Physics

Web Site: http://www.odu.edu/physics

Charles E. Hyde, Chair
Stephen Bueltmann, Chief Departmental Advisor
Sebastian Kuhn, J. Wallace Van Orden, Lawrence Weinstein, Associate Departmental Advisors

Bachelor of Science - Physics Major

The Department of Physics offers a major in physics with five program concentrations leading to the B. S. degree and the B. S. 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 B. S. 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 B.S. and B.S.E.E. 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 M.B.A. program. Students must earn a minimum of 150 credits (120 for the undergraduate degree and 30 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 A.S., A.A., or A.A.S. (university parallel) degree from a Virginia Community College or Richard Bland College automatically satisfy the lowest-level general education requirements. For Concentrations A and B, 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 M.B.A. core curriculum satisfies the upper-level general education requirement.

Graduation Requirements

All concentrations require completion of a minimum of 120 credit hours (150 credit hours for 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, completion of the Physics Exit Exam with a minimum score of 20th percentile, and Senior Assessment. Additional hours may be required to meet the foreign language requirement. All concentrations require a minimum grade of C in PHYS 261N-PHYS 262N. Concentrations A, B, D and E require a minimum cumulative grade point average of 2.00 overall and in the major. 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 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

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

<table>
<thead>
<tr>
<th>Skills</th>
<th>Composition (grade of C or better required in both courses)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ENGL 110C English Composition 3</td>
</tr>
<tr>
<td></td>
<td>ENGL 211C English Composition 3</td>
</tr>
<tr>
<td></td>
<td>or ENGL 231C Introduction to Technical Writing</td>
</tr>
<tr>
<td></td>
<td>Oral Communication 3</td>
</tr>
<tr>
<td></td>
<td>COMM 101R Public Speaking</td>
</tr>
<tr>
<td></td>
<td>or COMM 103R Voice and Diction</td>
</tr>
<tr>
<td></td>
<td>or COMM 112R Introduction to Interpersonal Communication</td>
</tr>
<tr>
<td></td>
<td>or DANC/THEA 152R Acting One</td>
</tr>
<tr>
<td></td>
<td>Mathematics (Satisfied by major)</td>
</tr>
<tr>
<td></td>
<td>Language and Culture (B.S. students’ competence must be at the 102 level. High school credit may satisfy the requirement.)</td>
</tr>
<tr>
<td></td>
<td>Information Literacy and Research</td>
</tr>
<tr>
<td></td>
<td>CS 120G Introduction to Information Literacy and Research 3</td>
</tr>
<tr>
<td></td>
<td>or CS 121G Introduction to Information Literacy and Research for Scientists</td>
</tr>
</tbody>
</table>

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 |
|        | 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 |

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 230E  Introduction to Ethics
PHIL 250E  World Religions: Beliefs and Values
PHIL 303E  Business Ethics
PHIL 344E  Environmental Ethics
PHIL 345E  Bioethics
PHIL 355E  Computer Ethics
PHIL 442E  Studies in Applied Ethics

Nature of Science (satisfied by the major)
Impact of Technology
Select one of the following: 3

