

Physics

Web Site: <http://www.odu.edu/physics> (<http://www.odu.edu/physics/>)

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Bachelor of Science in Physics - Astrophysics Major

The Department of Physics offers a major in astrophysics leading to the BS degree and the BS degree with honors. It is designed primarily for students preparing to do graduate study in astrophysics and related fields.

Bachelor of Science - Physics Major

The Department of Physics offers a major in physics with five program concentrations leading to the BS degree and the BS degree with honors.

- **Concentration A** (Research) is designed primarily for students preparing to do graduate study in physics and related fields or for students preparing to work professionally upon completion of the BS degree in various technical fields requiring the strongest preparation in physics.
- **Concentration B** (Professional) is designed for students who wish to create a specialized program of study which combines a strong foundation in physics with strong preparation in another field. Such other fields include engineering, medicine, computer science, business, and communications, to name a few.
- **Concentration C** (Education) is designed for students who are preparing to be high school physics teachers. This curriculum provides a solid foundation in both contemporary physics and in education pedagogy.
- **Concentration D** is a five-year, dual degree program in physics and electrical engineering. Students will receive a BS and BSEE upon graduation. Concentration D provides the highest level of preparation for both graduate school and positions in industry.
- **Concentration E** is a Bachelor of Science in physics and Master of Business Administration dual degree program. After students have satisfactorily completed their undergraduate requirements, they complete the remaining requirements in the MBA program. Students must earn a minimum of 150 credits (120 discrete credits for the undergraduate degree and 30 discrete credits for the graduate degree).

Degree Requirements

Degree requirements are comprised of three components:

1. Lower-level general education requirements.
2. Departmental requirements.
3. Upper-level general education requirements.

Some departmental requirements also satisfy upper- or lower-level general education requirements. Students earning the AS, AA, or AA&S (university parallel) degree from a Virginia Community College or Richard Bland College automatically satisfy the lower-level general education requirements. For Physics Concentrations A and B, as well as the astrophysics major, the upper-level general education requirement can be satisfied by any University-approved second major, minor, or two upper-division courses (6 credits) from outside the College of Sciences and not required by the major. For Concentration C, the upper-level general education requirement is satisfied by the Secondary Education Endorsement. For Concentration D, the second degree in electrical engineering satisfies the upper-level general education requirement, while for Concentration E, the MBA core curriculum satisfies the upper-level general education requirement.

Graduation Requirements

Both the physics major (all of its concentrations) and the astrophysics major require completion of a minimum of 120 credit hours (150 credit

hours for Physics Concentration D), which must include both a minimum of 30 credit hours overall and 12 credit hours in upper-level courses in the major program from Old Dominion University, completion of ENGL 110C, ENGL 211C or ENGL 221C or ENGL 231C, and the writing intensive (W) course in the major with a grade of C or better, and Senior Assessment. Additionally, the physics major (all concentrations) requires completion of the Physics Exit Exam with a minimum score of 20th percentile, and the astrophysics major requires completion of the Astrophysics Exit Exam with a minimum score of 20th percentile. Additional hours may be required to meet the foreign language requirement. All physics concentrations and the astrophysics major require a minimum grade of C in PHYS 261N-PHYS 262N, PHYS 231N-PHYS 232N, or PHYS 226N-PHYS 227N. Physics Concentrations A, B, D and E, as well as the astrophysics major require a minimum cumulative grade point average of 2.00 overall and in the major. Physics Concentration C requires a minimum 2.75 grade point average overall, in the major, and in the professional education core, with no grade less than a C- in the major and professional education core. The professional education core satisfies the upper-level general education requirement.

Math Minor

Physics majors in Concentrations A or B, and astrophysics majors wishing to complete a minor in applied mathematics can do so with just two additional math courses. Please consult the Department of Mathematics section of the Catalog for details.

Lower-Level General Education Requirements

(Physics Concentrations A, B, C, E, and astrophysics major; for Physics Concentration D refer to the electrical and computer engineering section in the College of Engineering and Technology.)

Skills

Composition (grade of C or better required in both courses)		
ENGL 110C	English Composition	3
ENGL 211C	Introduction to Academic Writing	3
or ENGL 231C	Introduction to Technical and Scientific Writing	
Oral Communication		
COMM 101R	Public Speaking	3
or COMM 103R	Voice and Diction	
or COMM 112R	Introduction to Interpersonal Communication	
or DANC/	Acting One	
THEA 152R		

Mathematics (Satisfied by major)

Language and Culture (BS students' competence must be at the 102 level. High school credit may satisfy the requirement.) 0-6

Information Literacy and Research

CS 120G	Introduction to Information Literacy and Research	3
or CS 121G	Introduction to Information Literacy and Research for Scientists	
or OEAS 130G	Research Skills and Information Literacy for the Natural Sciences	

Ways of Knowing

Human Creativity

Select one of the following: 3

ARTH 121A	Introduction to the Visual Arts
ARTS 122A	Visual Communication
COMM/THEA 270A	Film Appreciation
DANC 185A	Dance and Its Audience
MUSC 264A	Music in History and Culture
SEPS 223A	Visual Merchandising and Display
THEA 241A	The Theatre Experience

Interpreting the Past

Select one of the following: 3

HIST 100H	Interpreting the World Past Since 1500
HIST 101H	Interpreting the Asian Past
HIST 102H	Interpreting the European Past
HIST 103H	Interpreting the Latin America Past
HIST 104H	Interpreting the American Past
HIST 105H	Interpreting the African Past
THEA 243H	Theatre Histories
Literature	
Select one of the following: 3	
ENGL 112L	Introduction to Literature
ENGL 114L	American Writers, American Experiences
WCS 100L	Introduction to World Literatures and Cultures
Philosophy and Ethics	
Select one of the following: 3	
PHIL 110P	Introduction to Philosophy
PHIL 120P	Logic and Philosophy
PHIL 150P	Life, Death, and Meaning
or REL 150P	Life, Death, and Meaning
PHIL 155E	Human Nature
or REL 155E	Human Nature
PHIL 230E	Introduction to Ethics
PHIL 235E	Love, Sex, and Desire
or REL 235E	Love, Sex, and Desire
PHIL 250E	World Religions: Beliefs and Values
PHIL 270P	Truth and Perception
PHIL 303E	Business Ethics
PHIL 344E	Environmental Ethics
PHIL 345E	Bioethics
PHIL 355E	Cybersecurity Ethics
PHIL 442E	Studies in Applied Ethics
Nature of Science (satisfied by the major)	
Impact of Technology	
Select one of the following: 3	
BDA 200T	Elements of Data Science
BIOL 470T	Diseases that Changed our World
CHEM 171T	Influence of Polymers on Society
CHEM 173T	Nutritional Biochemistry
CHEM 175T	Neurotechnology
CHEM 339T	The Chemistry of the Environment
CHEM 343T	Science and Technology in Art
COMM 280T	Entertainment Technologies
or THEA 280T	Entertainment Technologies
COMM 372T	Introduction to New Media Technologies
CS 300T	Computers in Society
CYSE 200T	Cybersecurity, Technology, and Society
or IT 200T	Cybersecurity, Technology, and Society
DNTH 440T	Telehealthcare Technology
ENGL 307T	Digital Writing
or IDS 307T	Digital Writing
GAME 201T	Introduction to Game Studies
GEOG 102T	Digital Earth: Geospatial Technology and Society
GEOG 306T	Hazards: Natural and Technological
HIST 304T	History of Medicine, Disease, and Health Technology
HIST 388T	Discovering Earth's History
HIST 389T	Technology and Civilization

