Physics

Chairperson: Brian Bennett, D.Phil.
Department of Physics website (http://www.marquette.edu/physics)

The Physics department at Marquette offers three majors that prepare students for graduate study, employment, professional training and diversification into a variety of other fields that require rigor and a combination of creative and analytical skills. The majors offered are Physics, Biophysics and Applied Physics. Physics students achieve a general understanding of leading edge computational, theoretical and experimental approaches to explaining diverse natural phenomena from sub atomic particles, to exotic stars and galaxies, and progress into areas as diverse as medicine, law, engineering and finance, as well as mainstream areas of physics such as particle physics, astrophysics, solid state, atomic and molecular physics. Biophysics students learn about the structures and mechanisms of living systems at the chemical, molecular, atomic and electronic levels, and become familiar with the techniques and instrumentation with which to study these. The Biophysics major is a rigorous preparation for a career in medicine or in the rapidly growing biomedical industry, or for further study and research in biophysical and biomedical sciences. Applied Physics students study a core physics curriculum along with practical and engineering techniques and applications, and carry out an intensive research or work-study program, in preparation for employment, specialist vocational training or further specialized study. Majors in the Physics department can apply for acceptance into the Disciplinary Honor Program in Physics near the end of their sophomore year. Completion of this experiential program involves six credits of independent research with a faculty member and enrollment in an accompanying seminar focused on the research skills typically found in successful scientists. Minors are offered in Physics, Astrophysics and Biophysics. In addition, together with the Graduate School of Management, the Department of Physics offers a five-year B.S./M.B.A. accelerated degree program.

Major in Physics

The major in physics consists of thirty-six (36) credit hours. Students complete the common physics core: one required physics core sequence of two courses (8 credit hours), five required physics core courses (15 credit hours), and six required physics seminar courses (7 credit hours). In addition, six (6) credit hours of upper division physics elective courses are required, for a total of 36 credit hours in the major. Physics majors must also complete four required mathematics courses (16 credit hours) and cognate studies in chemistry or computer science courses (8 credit hours) for a total of 24 credit hours of background course work.

Note:

- Students may develop areas of concentration that prepare them for specific careers. These concentrations build on the foundation of the common physics core. Students should refer to the section, Areas of Concentration in Physics.

Common Physics Core:		
Required Physics Core Sequence - Choose one of the following:		8
PHYS 1001 & PHYS 1002	General Physics 1 and General Physics 2	
PHYS 1003 & PHYS 1004	General Physics with Introductory Calculus 1 and General Physics with Introductory Calculus 2	
PHYS 1013 & PHYS 1014	Classical and Modern Physics with Calculus 1 and Classical and Modern Physics with Calculus 2	
Required Physics Core Courses:		
PHYS 2400	The Microscopic World	3
PHYS 2500	Oscillations and Waves with Laboratory	4
PHYS 3100	Classical Mechanics	3
PHYS 3056	Contemporary Physics Lab 1	2
PHYS 4031	Electricity and Magnetism 1	3
Required Seminar Courses:		
PHYS 1953	Discovering Physics	1
PHYS 1954	Communicating Physics	1
PHYS 2953	Computational Methods in Physics	1
PHYS 2954	Participating in Physics	1
PHYS 4954	Review and Preparation for Post-Graduate Life	1
PHYS 4997	Physics Exploration Capstone	2
Electives - Upper-division Physics courses		6
Total Credit Hours		36

Note:

- PHYS 1013 Classical and Modern Physics with Calculus 1 and PHYS 1014 Classical and Modern Physics with Calculus 2 are studio style courses recommended for students considering a physics major.

Required Background Mathematics and Chemistry or Computer Science Courses:

Mathematics Courses:		
MATH 1450	Calculus 1	4
MATH 1451	Calculus 2	4
MATH 2450	Calculus 3	4
MATH 2451	Differential Equations	4
Chemistry or Computer Science Courses:		8
Total Credit Hours		24

Typical Program for Physics Majors

Freshman

First Term	Hours	Second Term	Hours
PHYS 1013 (recommended)	4	PHYS 1014 (recommended)	4
PHYS 1953	1	PHYS 1954	1
MATH 1450	4	MATH 1451	4
ENGL 1001 or ESSV1 (MCC)	3	ENGL 1001 or ESSV1 (MCC)	3
PHIL 1001 or THEO 1001 (MCC)	3	PHIL 1001 or THEO 1001 (MCC)	3
	15		15

Sophomore

First Term	Hours	Second Term	Hours
PHYS 2400	3	PHYS 2500	4
PHYS 2954	1	PHYS 2953	1
MATH 2450	4	MATH 2451	4
CHEM/COSC Cognate course	4	CHEM/COSC Cognate course	4
CORE 1929 (MCC)	3	DCSV (MCC)[1, 2]	3
	15		16

Junior

First Term	Hours	Second Term	Hours
PHYS 3100	3	PHYS 4031	3
PHYS 4012	3	PHYS 3056	2
DSCV (MCC)[1, 2]	3	DSCV (MCC)[1, 2]	3
Electives	6	Elective	6
	15		14

Senior

First Term	Hours	Second Term	Hours
PHYS 4057	2	PHYS 4034	3
PHYS 4954	1	PHYS 4997	2
Physics electives (upper division)	6	Physics electives (upper division)	6
CORE 4929 (MCC)	3	Electives	4

	Physics	3
DSCV (MCC)[1,2]	3	
	15	15

Total credit hours: 120

1 The four courses in the Discovery Tier (DSCV) of the MCC must be completed in the same theme and include the following content areas: Humanities (HUM), Social Science (SSC), Natural Science and Mathematics (NSM) and one elective (ELE), which is an additional course from any of the three content areas. A maximum of two courses in the Discovery Tier can apply towards a primary major.

2 Students must also complete the Writing Intensive (WRIT) and Engaging Social System and Values 2 (ESSV2) requirements of the MCC. These requirements can be fulfilled through designated courses in the Discovery Tier or other degree requirements.

Note:
Physics Electives: A minimum of 8 credits of upper division physics courses (3000 and above) are required. Courses may range from 1 credit hour to 3 credit hours.

For Students Considering Graduate Study in Physics:

To meet admission expectations for graduate study in physics, students should complete the following recommended upper division elective curriculum for graduate study in physics as listed below. Physics majors must also complete required physics core sequence (8 credit hours), physics core courses (15 credit hours), and physics seminar courses (7 credit hours), as well as the background course work in mathematics (16 credit hours) and chemistry/computer science (8 credit hours) courses listed under the Physics major. This list is guidance for elective choices, not a replacement for the major requirements above.

Recommended Upper Division Electives for Graduate Study in Physics:

Physics Courses:		
PHYS 3056	Contemporary Physics Lab 1	2
PHYS 4012	Quantum Mechanics	3
PHYS 4034	Modern Optics	3
PHYS 4032	Electricity and Magnetism 2	3
PHYS 4057	Contemporary Physics Lab 2	2
PHYS 4062	Introduction to Thermodynamics	3
Mathematics Course:		
MATH 4210	Complex Variables	3
Additional Course: 3 credit hours in upper-division MATH		3
Total Credit Hours		22

Areas of Concentration

Students may use their electives to develop concentrations that prepare them for specific careers. These concentrations build on the foundation of the common physics core as well as the background course work in mathematics and chemistry. Students should refer to the requirements listed under **Major in Physics.** Students should also consult with their pre-professional adviser for specifics regarding the various medical and dental school admission requirements. Several possible concentrations are outlined below.

