courses as preparation for law school --- law schools actively discourage this approach. These courses are valuable (1) if a student is not sure that she or he will like the subject matter of law school; (2) if a student simply loves the content and wants to study it; or (3) if the course fulfills a major or other requirement.

Pre-Med

Sample plan of study for students wishing to pursue a medical school degree **(physics pre-med track):**

The program outlined below does not show the required Lifelong Fitness and Activity courses, nor does it show any fractional credits for musical or athletic activities.

First Semester of First Year
PHY-195 The Cosmic Universe (CU)
PHY-196 CU Lab (0.25)
MCS-121 Calculus I
General Education (CUR-100 or FTS-100)
General Education

Second Semester of First Year
PHY-205 The Mechanical Universe (MU)
PHY-206 MU Lab (0.25)
MCS-122 Calculus II
General Education
General Education

First Semester Second Year
PHY-215 The Electromagnetic Universe
PHY-216 EU Lab (0.25)
PHY-250 Applied Mathematics
CHE-107 Principles of Chemistry
General Education

Second Semester Second Year
PHY-225 The Quantum Universe
PHY-270 Electronics
PHY-271 Electronics Lab (0.25)
CHE-141 Organic Chemistry
General Education

First Semester Third Year
PHY-305 Experimental Modern Physics
CHE-251 Organic Chemistry II
BIO-101 Principles of Biology
General Education/Elective

Second Semester Third Year
PHY-370 Advanced Math Methods of Physics
CHE-258 Inorganic Chemistry I
BIO-102 Organismal Biology
General Education/Elective

First Semester Fourth Year
PHY-399 Physics Seminar (0.25)
BIO-201 Cell and Molecular Biology
CHE-255 Biochemistry (or in spring)
General Education/Elective
General Education/Elective

Second Semester Fourth Year
Physics Elective PHY-320*, 330*, 340*, or 360
(along with PHY-365 Course Project in Physics)
General Education/Elective
General Education/Elective
General Education/Elective

* These courses are offered on a rotating schedule.

Students considering the physics pre-med track should work closely with their physics and pre-med advisors to ensure that they have completed the requirements for the physics major and have taken as many traditional pre-med related courses as their schedule allows.

The sample plan of study, outlined above, enables the student to be fully prepared to take the MCAT exam in the spring of their senior year. This would generally necessitate that students wait a year before entering medical school. If this delay is not desirable, students have two main alternatives, (1) begin the entire biology/chemistry staggered sequence in the first year; or (2) start the biology courses in the second year. Students are reminded that overall GPA is important to medical schools.

In addition to the biology and chemistry courses listed above, medical schools require successful completion of,

PSY-100 General Psychology
MCS-142 Introduction to Statistics
An English Literature course
A writing intensive course (generally medical schools like to see a writing course from the English Department)

Again, please be sure to consult the pre-med advisor, as well as your physics advisor.