HIST/HNRS 386T/SCI 302T	The Evolution of Modern Science
IT 360T	Principles of Information Technology
MUSC 335T	Music Technology Survey
OEAS 220T	Introduction to Meteorology
PHIL 383T	Philosophy of Technology & Innovation
POLS 350T	Technology and War
POLS 458T	Weapons of Mass Destruction in Global Security
STEM 110T	Technology and Your World
STEM 370T	Technology and Society
WMST 390T	Women, Gender, and Technology Worldwide
Human Behavior	
Select one of the following: 3	
AAST 100S	Introduction to African American Studies
ANTR 110S	Introduction to Anthropology
COMM 200S	Introduction to Human Communication
CPD 100S	Leadership and Society
or SOC 100S	Leadership and Society
CRJS 215S	Introduction to Criminology
ECON 200S	Basic Economics
ECON 201S	Principles of Macroeconomics
ECON 202S	Principles of Microeconomics
ENTR 201S	Introduction to Entrepreneurship
FIN 210S	Personal Financial Literacy
FOUN 101S	Learning to Learn
GEOG 100S	Human Geography
GEOG 101S	Environmental Geography
HMS 200S	Personal Health and Wellness
POLS 100S	Introduction to International Politics
POLS 101S	Introduction to American Politics
POLS 102S	Introduction to Comparative Government and Politics
PRTS 210S	Leisure and Human Behavior
PSYC 201S	Introduction to Psychology
PSYC 203S	Lifespan Development
SEPS 203S	Dress, Culture and Society
SOC 201S	Introduction to Sociology
SOC 203S	Diversity and Society
WMST 201S	Introduction to Women's, Gender, and Sexuality Studies

Total Hours **30-36**

Four-Year Plan - Physics, Astrophysics Major - BS (<http://catalog.odu.edu/undergraduate/collegeofsciences/physics/physics-astrophysics-bs-fouryearplan/>)

- The four-year plan is a suggested curriculum to complete this degree program in four years. It is just one of several plans that will work and is presented only as broad guidance to students. Each student is strongly encouraged to develop a customized plan in consultation with their academic advisor. Additional information can also be found in Degree Works.

Departmental Requirements for BS in Astrophysics

MATH 211	Calculus I	4
MATH 212	Calculus II	4
MATH 312	Calculus III	4
or MATH 285	Transfer Credit for Calculus III	

MATH 307	Ordinary Differential Equations	3
or MATH 280	Transfer Credit for Ordinary Differential Equations	
Select one of the following:		3
MATH 316	Introductory Linear Algebra	
MATH 401	Partial Differential Equations	
MATH 421	Applied Mathematics II: Mathematical Modeling	
MATH 422	Applied Complex Variables	
CHEM 121N & CHEM 122N	Foundations of Chemistry I Lecture and Foundations of Chemistry I Laboratory	4
CS 150	Problem Solving and Programming I	4
Select one of the following:		4
PHYS 103N	Introductory Astronomy of the Solar System	
PHYS 104N	Introductory Astronomy of Galaxies and Cosmology	
PHYS 120	Physics in the 21st Century	1
or PHYS 309	Physics on the Back of an Envelope	
PHYS 261N	Advanced University Physics I	4
or PHYS 231N	University Physics I	
or PHYS 226N	Honors: University Physics I	
PHYS 262N	Advanced University Physics II	4
or PHYS 232N	University Physics II	
or PHYS 227N	Honors: University Physics II	
PHYS 303	Intermediate Experimental Physics	3
PHYS 319	Analytical Mechanics	3
PHYS 323	Modern Physics	3
PHYS 355	Mathematical Methods of Physics	3
PHYS 420	Introductory Computational Physics	3
PHYS 425	Electromagnetism I	3
PHYS 452	Introduction to Quantum Mechanics	3
PHYS 454	Thermal and Statistical Physics	3
PHYS 499W	Senior Thesis *	3
or PHYS 489W & PHYS 490W	Senior Thesis I and Senior Thesis II	
ASTP 313	Elements of Astrophysics	3
ASTP 414	Relativity and Cosmology	3
Select two of the following:		6
PHYS 413	Methods of Experimental Physics	
PHYS 453	Electromagnetism II	
PHYS 456	Intermediate Quantum Mechanics	
Choose one of the following:		3
ASTP 495	Special Topics in Astrophysics (Exoplanets / Atmospheric Spectroscopy / Satellite Remote Sensing)	
Total Hours		81

* Grade of C or better required in PHYS 499W or both PHYS 489W and PHYS 490W

Four-Year Plan - Physics Major - Research Concentration - BS (<http://catalog.odu.edu/undergraduate/collegeofsciences/physics/physics-research-bs-fouryearplan/>)

- The four-year plan is a suggested curriculum to complete this degree program in four years. It is just one of several plans that will work and is presented only as broad guidance to students. Each student is strongly encouraged to develop a customized plan in consultation with their academic advisor. Additional information can also be found in Degree Works.

Departmental Requirements for Research Concentration (A)