Pre-medical/Pre-dental Concentration for Physics Majors

To pursue medical or dental professional studies, students should follow the pre-medical/pre-dental concentration or the physics in medicine concentration. The pre-medical/pre-dental concentration replaces the upper division physics elective courses for the major with the below courses. Students in this concentration must still complete the required physics core sequence (8 credit hours), physics core courses (15 credit hours), and physics seminar courses (7 credit hours), as well as the background course work in mathematics (16 credit hours) and chemistry/computer science (8 credit hours) courses listed under the Physics major. Courses used for the chemistry/computer science cognate requirement may not be the required courses for this concentration.

Pre-medical/Pre-dental Concentration:

Biology Courses:		
BIOL 1001	General Biology 1	3
BIOL 1002	General Biology 2	3
BIOL 2001	Principles of Biological Investigation	3
Chemistry Courses:		
CHEM 2113	Organic Chemistry for Majors 1	4

CHEM 2114	Organic Chemistry for Majors 2	4
Total Credit Hours		17

Physics in Medicine Concentration (Research)

The physics in medicine concentration, which is recommended for students interested in biomedical research, replaces the upper division physics elective courses for the physics major with the below courses. Students in this concentration must still complete the required physics core sequence (8 credit hours), physics core courses (15 credit hours), and physics seminar courses (7 credit hours), as well as the background course work in mathematics (16 credit hours) and chemistry/computer science (8 credit hours) courses listed under the Physics major. Courses used for the chemistry/computer science cognate requirement may not be the required courses for this concentration.

Medicine Concentration (Research):		
Biology Courses:		
BIOL 1001	General Biology 1	3
BIOL 1002	General Biology 2	3
BIOL 2001	Principles of Biological Investigation	3
Chemistry Courses:		
CHEM 2113	Organic Chemistry for Majors 1	4
CHEM 2114	Organic Chemistry for Majors 2	4
Mathematics Course:		
MATH 4720	Statistical Methods	3
Physics Course:		
PHYS 3953	Biophysics Seminar	1
Physics electives should include:		
PHYS 4012	Quantum Mechanics	3
PHYS 4032	Electricity and Magnetism 2	3
Total Credit Hours		27

Computational Physics Concentration

The computational physics concentration serves to develop competence in using the computer as a scientific tool, and replaces the upper division physics elective courses for the physics major with the below courses. Students in this concentration must still complete the required physics core sequence (8 credit hours), physics core courses (15 credit hours), and physics seminar courses (7 credit hours), as well as the background course work in mathematics (16 credit hours) and chemistry/computer science (8 credit hours) courses listed under the Physics major. Courses used for the chemistry/computer science cognate requirement may not be the required courses for this concentration.

Computational Physics Concentration:		
Mathematics Course:		
MATH 3100	Linear Algebra and Matrix Theory	3
Computer Science Courses:		
COSC 1010	Introduction to Software Development	4
COSC 1020	Object-Oriented Software Design	4
COSC 2100	Data Structures	3
COSC 2200	Hardware Systems	4
Two additional upper-level COSC courses.		6
Physics elective course:		
PHYS 2049	Computational Physics	3
Total Credit Hours		27

Mathematical Physics Concentration

The mathematical physics concentration develops the mathematical aspects of physics, and replaces the upper division physics elective courses for the physics major with the below courses. Students in this concentration must still complete the required physics core sequence (8 credit hours), physics core courses (15 credit hours), and physics seminar courses (7 credit hours), as well as the background course work in mathematics (16 credit hours) and chemistry/computer science (8 credit hours) courses listed under the Physics major. Courses used for the chemistry/computer science cognate requirement may not be the required courses for this concentration.

Mathematical Physics Concentration:		
Mathematics Courses:		
MATH 3100	Linear Algebra and Matrix Theory	3
MATH 4120	Abstract Algebra 1	3
MATH 4210	Complex Variables	3
Two physics elective courses:		
PHYS 4012	Quantum Mechanics	3
PHYS 4062	Introduction to Thermodynamics	3
Total Credit Hours		15

Physics B.S./M.B.A. Accelerated Degree Program

The Department of Physics together with the Graduate School of Management offers an accelerated degree program which allows students to earn both their B.S. in Physics and master of business administration (M.B.A.) all within in a five-year time period.

During the first four years of the program, students complete both their course work requirements for their Physics B.S. degree and the necessary prerequisite courses for the M.B.A. degree in the College of Business Administration. In addition, undergraduate students begin their M.B.A. graduate work in their senior year by taking two graduate level courses.

To be considered for admission to the B.S./M.B.A. five-year program, applicants must formally apply to the Graduate School of Management during their junior year at Marquette University. For more detailed information and details of a typical five-year course work plan, please refer to the Graduate School of Management Bulletin and contact the Department of Physics or the Graduate School of Management.

Major in Biophysics

The major in biophysics consists of 51 credit hours. Students complete the common physics core: one required physics core sequence of two courses (8 credit hours) and five required physics core courses (16 credit hours); one required biology core sequence (6 credit hours), and three required biology courses (9 credit hours); six credit hours of approved physics electives from Group A and six additional credit hours of approved upper division electives (12 credit hours) in either biology, chemistry, mathematics or physics, taken from Groups A and B, listed below. In addition, students complete four required mathematics courses (16 credit hours), and four required chemistry courses (16 credit hours) for a total of 32 credit hours of background course work.

Common Biophysics Core:

Required Physics Core:		
Choose one sequence of the following (PHYS 1013 / PHYS 1014 are recommended):		8
PHYS 1001 & PHYS 1002	General Physics 1 and General Physics 2	
PHYS 1003 & PHYS 1004	General Physics with Introductory Calculus 1 and General Physics with Introductory Calculus 2	
PHYS 1013 & PHYS 1014	Classical and Modern Physics with Calculus 1 and Classical and Modern Physics with Calculus 2	
PHYS 2400	The Microscopic World	3
PHYS 2500	Oscillations and Waves with Laboratory	4
PHYS 4031	Electricity and Magnetism 1	3
PHYS 4046	The Physical Basis of Biological Structure and Function	3
PHYS 4065	Experimental Methods in Molecular Biophysics	3
Required Biology Core:		
BIOL 1001 & BIOL 1002	General Biology 1 and General Biology 2	6
BIOL 3301	Cell Biology	3
BIOL 4101	Biochemistry and the Molecular Basis of Biology	3
BIOL 4102	Experimental Molecular Biology	3
or BIOL 4302	Experimental Cell Biology	
Electives: Upper-division courses in Biology, Chemistry, Mathematics or Physics from the list of recommended electives below.		12
Total Credit Hours		51

Note: PHYS 1013 (http://bulletin.marquette.edu/undergrad/helenwayklinglercollegeofartsandsciences/physics_phys) Classical and Modern Physics with Calculus 1 and PHYS 1014 (http://bulletin.marquette.edu/undergrad/helenwayklinglercollegeofartsandsciences/physics_phys) Classical and Modern Physics with Calculus 2 are studio style courses recommended for students considering a physics major.