BIOL 470T  Diseases that Changed our World
CHEM 171T  Influence of Polymers on Society
CHEM 173T  Nutritional Biochemistry
CHEM 339T  The Chemistry of the Environment
CHEM 343T  Science and Technology in Art
COMM 372T  Introduction to New Media Technologies
CS 300T  Computers in Society
DNTH 440T  Telehealthcare Technology
EET 370T  Energy and the Environment
ENGL 307T  Digital Writing
or IDS 307T  Digital Writing
GEOG 306T/  The History of Sex and Sexual and Reproductive Technologies
HIST 300T  The History of Sex and Sexual and Reproductive Technologies
HIST 304T  History of Medicine, Disease, and Health Technology
HIST 314T  Towers, Tanks and Time: Technology on the Eve of WWI
HIST 388T  Discovering Earth's History
HIST 389T  Technology and Civilization
HIST 386T/  The Evolution of Modern Science
SCI 302T  Principles of Information Technology
MUSC 335T  Music Technology Survey
OEAS 220T  Introduction to Meteorology
PHIL 383T  Technology: Its Nature and Significance
POL 350T  Technology and War
POL 458T  Weapons of Mass Destruction in Global Security
STEM 110T  Technology and Your World
STEM 370T  Technology and Society
WMST 390T  Women 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
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
GEOG 100S  Cultural Geography
GEOG 101S  Environmental Geography
POLS 100S  Introduction to International Politics
POLS 101S  Introduction to American Politics
POLS 102S  Introduction to Comparative Government and Politics
PSYC 201S  Introduction to Psychology
PSYC 203S  Lifespan Development
SOC 201S  Introduction to Sociology
WMST 201S  Introduction to Women's Studies

Total Hours 30-36

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 1
MATH 307  Ordinary Differential Equations 3
or MATH 280  Transfer Credit for Ordinary Differential Equations 3

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  Foundations of Chemistry I Lecture 4
CHEM 122N  Foundations of Chemistry I Laboratory* 1
CHEM 123N  Foundations of Chemistry II Lecture 4
CHEM 124N  Foundations of Chemistry II Laboratory* 1

CS 150  Problem Solving and Programming I 4
PHYS 261N  Advanced University Physics I 4
PHYS 262N  Advanced University Physics II 4
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  Senior Thesis I 3
PHYS 499W  Senior Thesis I 3
PHYS 490W  Senior Thesis II 3
PHYS 120  Physics in the 21st Century, ECE 111 is for students considering Physics Track D 1-2
or PHYS 309  Physics on the Back of an Envelope 1-2
or ECE 111  Information Literacy and Research for Electrical and Computer Engineering 1-2

Select two of the following: 6

PHYS 313  Elements of Astrophysics
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

* CHEM 137N/CHEM 138N may be taken instead of CHEM 121N/CHEM 122N and CHEM 123N/CHEM 124N
** Grade of C or better required in PHYS 499W or both PHYS 489W and PHYS 490W

Physics 2
### Departmental Requirements for Professional Concentration (B)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 211</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>MATH 212</td>
<td>Calculus II</td>
<td>4</td>
</tr>
<tr>
<td>MATH 312</td>
<td>Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>or MATH 285</td>
<td>Transfer Credit for Calculus III</td>
<td></td>
</tr>
<tr>
<td>MATH 307</td>
<td>Ordinary Differential Equations</td>
<td>3</td>
</tr>
<tr>
<td>or MATH 280</td>
<td>Transfer Credit for Ordinary Differential Equations</td>
<td></td>
</tr>
</tbody>
</table>

Select one of the following:

- 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 *

**CHEM 123N** & **CHEM 124N**: Foundations of Chemistry II Lecture and Foundations of Chemistry II Laboratory *

- CS 150: Problem Solving and Programming I
- PHYS 261N: Advanced University Physics I
- PHYS 262N: Advanced University Physics II
- PHYS 323: Modern Physics
- PHYS 319: Analytical Mechanics
- PHYS 303: Intermediate Experimental Physics
- PHYS 355: Mathematical Methods of Physics
- PHYS 413: Methods of Experimental Physics
- PHYS 425: Electromagnetism I
- PHYS 452: Introduction to Quantum Mechanics
- PHYS 454: Thermal and Statistical Physics

Select one of the following:

- PHYS 420: Introductory Computational Physics
- PHYS 453: Electromagnetism II
- PHYS 456: Intermediate Quantum Mechanics
- PHYS 499W: Senior Thesis **
- or PHYS 489W: Senior Thesis I & PHYS 490W: Senior Thesis II
- PHYS 120: Physics in the 21st Century
- or PHYS 309: Physics on the Back of an Envelope

Select two of the following: **

- PHYS 313: Elements of Astrophysics
- 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

### Total Hours

75

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**Note:** 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.