MATH 211	Calculus I	4
MATH 212	Calculus II	4
MATH 312	Calculus III	4
or MATH 285	Transfer Credit for Calculus III	
MATH 307	Ordinary Differential Equations	3
or MATH 280	Transfer Credit for Ordinary Differential Equations	
Select one of the following:		3
MATH 316	Introductory Linear Algebra	
MATH 401	Partial Differential Equations	
MATH 421	Applied Mathematics II: Mathematical Modeling	
MATH 422	Applied Complex Variables	
CHEM 121N & CHEM 122N	Foundations of Chemistry I Lecture and Foundations of Chemistry I Laboratory	4
CHEM 123N & CHEM 124N	Foundations of Chemistry II Lecture and Foundations of Chemistry II Laboratory	4
CS 150	Problem Solving and Programming I	4
PHYS 261N	Advanced University Physics I	4
or PHYS 231N	University Physics I	
or PHYS 226N	Honors: University Physics I	
PHYS 262N	Advanced University Physics II	4
or PHYS 232N	University Physics II	
or PHYS 227N	Honors: University Physics II	
PHYS 303	Intermediate Experimental Physics	3
PHYS 319	Analytical Mechanics	3
PHYS 323	Modern Physics	3
PHYS 355	Mathematical Methods of Physics	3
PHYS 413	Methods of Experimental Physics	3
PHYS 420	Introductory Computational Physics	3
PHYS 425	Electromagnetism I	3
PHYS 452	Introduction to Quantum Mechanics	3
PHYS 453	Electromagnetism II	3
PHYS 454	Thermal and Statistical Physics	3
PHYS 456	Intermediate Quantum Mechanics	3
PHYS 499W	Senior Thesis *	3
or PHYS 489W & PHYS 490W	Senior Thesis I and Senior Thesis II	
PHYS 120	Physics in the 21st Century **	1-2
or PHYS 309	Physics on the Back of an Envelope	
or ECE 111	Information Literacy and Research for Electrical and Computer Engineering	
Select two of the following: ***		6
ASTP 313	Elements of Astrophysics	
PHYS 411	Introduction to Atomic Physics	
ASTP 414	Relativity and Cosmology	
PHYS 415	Introduction to Nuclear and Particle Physics	
PHYS 416	Introduction to Solid State Physics	
PHYS 417	Introduction to Particle Accelerator Physics	

* Grade of C or better required in PHYS 499W or both PHYS 489W and PHYS 490W

** ECE 111 is for students considering Physics Track D.

*** With at least three credits at the 400-level.

Four-Year Plan - Physics Major - Professional Concentration - BS (<http://catalog.odu.edu/undergraduate/collegeofsciences/physics/physics-professional-bs-fouryearplan/>)

- The four-year plan is a suggested curriculum to complete this degree program in four years. It is just one of several plans that will work and is presented only as broad guidance to students. Each student is strongly encouraged to develop a customized plan in consultation with their academic advisor. Additional information can also be found in Degree Works.

Departmental Requirements for Professional Concentration (B)

MATH 211	Calculus I	4
MATH 212	Calculus II	4
MATH 312	Calculus III	4
or MATH 285	Transfer Credit for Calculus III	
MATH 307	Ordinary Differential Equations	3
or MATH 280	Transfer Credit for Ordinary Differential Equations	
Select one of the following:		3
MATH 316	Introductory Linear Algebra	
MATH 401	Partial Differential Equations	
MATH 421	Applied Mathematics II: Mathematical Modeling	
MATH 422	Applied Complex Variables	
CHEM 121N & CHEM 122N	Foundations of Chemistry I Lecture and Foundations of Chemistry I Laboratory	4
CHEM 123N & CHEM 124N	Foundations of Chemistry II Lecture and Foundations of Chemistry II Laboratory	4
CS 150	Problem Solving and Programming I	4
PHYS 261N	Advanced University Physics I	4
or PHYS 231N	University Physics I	
or PHYS 226N	Honors: University Physics I	
PHYS 262N	Advanced University Physics II	4
or PHYS 232N	University Physics II	
or PHYS 227N	Honors: University Physics II	
PHYS 323	Modern Physics	3
PHYS 319	Analytical Mechanics	3
PHYS 303	Intermediate Experimental Physics	3
PHYS 355	Mathematical Methods of Physics	3
PHYS 413	Methods of Experimental Physics	3
PHYS 425	Electromagnetism I	3
PHYS 452	Introduction to Quantum Mechanics	3
PHYS 454	Thermal and Statistical Physics	3
Select one of the following:		3
PHYS 420	Introductory Computational Physics	
PHYS 453	Electromagnetism II	
PHYS 456	Intermediate Quantum Mechanics	
PHYS 499W	Senior Thesis *	3
or PHYS 489W & PHYS 490W	Senior Thesis I and Senior Thesis II	
PHYS 120	Physics in the 21st Century	1
or PHYS 309	Physics on the Back of an Envelope	
Select two of the following: **		6
ASTP 313	Elements of Astrophysics	
PHYS 411	Introduction to Atomic Physics	
ASTP 414	Relativity and Cosmology	
PHYS 415	Introduction to Nuclear and Particle Physics	
PHYS 416	Introduction to Solid State Physics	

- * Grade of C or better required in PHYS 499W or both PHYS 489W and PHYS 490W
- ** With at least three credits at the 400-level.

Elective Credit

Elective credit may be needed to meet the minimum requirement of 120 credit hours.

Bachelor of Science - Physics Major with Teacher Education Licensure

Due to changing University requirements, national accreditation standards, and the Virginia Board of Education licensure regulations, the teacher preparation programs in the College of Sciences are under constant revision. Any changes resulting from these factors supersede the program requirements described in this Catalog. Students are encouraged to obtain current program information from their advisors and the Office of Clinical Experiences website at <https://www.odu.edu/oce> (<https://www.odu.edu/oce/>).

Admission

Students must first declare the physics (Concentration C) teacher preparation concentration as their major with the physics departmental advisor. All students must apply for and be admitted into the approved physics teacher preparation program. Students must meet the required criteria for admission by earning the minimum required grade point averages (GPA).

Virginia Board of Education Prescribed Assessments for Admission to an Approved Teacher Education Program

Old Dominion University students seeking admission to an approved teacher education program must satisfy the Virginia Board of Education required assessment for admission into an approved teacher education program. The requirement can be satisfied by meeting a passing score in the following:

- Virginia Communication and Literacy Assessment (VCLA): Scaled passing score of 235 for the reading subtest and score of 235 for the writing subtest OR a composite score of 470 for the assessment.

For the most current information on the prescribed Virginia Board of Education admission assessment, visit the Virginia Department of Education at <https://www.doe.virginia.gov/>.

Required Grade Point Averages (GPA)

- A cumulative GPA of 2.75 is required.
- A major/content GPA of 2.75 is required - all physics courses and all other science content courses must be passed with a grade of C- or higher.
- A professional education GPA of 2.75 is required – all professional education courses must be passed with a grade of C- or higher.

Although students may enroll in a limited number of education courses, students must be admitted into the approved physics teacher preparation program prior to enrolling in any instructional strategies practicum education course. Students must also meet with an education advisor in the Office of Clinical Experiences.

Continuance

Students must maintain a cumulative GPA of 2.75, a major/content GPA of 2.75 and a professional education GPA of 2.75. Physics courses must be passed with a grade of C- or higher. The remaining courses required for the major and in the professional education core must be completed with a grade of C- or higher for continuance. A professional education GPA of 2.75 is required for continuance. Students must take and pass the Praxis Subject Assessment, Physics content knowledge (formerly Praxis II) prior to or while enrolled in the instructional strategies course. All assessments must

be passed prior to the start of the Teacher Candidate Internship Orientation session.