Biophysics Major Recommended Electives:

The major requires 12 credit hours of electives which should be drawn from these lists as follows: 6 credit hours of approved upper division electives in physics must be taken from Group A; six additional credit hours of approved upper division electives in biology, chemistry, mathematics or physics must be taken from courses in either Group A or Group B. Any exceptions must be approved by the Physics Department.

Group A:

PHYS 3100	Classical Mechanics	3
PHYS 4012	Quantum Mechanics	3
PHYS 4032	Electricity and Magnetism 2	3
PHYS 4062	Introduction to Thermodynamics	3
PHYS 4071	Atomic Physics	3

Group B:

PHYS 4956	Undergraduate Research in Physics [1]	1-3
BIOL 3201	Genetics	3
BIOL 4102	Experimental Molecular Biology	3
BIOL 4202	Experimental Genetics	3
BIOL 4302	Experimental Cell Biology	3
BIOL 4501	Cellular Neurobiology	3
BIOL 4502	Experimental Neurobiology	3
BIOL 4701	Human Physiology	4
BIOL 4702	Experimental Physiology	3
BIOL 4956	Laboratory Research Project in Biological Sciences [1]	1-3
BIOL 8101	Protein Structure and Function [2]	2
BIOL 8102	Biochemistry and Function of Nucleic Acids [2]	2
BIOL 8506	Cellular Neurophysiology [2]	2
CHEM 4431	Physical Chemistry: Fundamentals with Applications in Biological Sciences	3
CHEM 4433	Physical Chemistry 1	3
CHEM 4434	Physical Chemistry 2	3
CHEM 4530	Biochemistry 1: Macromolecular Structure and Function	3
CHEM 4956	Undergraduate Research in Chemistry [1]	1-3
MATH 4740	Biostatistical Methods and Models	3

[1] Credits from these courses to satisfy elective requirements require prior recommendation of academic adviser, course instructor and consent of department chair. Highly recommended for students interested in a research career in biophysics.

[2] Requires consent of Biology department for undergraduate admission to a graduate level course.

Required Background Mathematics and Chemistry Courses:

Math Courses:		
MATH 1450 & MATH 1451	Calculus 1 and Calculus 2	8
MATH 2450	Calculus 3	4
MATH 2451	Differential Equations	4
Chemistry Courses:		
CHEM 1001 & CHEM 1002	General Chemistry 1 and General Chemistry 2	8
CHEM 2111 & CHEM 2112	Organic Chemistry 1 and Organic Chemistry 2	8
Total Credit Hours		32

Typical Program for Biophysics Majors

Freshman

First Term	Hours	Second Term	Hours
BIOL 1001	3	BIOL 1002	3
CHEM 1001	4	CHEM 1002	4
PHYS 1001, 1003, or 1013[1]	4	PHYS 1002, 1004, or 1014[1]	4
ENGL 1001 or ESSV1 (MCC)	3	ENGL 1001 or ESSV1 (MCC)	3
	14		14

Sophomore

First Term	Hours	Second Term	Hours
BIOL 3301	3	CHEM 2112	4
CHEM 2111	4	MATH 1451	4
MATH 1450	4	CORE 1929 (MCC)	3
PHIL 1001 or THEO 1001 (MCC)	3	PHIL 1001 or THEO 1001 (MCC)	3
	14		14

Junior

First Term	Hours	Second Term	Hours
BIOL 4101	3	MATH 2451	4
MATH 2450	4	BIOL 4102 or 4302	3
PHYS 2400	3	PHYS 2500	4
PHYS 4031	3	DSCV (MCC)[2, 3]	3
DSCV (MCC)[2, 3]	3	DSCV (MCC)[2, 3]	3
	16		17

Senior

First Term	Hours	Second Term	Hours
PHYS 4046	3	PHYS 4065	3
Group A elective[5]	3	Group A elective [5]	3
Group A or B elective [6]	3	Group A or B elective[6]	3
CORE 4929 (MCC)	3	Electives	7
DSCV (MCC)[2, 3]	3		
	15		16

Total credit hours: 120

1 PHYS 1013/1014 recommended.

2 The four courses in the Discovery Tier (DSCV) of the MCC must be completed in the same theme and include the following content areas: Humanities (HUM), Social Science (SSC), Natural Science and Mathematics (NSM) and one elective (ELE), which is an additional course from any of the three content areas. A maximum of two courses in the Discovery Tier can apply towards a primary major.

3 Students must also complete the Writing Intensive (WRIT) and Engaging Social System and Values 2 (ESSV2) requirements of the MCC. These requirements can be fulfilled through designated courses in the Discovery Tier or other degree requirements.

4 BIOL 4102 may be substituted. BIOL 4102 is offered in the fall term. BIOL 4102 requires BIOL 4101, which may be taken concurrently.

5 Upper division physics elective from PHYS 3011, PHYS 4012 (strongly recommended), PHYS 4032 and PHYS 4062 (strongly recommended).

6	Elective from: PHYS 3011, 3995*, 4012, 4032, 4062; BIOL 3201, 4202, 4501, 4502, 4701, 4956*, 8101, 8102, 8506; CHEM 4431, 4433, 4434, 4530, 4956*; MATH 4740. *These courses require prior recommendation of academic adviser and consent of department chair; these courses are highly recommended for student interested in a career in biophysics research.

Major in Applied Physics

The major in applied physics consists of up to 42 credit hours. Students complete a physics core consisting of: an introductory physics sequence of two courses (8 credit hours); five required physics courses covering electromagnetism, modern physics, mechanics, and thermodynamics (15 credit hours); computer programming (3-4 credit hours); and laboratories in contemporary techniques and in electronics (4 credit hours). Students are required to complete 9 credit hours of electives in engineering (6 credit hours of upper division electives). In certain cases, formal prerequisites for the Engineering elective courses can be waived with (a) prior approval from the Engineering Advising Center, and (b) concurrent enrollment in PHYS 2929 Applied Physics Bridge to Engineering. Applied Physics students should consult with their academic adviser and the Engineering Advising Center for permission to enroll in these courses. Either a research project in applied physics or cooperative work-study experience is required, typically carried out full-time over two summer terms. Additional physics, engineering, chemistry, computing, math, biology or other elective courses may be taken to fulfill the overall requirements for the B.S. degree and/or the prerequisite requirements for some upper division electives.