Background Clearance Requirement

Old Dominion University requires a background clearance check of candidates interested in many of the professional education programs. Professional education programs have several field experiences that are required for continuance and graduation from the program. The background clearance must be successfully completed prior to a field experience placement. Candidates will be provided a field experience placement when the background check process is completed with resolution of any issues. The process to complete the ODU clearance background check is located at: <http://www.odu.edu/success/academic/teacher-education/placement/background-checks> (<http://www.odu.edu/success/academic/teacher-education/placement/background-checks/>). The ODU clearance process includes: an FBI fingerprint, a child protective service/social service review, and a Virginia State Police sex offender registry review. Candidates interested in the professional education programs are advised to complete this clearance process immediately upon entry into the program since the clearance process takes a minimum of eight weeks to complete.

Virginia Board of Education Prescribed Assessments for Licensure

Praxis Subject Assessment, Physics content knowledge (test code: 5265) – passing score of 147 is required.

To review more information on the Virginia Board of Education prescribed assessments visit the Office of Clinical Experiences website, www.odu.edu/oce (<http://www.odu.edu/oce/>).

Graduation

Requirements for graduation include completion of ENGL 110C, ENGL 211C or ENGL 221C or ENGL 231C, and the writing intensive (W) course in the major with a grade of C or better, completion of the Senior Assessment, completion of the Physics Exit Exam with a minimum score of 20th percentile, a minimum cumulative 2.75 GPA, in the major area, and in the professional education core, with no grade less than a C- in the major and the professional education core; successful completion of the Teacher Candidate Internship and a minimum of 120 credit hours, which must include both a minimum of 30 credit hours overall and 12 credit hours in upper-level courses in the major program from Old Dominion University.

Four-Year Plan - Physics Major with Teacher Education Licensure - BS (<http://catalog.odu.edu/undergraduate/collegeofsciences/physics/physics-physicsed-bs-fouryearplan/>)

- *The four-year plan is a suggested curriculum to complete this degree program in four years. It is just one of several plans that will work and is presented only as broad guidance to students. Each student is strongly encouraged to develop a customized plan in consultation with their academic advisor. Additional information can also be found in Degree Works.*

The curriculum is as follows:

Departmental Requirements for Education Concentration (C)

MATH 211	Calculus I	4
MATH 212	Calculus II	4
MATH 307	Ordinary Differential Equations	3
or MATH 280	Transfer Credit for Ordinary Differential Equations	
MATH 312	Calculus III	4
or MATH 285	Transfer Credit for Calculus III	
CHEM 121N & CHEM 122N	Foundations of Chemistry I Lecture and Foundations of Chemistry I Laboratory	4
CHEM 123N & CHEM 124N	Foundations of Chemistry II Lecture and Foundations of Chemistry II Laboratory	4

CS 150	Problem Solving and Programming I	4
PHYS 103N	Introductory Astronomy of the Solar System	4
or PHYS 104N	Introductory Astronomy of Galaxies and Cosmology	
PHYS 261N	Advanced University Physics I	4
or PHYS 231N	University Physics I	
or PHYS 226N	Honors: University Physics I	
PHYS 262N	Advanced University Physics II	4
or PHYS 232N	University Physics II	
or PHYS 227N	Honors: University Physics II	
PHYS 323	Modern Physics	3
PHYS 319	Analytical Mechanics	3
PHYS 303	Intermediate Experimental Physics	3
PHYS 120	Physics in the 21st Century	1
or PHYS 309	Physics on the Back of an Envelope	
PHYS 355	Mathematical Methods of Physics	3
PHYS 413	Methods of Experimental Physics	3
PHYS 425	Electromagnetism I	3
PHYS 499W	Senior Thesis *	3
or PHYS 489W & PHYS 490W	Senior Thesis I and Senior Thesis II	

Total Hours **61**

* Grade of C or better required in PHYS 499W or both PHYS 489W and PHYS 490W

The Professional Education Core Courses and Requirements

STEM 101	Step 1 – Inquiry Approaches to Teaching STEM	1
STEM 102	Step 2 - Inquiry Based STEM Lesson Design	1
STEM 201	Knowing and Learning in STEM Education	3
STEM 202	Classroom Interactions in STEM Education	3
STEM 401	Project Based Instruction in STEM Education	3
STEM 485	Apprentice Teaching	9
STEM 402	Perspectives on STEM	3
PHYS 468W	Research Methods in Mathematics and Sciences	3

Total Hours **26**

Bachelor of Science - Dual Degree: Bachelor of Science in Physics and Bachelor of Science in Electrical Engineering

Five-Year Plan - Dual Degree - Physics and Electrical Engineering -BS (<http://catalog.odu.edu/undergraduate/collegeofsciences/physics/physics-dualdegree-ee-bs-fouryearplan/>)

- *The five-year plan is a suggested curriculum to complete this degree program in five years. It is just one of several plans that will work and is presented only as broad guidance to students. Each student is strongly encouraged to develop a customized plan in consultation with their academic advisor. Additional information can also be found in Degree Works.*

Departmental Requirements for Concentration D (Dual Degree in Physics and Electrical Engineering)

Students in this concentration must earn a minimum of 150 credit hours.

Common Course Requirements

CHEM 121N & CHEM 122N	Foundations of Chemistry I Lecture and Foundations of Chemistry I Laboratory	4
MATH 211	Calculus I	4
MATH 212	Calculus II	4
MATH 312	Calculus III	4
or MATH 285	Transfer Credit for Calculus III	
MATH 307	Ordinary Differential Equations	3
or MATH 280	Transfer Credit for Ordinary Differential Equations	
ENGN 150	Computer Programming for Engineering Problem Solving	4
PHYS 261N	Advanced University Physics I	4
or PHYS 231N	University Physics I	
or PHYS 226N	Honors: University Physics I	
PHYS 262N	Advanced University Physics II	4
or PHYS 232N	University Physics II	
or PHYS 227N	Honors: University Physics II	

Physics Course Requirements

CHEM 123N & CHEM 124N	Foundations of Chemistry II Lecture and Foundations of Chemistry II Laboratory	4
PHYS 319	Analytical Mechanics	3
PHYS 323	Modern Physics	3
PHYS 355	Mathematical Methods of Physics	3
PHYS 413	Methods of Experimental Physics	3
PHYS 420	Introductory Computational Physics	3
PHYS 425	Electromagnetism I	3
PHYS 452	Introduction to Quantum Mechanics	3
PHYS 453	Electromagnetism II	3
or ECE 323	Electromagnetics	
PHYS 454	Thermal and Statistical Physics	3
PHYS 456	Intermediate Quantum Mechanics	3
PHYS 499W	Senior Thesis *	3
or PHYS 489W & PHYS 490W	Senior Thesis I and Senior Thesis II	
Select one of the following:		3
PHYS 411	Introduction to Atomic Physics	
PHYS 415	Introduction to Nuclear and Particle Physics	
PHYS 416	Introduction to Solid State Physics	
PHYS 417	Introduction to Particle Accelerator Physics	

Engineering Course Requirements

ENGN 110	Explore Engineering and Technology	2
ECE 111	Information Literacy and Research for Electrical and Computer Engineering	2
ECE 201	Circuit Analysis I	3
ECE 202	Circuit Analysis II	3
ECE 241	Fundamentals of Computer Engineering	4
ECE 287	Fundamental Electric Circuit Laboratory	2
ECE 302	Linear System Analysis	3
ECE 303	Introduction to Electrical Power	3
ECE 304	Probability, Statistics, and Reliability	3
ECE 313	Electronic Circuits	4
ECE 332	Microelectronic Materials and Processes	3
ECE 381	Introduction to Discrete-time Signal Processing	3
ECE 387	Microelectronics Fabrication Laboratory	3
ECE 485W	Electrical Engineering Design I	3
ECE 486	Preparatory ECE Senior Design II	2
ECE 487	ECE Senior Design II	2
ECE Tech Elective I, II, III, IV		12

ENMA 480	Ethics and Philosophy in Engineering Applications (meets philosophy and ethics requirement)	3
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Total Hours **131**

* Grade of C or better required in PHYS 499W or both PHYS 489W and PHYS 490W

Departmental Requirements for Concentration E (BS Physics and MBA)Five-Year Plan - BS Physics and MBA (<http://catalog.odu.edu/undergraduate/collegeofsciences/physics/physics-dualdegree-mba-fouryearplan/>)

- The five-year plan is a suggested curriculum to complete this degree program in five years. It is just one of several plans that will work and is presented only as broad guidance to students. Each student is strongly encouraged to develop a customized plan in consultation with their academic advisor. Additional information can also be found in Degree Works.

Students in this concentration must earn a minimum of 150 credit hours (120 discrete credit hours for the undergraduate degree and 30 discrete credit hours for the graduate degree).

Physics Course Requirements

MATH 211	Calculus I	4
MATH 212	Calculus II	4
MATH 312	Calculus III	4
or MATH 285	Transfer Credit for Calculus III	
MATH 307	Ordinary Differential Equations	3
or MATH 280	Transfer Credit for Ordinary Differential Equations	
Select one of the following:		3
MATH 316	Introductory Linear Algebra	
MATH 401	Partial Differential Equations	
MATH 421	Applied Mathematics II: Mathematical Modeling	
MATH 422	Applied Complex Variables	
CHEM 121N & CHEM 122N	Foundations of Chemistry I Lecture and Foundations of Chemistry I Laboratory	4
CHEM 123N & CHEM 124N	Foundations of Chemistry II Lecture and Foundations of Chemistry II Laboratory	4
CS 150	Problem Solving and Programming I	4
PHYS 261N	Advanced University Physics I	4
or PHYS 231N	University Physics I	
or PHYS 226N	Honors: University Physics I	
PHYS 262N	Advanced University Physics II	4
or PHYS 232N	University Physics II	
or PHYS 227N	Honors: University Physics II	
PHYS 323	Modern Physics	3
PHYS 319	Analytical Mechanics	3
PHYS 303	Intermediate Experimental Physics	3
PHYS 355	Mathematical Methods of Physics	3
PHYS 413	Methods of Experimental Physics	3
PHYS 425	Electromagnetism I	3
PHYS 452	Introduction to Quantum Mechanics	3
PHYS 454	Thermal and Statistical Physics	3
Select one of the following:		3
PHYS 420	Introductory Computational Physics	
PHYS 453	Electromagnetism II	
PHYS 456	Intermediate Quantum Mechanics	
PHYS 499W	Senior Thesis *	3

or PHYS 489W & PHYS 490W	Senior Thesis I and Senior Thesis II	
Approved Physics Seminar		1
Select one of the following:		3
ASTP 313	Elements of Astrophysics	
PHYS 411	Introduction to Atomic Physics	
ASTP 414	Relativity and Cosmology	
PHYS 415	Introduction to Nuclear and Particle Physics	
PHYS 416	Introduction to Solid State Physics	
PHYS 417	Introduction to Particle Accelerator Physics	
Total Hours		72

* Grade of C or better required in PHYS 499W or both PHYS 489W and PHYS 490W

Upper-Division General Education

The upper-division general education requirement is met by the MBA coursework.

MBA Coursework

MBA courses may be taken beginning with the second semester of the junior year. Students must maintain a 3.0 grade point average in these courses to continue in the program. Additional information can be found in the section on BS/MBA Linked Program at the beginning of the College of Sciences section of this Catalog and the Strome College of Business section in the Graduate Catalog (<http://catalog.odu.edu/graduate/stromecollegeofbusiness/>).

Senior Thesis

An important feature of all concentrations is the Senior Thesis, which is based on individual research done under the supervision of a faculty advisor. The Senior Thesis is a capstone experience that gives a student the opportunity to apply knowledge and skills acquired in the classroom to real-life research problems in physics. This research can be done either in on-campus laboratories and facilities or at other scientific institutions in the region where departmental faculty members perform research, such as the Thomas Jefferson National Accelerator Facility (including the Applied Research Center) or the Langley Research Center of NASA. On completion of the project, the student must prepare a written final report and make an oral presentation of the results to the department. The senior thesis can be completed in one semester, by taking PHYS 499W, or in two semesters, by taking the PHYS 489W & PHYS 490W sequence.

Minor in Physics

PHYS 231N-PHYS 232N or PHYS 261N-PHYS 262N or PHYS 226N-PHYS 227N must be completed as prerequisites for the minor in physics and are not included in the calculation of the grade point average for the minor. The minor in physics requires completion of all courses specified as a requirement for the minor, with an overall cumulative grade point average of 2.00 or better in these courses exclusive of 100/200 level courses and prerequisite courses.

PHYS 319	Analytical Mechanics	3
PHYS 323	Modern Physics	3
Two 300 or 400-level PHYS courses		6
Total Hours		12

Students must complete a minimum of six credit hours of 300-level or 400-level PHYS courses in the minor requirement through courses offered by Old Dominion University. Up to three credits can be in Independent Study courses, with approval of the chief departmental advisor. Any substitutions must be approved in writing by the chief departmental advisor.

BS Degree with Honors

Qualified students may receive the BS degree with honors (to be noted on their diplomas) by completing specified additional requirements. At the time of application for this designation, a student must have a GPA of 3.50 or higher in physics, a GPA of 3.25 or higher overall, must have completed two contract honors courses, and must have completed 60 credit hours (of which at least 54 must be in grade-point graded courses) at Old Dominion University. (Contract honors courses are specialized courses of individual study under the direct supervision of a professor. Permission to take these courses is granted jointly by the Department of Physics and the Honors College.)