Required Courses		
PHYS 1003 & PHYS 1004	General Physics with Introductory Calculus 1 and General Physics with Introductory Calculus 2	8
or PHYS 1013 & PHYS 1014	Classical and Modern Physics with Calculus 1 and Classical and Modern Physics with Calculus 2	
EECE 1610	Introduction to Computer Programming	3-4
or COSC 1010	Introduction to Software Development	
PHYS 2400	The Microscopic World	3
PHYS 2500	Oscillations and Waves with Laboratory	4
PHYS 3100	Classical Mechanics	3
PHYS 3056	Contemporary Physics Lab 1	2
PHYS 3989 & PHYS 4989	Applied Physics Immersion Experience 1 and Applied Physics Immersion Experience 1 - Grading Period	1
PHYS 3990 & PHYS 4990	Applied Physics Immersion Experience 2 and Applied Physics Immersion Experience 2 - Grading Period	1
PHYS 4031	Electricity and Magnetism 1	3
PHYS 4062	Introduction to Thermodynamics	3
Engineering Electives (At least 6 credits must be 3000 or 4000 level)		9
Total Credit Hours		40-41

Recommended Engineering Electives - Engineering electives should be chosen with the assistance of your major adviser and may include the following:

GEEN 2130	Mechanics of Materials	3
MEEN 3210	Measurements and Controls	3
MEEN 3320	Fluid Mechanics	3
EECE 2710	Introduction to Computer Hardware and Software	3
EECE 2030	Digital Electronics	3
EECE 3010	Electronic Devices and Applications	3
EECE 4510	Digital Signal Processing	3
ELEN 2020	Electric Circuits 2	3
ELEN 3001	Electric Circuits and Machinery	3
ELEN 3020	Linear Systems Analysis	3
ELEN 3210	Electric Drives	3
ELEN 4110	Microwave Engineering	3
ELEN 4310	Control Systems	3

TYPICAL PROGRAM FOR APPLIED PHYSICS MAJOR

Freshman

First Term	Hours	Second Term	Hours
MATH 1450	4	MATH 1451	4
ENGL 1001 or ESSV1 (MCC)	3	ENGL 1001 or ESSV1 (MCC)	3
PHIL 1001 or THEO 1001 (MCC)	3	PHIL 1001 or THEO 1001 (MCC)	3
PHYS 1003 or 1013	4	PHYS 1004 or 1014	4
	14		14

Sophomore

First Term	Hours	Second Term	Hours	Summer Term	Hours
EECE 1610 or COSC 1010	3	MATH 2451	4	PHYS 3989	0
MATH 2450	4	PHYS 2500	4		
PHYS 2400	3	DSCV (MCC)[1, 2]	3		
CORE 1929 (MCC)	3	Elective	3		
Elective	3				
	16		14		0

Junior

First Term	Hours	Second Term	Hours	Summer Term	Hours
PHYS 3100	3	PHYS 4032	3	PHYS 3990	0
PHYS 3056	2	Engineering elective - 3000+ level	3		
PHYS 4031	3	Upper-division Physics elective	3		
PHYS 4989	1	DSCV (MCC)[1, 2]	3		
Engineering elective - 2000+ level	3	Elective	3		
DSCV (MCC)[1, 2]	3				
	15		15		0

Senior

First Term	Hours	Second Term	Hours
PHYS 4990	1	PHYS 4062	3
Engineering elective - 3000+ level	3	Electives	10
Electives	9	CORE 4929 (MCC)	3
DSCV (MCC)[1, 2]	3		
	16		16

Total credit hours: 120

1 The four courses in the Discovery Tier (DSCV) of the MCC must be completed in the same theme and include the following content areas: Humanities (HUM), Social Science (SSC), Natural Science and Mathematics (NSM) and one elective (ELE), which is an additional course from any of the three content areas. A maximum of two courses in the Discovery Tier can apply towards a primary major.

2 Students must also complete the Writing Intensive (WRIT) and Engaging Social System and Values 2 (ESSV2) requirements of the MCC. These requirements can be fulfilled through designated courses in the Discovery Tier or other degree requirements.

Minor in Physics

The minor in physics consists of a total of 20 credit hours: one required physics sequence (8 credit hours) and 12 credit hours in physics elective courses as listed below:

Required Physics Sequence: Choose one of the following:		8
PHYS 1001 & PHYS 1002	General Physics 1 and General Physics 2	
PHYS 1003 & PHYS 1004	General Physics with Introductory Calculus 1 and General Physics with Introductory Calculus 2	
PHYS 1013 & PHYS 1014	Classical and Modern Physics with Calculus 1 and Classical and Modern Physics with Calculus 2	
Electives: Choose 12 credit hours of Physics courses		12
Total Credit Hours		20

Department of Public Instruction Certification

To pursue Department of Public Instruction certification, College of Education students should complete the following requirements which consist of a total of 22 credit hours: one required physics sequence (8 credit hours), three required physics courses (10 credit hours) and 4 credit hours in physics elective courses as listed below:

Required Physics Sequence: Choose one of the following:		8
PHYS 1001 & PHYS 1002	General Physics 1 and General Physics 2	
PHYS 1003 & PHYS 1004	General Physics with Introductory Calculus 1 and General Physics with Introductory Calculus 2	
PHYS 1013 & PHYS 1014	Classical and Modern Physics with Calculus 1 and Classical and Modern Physics with Calculus 2	
Required Physics Courses:		
PHYS 1009	Earth and Environmental Physics	3
PHYS 2400	The Microscopic World	3
PHYS 2500	Oscillations and Waves with Laboratory	4
Electives: Choose 4 credit hours of Physics courses		4
Total Credit Hours		22

Minor in Astronomy

The Astronomy Minor is intended for students who are interested in learning about modern astronomy and astrophysics.

NON-PHYSICS MAJORS: the minor in astronomy requires one introductory physics sequence (8 credit hours) and four required physics courses (12 credit hours) for a total of 20 credit hours as listed below:

Required Physics Sequence - Choose one of the following:		8
PHYS 1001 & PHYS 1002	General Physics 1 and General Physics 2	
PHYS 1003 & PHYS 1004	General Physics with Introductory Calculus 1 and General Physics with Introductory Calculus 2	
PHYS 1013 & PHYS 1014	Classical and Modern Physics with Calculus 1 and Classical and Modern Physics with Calculus 2	
Required Courses:		
PHYS 1008	Astronomy and Space Physics	3
PHYS 2400	The Microscopic World	3
PHYS 3021	Introduction to Theoretical Astrophysics	3
PHYS 3022	Introduction to Observational Astronomy	3
Total Credit Hours		20

Note:

- Students who complete PHYS 1001 General Physics 1 and PHYS 1002 General Physics 2 must also take the math requisites for PHYS 1003 General Physics with Introductory Calculus 1 and PHYS 1004 General Physics with Introductory Calculus 2 (MATH 1450 Calculus 1 and MATH 1451 Calculus 2) in order to meet the mathematics level of PHYS 3021 Introduction to Theoretical Astrophysics and PHYS 3022 Introduction to Observational Astronomy.

PHYSICS MAJORS: the minor in astronomy requires the following, taken under the guidance of one of our astronomy/astrophysics faculty with a topic being in the realm of astronomy or astrophysics. **Note:** If the PHYS 4931 Topics in Contemporary Physics course is used for the astronomy minor requirement, it may not then be used for a physics major elective course requirement. The astronomy minor for a physics major requires a total of 12 credit hours beyond the physics major requirements. The required introductory physics sequence is completed as part of the physics major requirements.