Advanced Placement

Advanced placement credit is awarded to students who earn qualifying scores on AP and IB subject examinations. See the equivalency charts on the Office of Undergraduate Admissions website at <https://www.odu.edu/admission/undergraduate/credit> (<https://www.odu.edu/admission/undergraduate/credit/>).

Advanced placement credit for courses other than PHYS 111N-PHYS 112N and PHYS 231N-PHYS 232N may be received on the basis of examinations administered by the Department of Physics. Permission to take such an examination must be obtained from the chief departmental advisor. Students may also refer to the Policy on Prior Learning Assessment Credit Options at the Undergraduate Level found in this Catalog.

Clifford L. and Lillian R. Adams Scholarship

The Department of Physics selects one or more students each year to receive the Clifford L. and Lillian R. Adams Scholarship. The recipient must be a declared physics major and may be an entering freshman, a transfer student, or a continuing student. Selection is based on a student's academic record, relevant test scores, and recommendations. The award is renewable.

ASTROPHYSICS Courses

ASTP 313. Elements of Astrophysics. 3 Credits.

A one-semester course covering the important topics of modern astrophysics. The elementary physical basis of stellar structure and evolution is derived from first principles. Theoretical and observational details of white dwarfs, neutron stars, pulsars, and black holes are developed. Elements of Big Bang cosmology are also presented. Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N.

ASTP 414. Relativity and Cosmology. 3 Credits.

Introduction to special and general relativity and cosmology. The course covers the current understanding of the structure and evolution of the Universe. The most important unsolved cosmological problems will be discussed, as well as current efforts/theories that may lead to the solution. Special and general relativity, Einstein's field equations, Friedmann-Lemaître-Robertson-Walker metric, Friedmann's equations, Schwarzschild solution and black holes, Big Bang, cosmic microwave background radiation, dark matter and dark energy are covered. Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N and MATH 312 or MATH 307.

ASTP 495. Special Topics in Astrophysics. 3 Credits.

In-depth study of a selected topic in astrophysics at the advanced undergraduate level. May include a laboratory or computational component. Prerequisites: Permission of the instructor.

PHYSICS Courses

PHYS 101N. Conceptual Physics. 4 Credits.

An introductory descriptive course which develops and illustrates the concepts of physics in terms of phenomena encountered in daily life. Topics include mechanics, electricity and magnetism. (offered fall, summer).

PHYS 102N. Conceptual Physics. 4 Credits.

An introductory descriptive course which develops and illustrates the concepts of physics in terms of phenomena encountered in daily life. Topics include sound, light, fluids and heat. (offered spring) Prerequisites: PHYS 101N.

PHYS 103N. Introductory Astronomy of the Solar System. 4 Credits.

A study of the physical principles and scientific investigation of objects in our solar system. Emphasis on how we acquire knowledge of celestial objects to develop models of our universe.

PHYS 104N. Introductory Astronomy of Galaxies and Cosmology. 4 Credits.

Emphasizes the study of stars, star systems, cosmology and relativity. Emphasis on how we acquire knowledge of celestial objects to develop models of our universe.

PHYS 109. Introductory Astronomy Laboratory. 1 Credit.

An introductory laboratory course in astronomy dealing with experiments about the laws of nature that apply to objects in our solar system.

Prerequisite: written permission of the chief departmental advisor of the Physics Department.

PHYS 111N. Introductory General Physics. 4 Credits.

Emphasizes mechanics, wave motion and heat and will also cover the needed elements of trigonometry and vectors. Students receiving credit for PHYS 111N cannot receive credit for PHYS 102N either simultaneously or subsequently. (offered fall, spring, summer) Prerequisite: MATH 102M or MATH 103M or MATH 162M or MATH 166.

PHYS 112N. Introductory General Physics. 4 Credits.

Emphasizes electricity, light, and introduction to modern physics. Prerequisites: PHYS 111N and MATH 102M (or MATH 103M) or MATH 162M or MATH 166. (offered fall, spring, summer).

PHYS 113. Physics Laboratory. 1 Credit.

Available for pass/fail grading only. An introductory laboratory covering experiments from mechanics, wave motion, heat and sound. Prerequisites: written permission of the chief departmental advisor of the Physics Department.

PHYS 114. Physics Laboratory. 1 Credit.

Available for pass/fail grading only. An introductory laboratory covering experiments from electricity, magnetism, and optics. Prerequisites: written permission of the chief departmental advisor of the Physics Department.

PHYS 120. Physics in the 21st Century. 1 Credit.

This seminar will provide students with a broad introduction to the cutting edge of physics research and its applications in diverse areas of contemporary physics. Recommended for incoming students interested in physics and the natural sciences.

PHYS 126N. Honors: Introductory Astronomy. 4 Credits.

Open only to students in the Honors College. A special honors version of PHYS 103N.

PHYS 127N. Honors: Introductory Astronomy. 4 Credits.

Open only to students in the Honors College. A special honors version of PHYS 104N.

PHYS 197. Undergraduate Research Experience in Physics. 0 Credits.

Student participation in a supervised, undergraduate research experience for which credit will not apply to the degree. Experience must be related to the student's major, minor or career area of interest. Prerequisites: permission of the instructor.

PHYS 226N. Honors: University Physics I. 4 Credits.

Open only to students in the Honors College. A special honors version of PHYS 231N. This course also includes a Recitation Section for more in-depth discussion of advanced problems. Prerequisites: MATH 211 with a grade of C or better. Pre- or corequisite: MATH 212.

PHYS 227N. Honors: University Physics II. 4 Credits.

Open only to students in the Honors College. A special honors version of PHYS 232N, including a recitation section for discussion of advanced problems. Prerequisites: PHYS 231N or PHYS 226N or PHYS 261N with a grade of C or better, and both MATH 211 and MATH 212 each with a grade of C or better.

PHYS 231N. University Physics I. 4 Credits.

A general introduction to physics in which the principles of classical and modern physics are applied to the solution of physical problems. The reasoning through which solutions are obtained is stressed. Topics include mechanics, fluids, and thermodynamics. This course is designed for majors in the physical sciences, engineering, mathematics, and computational sciences. Students receiving credit for PHYS 231N and PHYS 232N cannot simultaneously or subsequently receive credit for PHYS 101N and PHYS 102N or PHYS 111N and PHYS 112N. (offered fall, spring, summer) Prerequisites: MATH 211 with a grade of C or better. Pre- or corequisites: MATH 212 or permission of instructor.

PHYS 232N. University Physics II. 4 Credits.

A general introduction to physics in which the principles of classical and modern physics are applied to the solution of physical problems. The reasoning through which solutions are obtained is stressed. This course is designed for majors in the physical sciences, engineering, mathematics, and computational sciences. Topics include electricity and magnetism, and optics. Students receiving credit for PHYS 231N and PHYS 232N cannot simultaneously or subsequently receive credit for PHYS 101N and PHYS 102N or PHYS 111N and PHYS 112N. (offered fall, spring, summer) Prerequisites: PHYS 231N or PHYS 226N or PHYS 261N with a grade of C or better, and both MATH 211 and MATH 212 with each a grade of C or better.

PHYS 261N. Advanced University Physics I. 4 Credits.

This calculus-based course is the required introductory course for Physics majors. In addition to the physics curriculum of PHYS 231N, this course has a recitation section for advanced problems and additional mathematical preparation for advanced courses in physics. Prerequisites: MATH 211, with a grade of C or better. Pre- or corequisite: MATH 212.

PHYS 262N. Advanced University Physics II. 4 Credits.

This calculus-based course is the required introductory course for Physics majors. In addition to the physics curriculum of PHYS 232N, this course has a recitation section for advanced problems and additional mathematical preparation for advanced courses in physics. Prerequisites: PHYS 261N with a grade of C or better; MATH 211 and MATH 212, each with a grade of C or better.

PHYS 297. Undergraduate Research I. 1-3 Credits.

This course offers students at the Freshman and Sophomore levels their first opportunity to work one-on-one with a research mentor to acquire and develop skills in research techniques, information literacy, research planning, proposal preparation and report writing. Research experiences may include but are not limited to hands-on instrument control to collect and analyze data, including graphical, statistical and error analysis of their data. Students will also be instructed on accepted methods for dissemination of data, including written, oral and poster presentation, as well as procedures for research proposal preparation and submission. Students will be required to deliver to their peers and department faculty at the end of semester an oral and written presentation of their research, as well as a poster presentation at an annual department or university event including the ODU Undergraduate Research Symposium. Prerequisites: Permission of the instructor. Pre- or corequisite: PHYS 226N or PHYS 231N or PHYS 261N.

PHYS 303. Intermediate Experimental Physics. 3 Credits.

A laboratory-oriented course designed to provide students with a broad introduction to instrumentation and techniques used in modern physics laboratories. Topics to be covered include: basic electronics with an introduction to diode, transistor and op-amp circuitry, and an introduction to physical computing using LabView and Arduino micro controllers. Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N.

PHYS 309. Physics on the Back of an Envelope. 1 Credit.

Physicists should be able to estimate the order-of-magnitude of anything. How many atoms of Julius Caesar do you eat every day? How much waste does a nuclear power plant generate? Will develop concepts, relations and numbers useful for estimation. Will cover little new material, emphasizing already acquired knowledge. Will help students apply physics to real-life questions and understand which physical effects are appropriate on which scales. Seminar course. Prerequisites: PHYS 102N or PHYS 112N or PHYS 232N or PHYS 227N or PHYS 262N.

PHYS 311. Color in Nature and Art. 3 Credits.

Explores the relationship between light as stimulus and color perceived by us. Develops underlying concept of technology of art and applied art. Describes basis for optical phenomena involved in many facets of daily life. Topics include: the interaction of light and the visual perception it produces; the basic concept of spectra; wave, ray, and quantum optics; polarized light; photography; paintings; pigments; rainbows and mirages; color theory systems; formation of images; optical instruments. There is no physics prerequisite for this course. Prerequisite: MATH 102M (or MATH 103M).

PHYS 319. Analytical Mechanics. 3 Credits.

Fundamentals of Newtonian mechanics. Topics include kinematics, dynamics, energy and momentum, central forces and planetary motion, and resonance phenomena. (Offered Spring) Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N. Pre- or corequisite: MATH 307 or MATH 280.

PHYS 323. Modern Physics. 3 Credits.

Introduction to the wave nature of matter, with applications in materials science, atomic, and nuclear physics. Introduction to relativity, including applications in mechanics and electrodynamics. (Offered Fall) Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N and MATH 212.

PHYS 350. Light and Lasers. 3 Credits.

An analysis of those concepts of geometrical physical optics needed for the understanding of laser resonators, optical propagation, and radiation detection. A study of laser diodes, molecular, neutral and ion gas lasers, tuneable dye and excimer lasers. Laser applications in medicine, communications, information processing, holography, pollution detection, and material testing and fabrication are stressed. Prerequisite: PHYS 102N or PHYS 112N or PHYS 232N.

PHYS 355. Mathematical Methods of Physics. 3 Credits.

This course will provide a strong foundation in the mathematical methods and applications necessary for undergraduate study of physics beyond the introductory level. The course contains a mandatory recitation section. (Offered Fall) Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N and MATH 212. Pre- or corequisite: MATH 312 or MATH 285.

PHYS 367. Cooperative Education. 1-3 Credits.

May be repeated for credit. Available for pass/fail grading only. Student participation for credit based on the academic relevance of the work experience, criteria, and evaluative procedures as formally determined by the department and Career Development Services prior to the semester in which the work experience is to take place. Prerequisites: approval of the chief departmental advisor and Career Development Services in accordance with the policy for granting credit for Cooperative Education programs.

PHYS 368. Internship. 1-3 Credits.

Available for pass/fail grading only. Academic requirements will be established by the department and will vary with the amount of credit desired. Allows students to gain short duration career-related experience. Prerequisites: approval by the chief departmental advisor and Career Development Services.

PHYS 397. Undergraduate Research II. 1-3 Credits.

This course offers students at the Sophomore and Junior levels an opportunity to work one-on-one with a research mentor on a self-designed research project of mutual interest, and typically within the research field of their mentor. The student will demonstrate their knowledge of the research skills covered in PHYS 297 by formulating their own research plan and then collecting and analyzing their data. Students will also be instructed in research publication skills as well as conference standard presentation techniques. Students will be required to attend at least two conferences, within and outside the university. Prerequisites: PHYS 297, and PHYS 226N or PHYS 231N or PHYS 261N, and permission of instructor.

PHYS 406/506. Observational Astronomy. 3 Credits.

Observational techniques in astronomy with emphasis on constellation identification, celestial movements, and telescopic observation. Individualized night observations are required. Prerequisite: junior standing.

PHYS 408/508. Astronomy for Teachers. 3 Credits.

A course in astronomy dealing with stars and stellar systems. Topics will include observational astronomy, the electromagnetic spectrum, relativity, stellar and galactic structures, cosmology, and the search for extraterrestrial intelligence. Prerequisite: junior standing.

PHYS 411. Introduction to Atomic Physics. 3 Credits.

The hydrogen atom, radiative transitions, two-electron systems, many-electron atoms, interaction with external fields, theory of atomic spectra. Prerequisites: PHYS 452 and MATH 307.

PHYS 413/513. Methods of Experimental Physics. 3 Credits.

Experiments in classical and modern physics, designed to develop skills in the collection, analysis, and interpretation of experimental data. (Offered Spring) Prerequisites: PHYS 303 or ECE 287, and PHYS 323.

PHYS 415/515. Introduction to Nuclear and Particle Physics. 3 Credits.