Required Physics Sequence - Choose one of the following:		8
PHYS 1001 & PHYS 1002	General Physics 1 and General Physics 2	
PHYS 1003 & PHYS 1004	General Physics with Introductory Calculus 1 and General Physics with Introductory Calculus 2	
PHYS 1013 & PHYS 1014	Classical and Modern Physics with Calculus 1 and Classical and Modern Physics with Calculus 2	
Required Courses:		
PHYS 1008	Astronomy and Space Physics	3
PHYS 3021	Introduction to Theoretical Astrophysics	3
PHYS 3022	Introduction to Observational Astronomy	3
Choose one of the following:		3
PHYS 4034	Modern Optics	
PHYS 4065	Experimental Methods in Molecular Biophysics	
PHYS 4072	Introduction to Nuclear and Elementary Particle Physics	
PHYS 4931	Topics in Contemporary Physics	
Total Credit Hours		20

Minor in Biophysics

Biophysics is concerned with the application of the concepts and methods of physics to the solution of biological problems and to the understanding of biological processes. Students who complete the biophysics minor achieve a grasp of physics as it relates to solving biological problems, a general understanding of the nature of biological problems and of proteins and cell membranes in particular and of several techniques based on physics principles that are used in biological investigations.

Cognate requirements for the minor are one year each of introductory biology and introductory chemistry as follows:

Cognate Course Requirements:		
Required Biology Sequence:		6
BIOL 1001 & BIOL 1002	General Biology 1 and General Biology 2	
Required Chemistry Sequence:		8
CHEM 1001 & CHEM 1002	General Chemistry 1 and General Chemistry 2	
Total Credit Hours		14

Biophysics Minor Course Requirements:

Required Introduction to Organic Chemistry: Choose one of the following.		2-8
CHEM 2111 & CHEM 2112	Organic Chemistry 1 and Organic Chemistry 2	
or		
CHEM 2113 & CHEM 2114	Organic Chemistry for Majors 1 and Organic Chemistry for Majors 2	
or		
BISC 2050	Organic Chemistry for the Health Sciences	
Required Differential and Integral Calculus: Choose one of the following.		3-4
MATH 1410	Calculus for the Biological Sciences	
MATH 1450	Calculus 1	
Required Physics Sequence: Choose one of the following sequences.		8
PHYS 1001 & PHYS 1002	General Physics 1 and General Physics 2	

PHYS 1003 & PHYS 1004	General Physics with Introductory Calculus 1 and General Physics with Introductory Calculus 2	
PHYS 1013 & PHYS 1014	Classical and Modern Physics with Calculus 1 and Classical and Modern Physics with Calculus 2	
Physics Course Requirements:		
PHYS 4046	The Physical Basis of Biological Structure and Function (or equivalent by consent of Physics Dept)	3
PHYS 4065	Experimental Methods in Molecular Biophysics	3
PHYS 4956	Undergraduate Research in Physics [1]	3
Total Credit Hours		22-29

[1] PHYS 4956 Undergraduate Research in Physics must be taken for 3 cr. hrs.

Program Director: Dr. Andrew Kunz

Curriculum Requirements

Recommended Prerequisites:

PHYS 1003H	Honors General Physics with Introductory Calculus 1	4
PHYS 1004H	Honors General Physics with Introductory Calculus 2	4
Total Credit Hours		8

Requirements for Physics Disciplinary Honors:

PHYS 4953H	Honors Seminar in Physics	1
PHYS 4956H	Honors Undergraduate Research	6

- Students are expected to enroll in PHYS 4953H during the fall term of the junior year.
- The 6 credits of PHYS 4956H must be taken over at least two terms.

ELIGIBILITY

1. Overall cumulative GPA of 3.200 or higher at time of application.
2. Written statement – In a written statement (1-2 pages), the student should summarize his/her reasons for applying to the honors program. In addition, the statement should address the student's plans with respect to undergraduate research and career objectives.

APPLICATION

Students are encouraged to apply to the disciplinary honors program in physics during the spring term of their sophomore year. Applications may also be accepted in the fall term of the junior year in rare cases. Applications should be submitted directly to the physics department office. Sample statements, application deadlines and forms are available on the Department of Physics Web page. Additional questions can be directed to the disciplinary honors director, Dr. Andrew Kunz. The program director evaluates applications and makes decisions regarding admission to the program.

ACADEMIC STANDARDS

If a student drops below a 3.200 in any given term during the junior year or any subsequent year, the student receives a letter of warning from the director. If a student drops below a 3.200 cumulative GPA, they are placed on Honors Program academic probation; if they do not achieve a 3.200 cumulative by the end of the following term, they are removed from the program. Students must earn a grade of C or better in a course for it to count toward the disciplinary honors requirements.

Courses

PHYS 1001. General Physics 1. 4 cr. hrs.
Newton's laws, linear motion, circular and harmonic motion, fluids, heat, kinetic theory, wave motion and sound. 4 hrs. lec., 2 hrs. lab. Prereq: High school algebra, geometry, and trigonometry or equivalent.

PHYS 1002. General Physics 2. 4 cr. hrs.
Continuation of PHYS 1001. Electrostatics, DC circuits, magnetism, electromagnetic induction, light, optical instruments, interference and diffraction of light, modern physics. 4 hrs. lec., 2 hrs. lab. Prereq: PHYS 1001.

PHYS 1003. General Physics with Introductory Calculus 1. 4 cr. hrs.
Survey of classical physics for science and engineering majors. Kinematics in one and two dimensions. Newton's laws of motion and dynamics, including rotation of rigid bodies. Energy concepts in physical systems, harmonic motion and thermodynamics with applications. A command of high school algebra, geometry and trigonometry is assumed. Requires the use of introductory calculus. 3 hrs. lec., 2 hrs. lab., 1 hr. dis. Prereq: MATH 1450 which, may be taken concurrently.

PHYS 1003H. Honors General Physics with Introductory Calculus 1. 4 cr. hrs.
Survey of classical physics for science majors and engineering majors. Kinematics in one and two dimensions. Newton's laws of motion and dynamics, including rotation of rigid bodies. Energy concepts in physical systems, harmonic motion and thermodynamics with applications. A command of high school algebra, geometry and trigonometry is assumed. Requires the use of introductory calculus. Students cannot receive credit for both PHYS 1003 and PHYS 1013 or PHYS 1013H. As an Honors Program course, includes a more intensive research or project component. Prereq: MATH 1450, which may be taken concurrently; admission to Marquette University Honors Program.

PHYS 1004. General Physics with Introductory Calculus 2. 4 cr. hrs.
A continuation of PHYS 1003. A survey of classical electromagnetic theory, with an introduction to modern physics. Electricity and magnetism: Coulomb's law, Gauss' law, the electric field and the electric potential, circuits, Ampere's law, Faraday's law, electromagnetic waves. Classical and quantum waves, interference, optics. 3 hrs. lec., 2 hrs. lab., 1 hr. dis. Prereq: MATH 1450; PHYS 1001 or PHYS 1003 or PHYS 1013; MATH 1451 or MATH 1455, which may be taken concurrently.