An introduction to the structure of the atomic nucleus, natural and artificial radioactivity, nuclear decay processes and stability of nuclei, nuclear reactions, properties of nuclear forces, and nuclear models. Also, particle phenomenology, experimental techniques and the standard model. Topics include the spectra of leptons, mesons, and baryons; strong, weak, and electromagnetic interactions. Prerequisite: PHYS 452. Pre- or corequisite: MATH 307.

PHYS 416/516. Introduction to Solid State Physics. 3 Credits.

Introduction to solid state physics and materials science, with emphasis placed on the applications of each topic to experimental and analytical techniques. Topics include crystallography, thermal and vibrational properties of crystals and semiconductors, metals and the band theory of solids, superconductivity and the magnetic properties of materials. Prerequisites: PHYS 452 and MATH 307.

PHYS 417/517. Introduction to Particle Accelerator Physics. 3 Credits.

Fundamentals of relativistic particle dynamics including particle acceleration; weak and strong focusing; linear beam optics and particle transfer matrices; linear and non-linear synchrotron motion; introduction to the statistical descriptions of particle beams; and radiation production by accelerated relativistic particles. Examples relevant to betatrons, cyclotrons, synchrotrons, and linear accelerators will be given. Prerequisites: PHYS 319 or MAE 205, and PHYS 425 or ECE 323.

PHYS 420/520. Introductory Computational Physics. 3 Credits.

Introduction of computational methods and visualization techniques for problem solving in physics. Prerequisites: PHYS 319, PHYS 323, CS 150, and MATH 212.

PHYS 425/525. Electromagnetism I. 3 Credits.

A study of the classical theory and phenomena of electricity and magnetism. Topics include the calculation of electric and magnetic fields, magnetic and dielectric properties of matter, and an introduction to Maxwell's equations. The course contains a mandatory recitation section. Pre- or corequisite: PHYS 355. Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N and MATH 312 or MATH 285.

PHYS 451/551. Theoretical Mechanics. 3 Credits.

A mathematical study of the concepts of mechanics. Vector calculus methods are used. Topics include mechanics of a system of particles, Lagrangian mechanics, Hamilton's canonical equations, and motion of a rigid body. Prerequisites: PHYS 319, PHYS 355 and MATH 312.

PHYS 452/552. Introduction to Quantum Mechanics. 3 Credits.

Introduction to the physical and mathematical structure of quantum theory, including the historical and experimental origins of the subject. The subject matter includes techniques for solving the Schrodinger equation in one, two, and three dimensions. Both coordinate and momentum space representations are used. The harmonic oscillator and the Hydrogen atom receive particular attention. The course contains a mandatory recitation section. Prerequisites: PHYS 319, PHYS 323, and PHYS 355.

PHYS 453/553. Electromagnetism II. 3 Credits.

A course in electrodynamics developed from Maxwell's Equations. Topics include Maxwell's Equations, Conservation Laws, Electromagnetic Waves, Potentials and Fields, Radiation, and the interplay of electrodynamics and special relativity. The course contains a mandatory recitation section. Prerequisites: PHYS 425 or ECE 323 and MATH 312.

PHYS 454/554. Thermal and Statistical Physics. 3 Credits.

A study of the fundamental concepts of thermodynamics, kinetic theory, and statistical mechanics. Topics include the thermodynamics of simple systems, kinetic theory of gases, statistical mechanics of gases and an introduction to quantum statistics. Prerequisites: PHYS 319 and PHYS 323.

PHYS 456/556. Intermediate Quantum Mechanics. 3 Credits.

This course follows directly from PHYS 452. It includes a more detailed study of simple systems, an introduction to abstract quantum mechanics and Dirac notation, and applications to operator methods. Particular attention is paid to electron spin, angular momentum theory, operator treatment of the harmonic oscillator, the Pauli exclusion principle, perturbation theory, and scattering. The course contains a mandatory recitation section. Prerequisites: PHYS 323 and PHYS 452 or permission of the instructor.

PHYS 460. Fundamentals of Accelerator Physics and Technology with Simulations and Measurements Lab. 3 Credits.

Explores the historical development of accelerators and their past and present applications. Principles of acceleration, including the physics of linear accelerators, synchrotrons, and storage rings. Magnet design; machine lattice design and particle beam optics. Longitudinal and transverse beam dynamics, including synchrotron and betatron particle motion. Special topics will be reviewed, including synchrotron radiation, injection techniques, and collective effects and beam instabilities. Prerequisites: PHYS 319 and PHYS 425.

PHYS 467. Preparing for the Physics GRE. 1 Credit.

This course will review the style and scope of problems likely to be found on the Physics Graduate Record Exam (GRE). Emphasis is on quick solving of problems based on foundational knowledge and intuition. This course is particularly intended for students preparing to apply for graduate school, but may be of interest to all students. Prerequisites: PHYS 323 and PHYS 319.

PHYS 468W. Research Methods in Mathematics and Sciences. 3 Credits.

Emphasizes the tools and techniques used to solve scientific problems. Topics include use and design of experiments, use of statistics to interpret experimental results, mathematical modeling of scientific phenomena, and oral and written presentation of scientific results. Students will perform four independent inquiries, combining skills from mathematics and science to solve research problems. Required for Physics teaching licensure track; not available as upper-division elective in content area. This is a writing intensive course. Prerequisites: Admission to the Monarch Teach Program; PHYS 232N or MATH 212; and a grade of C or better in ENGL 211C or ENGL 221C or ENGL 231C.

PHYS 489W. Senior Thesis I. 1 Credit.

Part one of a two-semester option for completing the Senior Thesis. This is a writing intensive course. PHYS 489W plus PHYS 490W is equivalent to PHYS 499W. Prerequisites: permission of the instructor and a grade of C or better in ENGL 211C or ENGL 221C or ENGL 231C.

PHYS 490W. Senior Thesis II. 2 Credits.

Part two of a two-semester option for completing the Senior Thesis. PHYS 489W plus PHYS 490W is equivalent to PHYS 499W. This is a writing intensive course. Prerequisites: PHYS 489W.

PHYS 495/595. Special Topics in Physics. 1-3 Credits.

In-depth study of a selected topic in physics at the advanced undergraduate level. May include a laboratory or computational component. Prerequisite: permission of the instructor.

PHYS 497/597. Special Problems and Research. 1-3 Credits.

These courses afford the student an opportunity to pursue individual study and research. Prerequisite: senior standing or permission of the instructor.

PHYS 499W. Senior Thesis. 3 Credits.

Each student will undertake a research experience under the supervision of a department faculty member. The experience can be of an experimental, theoretical, or calculational type. A final oral and written report are required. The research may be completed on campus or at one of the department affiliated research organizations. This is a writing intensive course. (offered fall, spring, summer) Prerequisites: grade of C or better in ENGL 211C or ENGL 221C or ENGL 231C and permission of the instructor.