PHYS 1004H. Honors General Physics with Introductory Calculus 2. 4 cr. hrs.
A continuation of PHYS 1003. A survey of classical electromagnetic theory, with an introduction to modern physics. Electricity and magnetism: Coulomb's law, Gauss' law, the electric field and the electric potential, circuits, Ampere's law, Faraday's law, electromagnetic waves. Classical and quantum waves, interference, optics. Students cannot receive credit for both PHYS 1004 and PHYS 1014 or PHYS 1014H. As an Honors Program course, includes a more intensive research or project component. Prereq: MATH 1450; PHYS 1001, PHYS 1003, PHYS 1003H, PHYS 1013 or PHYS 1013H; MATH 1451 or MATH 1455, which may be taken concurrently; admission to Marquette University Honors Program.

PHYS 1007. Survey of Meteorology. 3 cr. hrs.
An introduction to the science of the atmosphere as it relates to the weather of the earth, including important environmental issues such as global warming and air pollution. Topics include: atmospheric gasses, heat transfer, causes of the seasons, humidity, clouds, atmospheric stability and motions, air masses, fronts, and pressure systems, thunderstorms, tornados, hurricanes and weather forecasting.

PHYS 1008. Astronomy and Space Physics. 3 cr. hrs.
Physics of the solar system, stars, galaxies and the universe. Experimental methods of observational astronomy, telescopes, and space probes. Special topics such as black holes, neutron stars and quasars are covered. Satisfies the Arts and Sciences College Curriculum Natural Science requirement.

PHYS 1009. Earth and Environmental Physics. 3 cr. hrs.
Impact of human activities on the environment, especially the consumption of fossil fuels. Population distribution and growth. Energy balance of the earth. Energy, land and water use, the water cycle. Effects of chemical and physical pollutants on water and the atmosphere. Course designed for non-science majors. Satisfies the Arts and Sciences College Curriculum Natural Science requirement.

PHYS 1013. Classical and Modern Physics with Calculus 1. 4 cr. hrs.
A study of motion in its various forms, translational, rotational, and vibrational, that emphasizes their underlying unity, especially the central role of energy and its conservation, and their basis in the fundamental Newtonian laws of motion and Einstein's special relativity. These ideas are used to explain thermal processes. 3 hrs. lec., 2 hrs. lab., 1 hr. quiz. Prereq: MATH 1450, which may be taken concurrently. A command of high school algebra, geometry, trigonometry is assumed. Requires the use of introductory calculus. Students cannot receive credit for both PHYS 1003 and PHYS 1013.

PHYS 1013H. Honors Classical and Modern Physics with Calculus 1. 4 cr. hrs.
A study of motion in its various forms, translational, rotational, and vibrational, that emphasizes their underlying unity, especially the central role of energy and its conservation, and their basis in the fundamental Newtonian laws of motion and Einstein's special relativity. These ideas are used to explain thermal processes. As an Honors Program course, includes a more intensive research or project component. 3 hrs. lec., 2 hrs. lab., 1 hr. quiz. Prereq: MATH 1450, which may be taken concurrently. A command of high school algebra, geometry, trigonometry is assumed. Requires the use of introductory calculus. Admission to Marquette University Honors Program. Students cannot receive credit for both PHYS 1003 and PHYS 1013 or PHYS 1013H.

PHYS 1014. Classical and Modern Physics with Calculus 2. 4 cr. hrs.
Continuation of PHYS 1013. Examines the development of energy as a fundamental concept, includes a study of electric and magnetic phenomena and their unification in the theory of electromagnetism. Applications are made to waves, geometric and physical optics, atomic spectra, and nuclear decay and introductory quantum mechanics including wave function and bound systems. 3 hrs. lec., 2 hrs. lab., 1 hr. quiz. Students cannot receive credit for both PHYS 1004 and PHYS 1014. Prereq: MATH 1450, MATH 1451 or MATH 1455, which may be taken concurrently; and PHYS 1001, PHYS 1003 or PHYS 1013.

PHYS 1014H. Honors Classical and Modern Physics with Calculus 2. 4 cr. hrs.
Continuation of PHYS 1013H. Examines the development of energy as a fundamental concept, includes a study of electric and magnetic phenomena and their unification in the theory of electromagnetism. Applications are made to waves, geometric and physical optics, atomic spectra, and nuclear decay and introductory quantum mechanics including wave function and bound systems. As an Honors Program course, includes a more intensive research or project component. 3 hrs. lec., 2 hrs. lab., 1 hr. quiz. Students cannot receive credit for both PHYS 1004 and PHYS 1014 or PHYS 1014H. Prereq: MATH 1450, MATH 1451 or MATH 1455, which may be taken concurrently; and PHYS 1001, PHYS 1003, PHYS 1013 or PHYS 1013H. Admission to Marquette University Honors Program.

PHYS 1020. Physics Laboratory Only. 1 cr. hr.
Prereq: Cons. of dept. ch.

PHYS 1030. Physics Lecture Only. 1-3 cr. hrs.
Prereq: Cons. of dept. ch.

PHYS 1953. Discovering Physics. 1 cr. hr.
An introduction to the department and the myriad career possibilities a degree in physics opens up to a student. This includes what the student groups do and why they're useful, what careers are available to physics majors, talks from faculty members about their research, tours of sites in industry that have internships available for physics students and attendance at department colloquia.

PHYS 1954. Communicating Physics. 1 cr. hr.
An introduction to scientific literature and literature searches. Students read, present, discuss and write overviews about journal articles and special topics. These topics could include general interest, breaking research and science ethics articles. Requires attendance at the department colloquia.

PHYS 2004. Modern Physics: Atoms, Particles, and Quanta. 3 cr. hrs.
A survey of 20th century physics concentrating on atoms and particles. Quantum mechanics: origins, the Schrodinger equation, the hydrogen atom, many-electron atoms and angular momentum. Introduction to special relativity. Nuclear structure, radioactivity, nuclear reactions, fission and fusion. Elementary particles, conservation laws, reactions, the Standard Model, and cosmology. Prereq: MATH 2450 and PHYS 1002; MATH 2450 and PHYS 1004; or MATH 2450 and PHYS 1014. Prerequisites may be taken concurrently.

PHYS 2005. Modern Physics: The States of Matter. 3 cr. hrs.
A survey of the physics of matter and materials. Atoms and the forces between them, molecules, the states of matter, kinetic theory, perfect and imperfect gases. Statistical physics: classical statistics and the Boltzmann factor, quantum statistics. The solid state: cohesion and structure, electrical, magnetic, thermal and elastic properties. The liquid state: cohesion and structure, latent heat and melting, flow in ideal and real liquids. Prereq: MATH 2450 and PHYS 1002; MATH 2450 and PHYS 1004; or MATH 2450 and PHYS 1014. Prerequisites may be taken concurrently.

PHYS 2049. Computational Physics. 3 cr. hrs.
Computational techniques applied to problems in the physical sciences. Construction of models of physical systems. Generation and analysis of data. The role of models in developing physical theories. Course assignments will use a variety of programming environments and commercial software.

PHYS 2055. Electronics Lab. 2 cr. hrs.
Introduction to electronic measuring equipment and circuits. Voltmeters, ammeters, ohmmeters, oscilloscopes, DC and AC circuits, resistance, impedance, passive and active filters, power supplies, op-amps, amplifiers, and analog-digital conversion. An introduction to error analysis and precision of measurement. 1 hr. lec., 3 hrs. lab. Prereq: PHYS 1004 or PHYS 1014.

PHYS 2400. The Microscopic World. 3 cr. hrs.
A survey, including applications, of quantum mechanics including the 1-D Schrodinger equation, the hydrogen atom and angular momentum. Atoms and the forces between them, molecules, the states of matter, kinetic theory, perfect and imperfect gases. Statistical physics: classical statistics and the Boltzmann factor, quantum statistics. Prereq: MATH 2450; PHYS 1002, PHYS 1004 or PHYS 1014; any of which may be taken concurrently.

PHYS 2500. Oscillations and Waves with Laboratory. 4 cr. hrs.
A comprehensive study of mechanical and electromagnetic oscillators and waves as understood with ordinary differential equations. Application includes the simple harmonic oscillator, driven/damped systems and coupled oscillators, scattering-interference/diffraction. Matrix methods, eigenvectors and eigenvalues, normal modes, complex variables, Fourier transformations. Prereq: PHYS 1002 or PHYS 1004 or PHYS 1014; PHYS 2400; MATH 2451, which may be taken concurrently.

PHYS 2929. Applied Physics Bridge to Engineering. 1 cr. hr.
Taken concurrently with approved courses offered by the Opus College of Engineering. With permission, a student may take this course in lieu of the prerequisite for the paired Engineering course. Addresses missing prerequisite content. Prereq: Cons. of instr.

PHYS 2953. Computational Methods in Physics. 1 cr. hr.
Designed to teach students to perform relevant computational tasks using Matlab. This software is used to solve computational physics problems, analyze experimental data, perform error analysis and create graphs and figures in a style appropriate for publication. Prereq: Concurrent enrollment in PHYS 2400, recommended.

PHYS 2954. Participating in Physics. 1 cr. hr.
Designed to prepare students to apply for Research Experiences for Undergraduates (REU's), summer positions, graduate schools, full-time career employment, Teaching Assistant and Research Assistant positions. Covers development of proposal, cover letter, research statement, curriculum vitae and resumes. Builds awareness of available resources.

PHYS 3011. Classical Mechanics. 3 cr. hrs.
Three-dimensional motion of a particle in both Cartesian and spherical coordinate systems. Newtonian dynamics, the classical harmonic oscillator, central forces. Lagrange and Hamilton's formulations of analytical mechanics, angular momentum, Kepler's problem, and the dynamics of a rigid body. Coupled oscillators. Prereq: MATH 2451 and PHYS 1002; MATH 2451 and PHYS 1004; or MATH 2451 and PHYS 1014. Prerequisites may be taken concurrently.

PHYS 3021. Introduction to Theoretical Astrophysics. 3 cr. hrs.
Introduction to astrophysical problems, with emphasis on underlying physical principles; includes the nature of stars, equations of state, stellar energy generations, stellar structure and evolution, astrophysical neutrinos, binary stars, white dwarfs, neutron stars and pulsars and novae and supernovae. Prereq: PHYS 1013 and PHYS 1014 or PHYS 1003 and PHYS 1004 or PHYS 1001 and PHYS 1002 and cons. of instr.

PHYS 3022. Introduction to Observational Astronomy. 3 cr. hrs.
Nature of the Milky Way galaxy from an observer's perspective: stellar statistics and distributions, stellar populations, spiral structure, the nucleus and halo. Nature of ordinary galaxies, galaxies in our Local Group, structure of voids and superclusters. Nature of peculiar objects: Seyfert galaxies, starburst galaxies, and quasars. Elementary aspects of physical cosmology. Introduction to techniques used in modern optical and radio astronomy with emphasis on the physical and mathematical understanding of the detection of electromagnetic radiation. Prereq: PHYS 1013 and PHYS 1014 or PHYS 1003 and PHYS 1004 or PHYS 1001 and PHYS 1002 and cons. of instr.; PHYS 2004 or PHYS 2400; PHYS 3021.

PHYS 3056. Contemporary Physics Lab 1. 2 cr. hrs.
Experiments in a variety of modern physics topics. Laboratory safety and methods, scientific writing and error analysis. Prereq: PHYS 2055 or PHYS 2500.

PHYS 3100. Classical Mechanics. 3 cr. hrs.
Three-dimensional motion of a particle in both Cartesian and spherical coordinate systems. Newtonian dynamics, central forces. Lagrange's and Hamilton's formulations of analytical mechanics, angular momentum, Kepler's problem and the dynamics of a rigid body. Prereq: MATH 2451; PHYS 1002, PHYS 1004 or PHYS 1014; PHYS 2500, all of which may be taken concurrently; or cons. of instr.

PHYS 3953. Biophysics Seminar. 1 cr. hr.
Frontiers in biophysics are explored through seminars offered across disciplines (biology, chemistry, physics, math, etc.) at Marquette and at neighboring institutions. May be repeated for credit. May not be used as an upper division elective course for the physics major. Prereq: Jr. stndg.

PHYS 3989. Applied Physics Immersion Experience 1. 0 cr. hrs.
For students completing a pre-approved full-time internship or co-op comprising of at least 240 hours. Placement internship in research or industry in an applied physics setting. Internships must be approved in advance. Responsibilities include relevant academic content. Grading and credits are accomplished by registering for PHYS 4989 during the following term. Fee. SNC/UNC grade assessment. Prereq: Cons. of instr.

PHYS 3990. Applied Physics Immersion Experience 2. 0 cr. hrs.
For students completing a pre-approved full-time internship or co-op comprising of at least 240 hours. Placement internship in research or industry in an applied physics setting. Internships must be approved in advance. Responsibilities include relevant academic content. Grading and credits are accomplished by registering for PHYS 4990 during the following term. Fee. SNC/UNC grade assessment. Prereq: Cons. of instr.

PHYS 4012. Quantum Mechanics. 3 cr. hrs.
Quantum states, state vectors, observables and operators. The formal structure of quantum mechanics. Time evolution of the state vector. The Hamiltonian. Position and momentum representations, and the wave function. One-dimensional wave mechanics and the harmonic oscillator. Three-dimensional wave mechanics. Symmetry, angular momentum, and the hydrogen atom. Fermions, and bosons. Perturbation methods. Prereq: MATH 2451; PHYS 2004 or PHYS 2500; or cons. of instr.

PHYS 4024. Modern Optics. 3 cr. hrs.
Geometric optics, classical wave theory of optics, interference, diffraction, polarization, electromagnetic theory of light, interaction of light and matter, lasers and coherence. Prereq: MATH 1451 and PHYS 1002; or MATH 1451 and PHYS 1004; or MATH 1451 and PHYS 1014.

PHYS 4031. Electricity and Magnetism 1. 3 cr. hrs.
Electrostatics: Coulomb's law and Gauss' law. The electric field in dielectric materials. Microscopic theory of Ohm's law and steady state currents. The magnetic field, Biot-Savart law, Ampere's law, the vector potential. Magnetic materials. Electromagnetic induction, Faraday's law. Maxwell's equations and electromagnetic waves. Prereq: MATH 2450 and PHYS 1002; or MATH 2450 and PHYS 1004; or MATH 2450 and PHYS 1014.

PHYS 4032. Electricity and Magnetism 2. 3 cr. hrs.
Boundary value problems: The solution of electrostatic and magnetostatic problems in continuous media. Microscopic theories of the dielectric and magnetic properties of materials. Electromagnetic waves in bounded regions. Reflection, refraction and dispersion. Radiation from accelerated charges. Antennae. Electrodynamics and the theory of special relativity. Prereq: PHYS 4031.

PHYS 4046. The Physical Basis of Biological Structure and Function. 3 cr. hrs.
The molecular processes of life occur in a complex aqueous molecular environment. Biological molecules and their environments are governed by the principles of physics. This course presents and explains physical techniques and models based on mechanics, thermodynamics, and electricity and magnetism, and shows how they apply to help characterize and understand the environments in which cells and biological molecules operate, while also helping to explain cellular and physiological processes. Prereq: PHYS 1002, 1004 or 1014 and CHEM 1002, MATH 1410 or MATH 1451.

PHYS 4050. Introduction to Einstein's General Theory of Relativity. 3 cr. hrs.
Special relativity including spacetime diagrams and 4-vectors. Tensor calculus, non-Euclidean geometry, and arbitrary coordinate systems. The Schwarzschild metric, orbits and precession, gravitational lensing, and black holes. Cosmological and gravitational wave solutions to the Einstein equation. Prereq: Physics 1003 & 1004; or 1013 & 1014; MATH 1450, MATH 1451 and MATH 2450.

PHYS 4057. Contemporary Physics Lab 2. 2 cr. hrs.
Further development of experimental techniques learned in PHYS 3056. Student-led development of projects. Prereq: PHYS 3056.

PHYS 4062. Introduction to Thermodynamics. 3 cr. hrs.
Fundamental concepts of thermodynamics: temperature, internal energy, entropy and thermodynamic potentials. Laws of thermodynamics, their consequences and applications. Introduction to statistical thermodynamics. Prereq: MATH 2450; PHYS 2005 or PHYS 2400.

PHYS 4065. Experimental Methods in Molecular Biophysics. 3 cr. hrs.
An introduction to the field of biological physics which develops the science and illustrates the applications of the techniques of X-ray diffraction and spin resonance to problems of biological interest: protein structural dynamics, ion channels and transport through cell membranes. Prereq: PHYS 2004 and PHYS 4031; or PHYS 2400 and PHYS 4031; or PHYS 4046.

PHYS 4071. Atomic Physics. 3 cr. hrs.
Quantum mechanics of one and many electron atoms. Spin, orbital, and total angular momentum. Atoms in electric and magnetic fields, the Stark effect and the Zeeman effect. Atomic transitions, symmetry and selection rules. The periodic table and shell structure. Modern spectroscopy. Prereq: PHYS 4012 and PHYS 4031.

PHYS 4072. Introduction to Nuclear and Elementary Particle Physics. 3 cr. hrs.
Experimental methods in nuclear and particle physics. Theories of nuclear structure, radioactivity, decay schemes, fission and fusion models, conservation laws. Elementary particle classifications and the Standard Model. Prereq: PHYS 4012.

PHYS 4075. Introduction to Solid State Physics. 3 cr. hrs.
Crystal structure of solids, the reciprocal lattice and diffraction. Lattice vibrations and thermal properties. Electrons in metals, band structure and semiconductors. The Fermi surface. Dielectric and magnetic properties of solids. Superconductivity. Prereq: PHYS 2005 or PHYS 2400; PHYS 4012.

PHYS 4931. Topics in Contemporary Physics. 3 cr. hrs.
Topics drawn from areas of current interest such as astrophysics, atmospheric physics, biophysics, condensed matter physics or particle physics. Prereq: Cons. of dept. ch.

PHYS 4953. Seminar in Physics. 1 cr. hr.
Critical analysis of the original works of scientists who have made significant contributions to Physics. May not be used as an upper division elective course for the physics major. Prereq: Cons. of dept. ch.

PHYS 4953H. Honors Seminar in Physics. 1 cr. hr.
Critical analysis of the original works of scientists who have made significant contributions to Physics. As an Honors Program course, includes a more intensive research or project component. May be repeated. May not be used as an upper division elective course for the physics major. Prereq: Admission to the PHYS Disciplinary Honors Program.

PHYS 4954. Review and Preparation for Post-Graduate Life. 1 cr. hr.
Includes a review of fundamental topics in physics in order to prepare for the Physics GRE exam, focusing on practice GRE exams. Additionally, applications for graduate school and/or employment in physics are discussed.

PHYS 4956. Undergraduate Research in Physics. 1-3 cr. hrs.
Research project conducted under the direction of a faculty advisor. Prereq: Consent of Instructor.

PHYS 4956H. Honors Undergraduate Research. 1-3 cr. hrs.
Experimental or theoretical research in an area of contemporary physics under the guidance of a physics faculty member who has expertise in that area. Successful completion includes a summary paper and an oral presentation to the regular physics faculty. As an Honors Program course, includes a more intensive research or project component. May be repeated. May not be used as an upper division elective course for the physics major. Prereq: Cons. of instr., Jr. stndg.; admission to the PHYS Disciplinary Honors Program.

PHYS 4989. Applied Physics Immersion Experience 1 - Grading Period. 1 cr. hr.
Full-time co-op or internship grading period. Grading for preceding co-op work assignment is accomplished by completing a report on the work assignment, a report on academic material related to the work assignment, and other materials, as required. Grading is completed during the school term following the work assignment. S/U grade assessment. Prereq: PHYS 3989.

PHYS 4990. Applied Physics Immersion Experience 2 - Grading Period. 1 cr. hr.
Full-time co-op or internship grading period. Grading for preceding co-op work assignment is accomplished by completing a report on the work assignment, a report on academic material related to the work assignment, and other materials, as required. Grading is completed during the school term following the work assignment. S/U grade assessment. Prereq: PHYS 3990.

PHYS 4995. Independent Study in Physics. 1-3 cr. hrs.
Independent study of special topics in physics under faculty supervision. Topics selected by students. May not be used as an upper division elective course for the physics major. Prereq: Cons. of dept. ch.

PHYS 4997. Physics Exploration Capstone. 2 cr. hrs.
Students propose and develop an independent project incorporating material you learned in the physics curriculum. The project must include a measurement of a physical system, and a theoretical prediction of the results. The project chosen can be any system, subject to budgetary constraints, but should target physics beyond the introductory level. In addition to the project, a written report and an oral presentation are required. Prereq: Sr. stndg.

PHYS 4999. Senior Thesis. 2 cr. hrs.
Independent research under the guidance of physics faculty. The topic may be chosen from any area of physics. Successful completion of the course includes a written thesis on the research and an oral presentation. May not be used as an upper division elective course for the physics major. Prereq: Sr. stndg. and cons. of dept. ch.; cons. of a regular physics faculty member.