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### 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 Teacher Education Services website at http://education.odu.edu/tes/.

### 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 passing the Virginia Board of Education prescribed assessments and earn the minimum required grade point averages (GPA).

### Virginia Board of Education prescribed assessments

Old Dominion University students seeking admission to an approved teacher education program must satisfy the Virginia Board of Education Required Assessment for Admission to an Approved Teacher Education Program. This requirement can be satisfied by meeting a passing score in one of the selected criteria below:

1. Passing Praxis I composite score of 532 by December 31, 2013; or
2. Passing Praxis Core Academic Skills Tests beginning January 1, 2014: Reading Score of 156, Writing Score of 162, and Mathematics Score of 150; or
3. Approved substitute test scores:
   a. SAT score of 1000 with at least 450 verbal and 510 mathematics taken prior to April 1, 1995; or
   b. SAT score of 1100 with at least 530 verbal and 530 mathematics taken after April 1, 1995 and before March 2016; or
   c. ACT composite score of 21 with ACT mathematics score of at least 21, and ACT English plus Reading score of at least 37, taken prior to April 1, 1995; or
   d. ACT composite score of 24 with ACT mathematics score of at least 22, and ACT English plus Reading score of at least 46, taken after April 1, 1995; or
   e. Praxis I Math test score of 178 by December 31, 2013 and a composite Virginia Communication and Literacy Assessment (hereafter referred to as the VCLA) score of 470; or
   f. Praxis Core Academic Skills Mathematics test score of 150 beginning January 1, 2014 and a VCLA score of 470; or
   g. SAT Mathematics test score of at least 510 taken prior to April 1, 1995 and a VCLA score of 470; or
   h. SAT Mathematics test score of at least 530 taken after April 1, 1995 and a composite VCLA score of 470; or
   i. ACT Mathematics test score of at least 21 taken prior to April 1, 1995 and a composite VCLA score of 470; or
   j. ACT Mathematics test score of at least 22 taken after April 1, 1995 and a composite VCLA score of 470.

**Note:** ACT scores taken prior to 1989 are not valid.

* A new SAT test was released in March 2016. Praxis Core substitute scores for the new SAT have not been determined.

For the most current information on the prescribed Virginia Board of Education admission assessment, visit the Teacher Education Services website, http://www.odu.edu/tes and review the Teacher Education Handbook.

### 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 Teacher Education Services.

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 Virginia Communication and Literacy Assessment (VCLA) and 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. 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
Virginia Communication and Literacy Assessment (VCLA) – a passing composite score of 470 is required on this reading and writing assessment
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 Teacher Education Services website, www.odu.edu/tes.

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.

The curriculum is as follows:

**Departmental Requirements for Education Concentration (C)**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 211</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>MATH 212</td>
<td>Calculus II</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 307</td>
<td>Ordinary Differential Equations</td>
<td>3</td>
</tr>
<tr>
<td>or MATH 280</td>
<td>Transfer Credit for Ordinary Differential Equations</td>
<td>3</td>
</tr>
<tr>
<td>MATH 312</td>
<td>Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>or MATH 285</td>
<td>Transfer Credit for Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>CHEM 121N &amp; CHEM 122N</td>
<td>Foundations of Chemistry I Lecture and Foundations of Chemistry I Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>CHEM 123N &amp; CHEM 124N</td>
<td>Foundations of Chemistry II Lecture and Foundations of Chemistry II Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>CS 150</td>
<td>Problem Solving and Programming I</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 103N</td>
<td>Introductory Astronomy of the Solar System</td>
<td>4</td>
</tr>
<tr>
<td>or PHYS 104N</td>
<td>Introductory Astronomy of Galaxies and Cosmology</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 261N</td>
<td>Advanced University Physics I</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 262N</td>
<td>Advanced University Physics II</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 323</td>
<td>Modern Physics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 319</td>
<td>Analytical Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 303</td>
<td>Intermediate Experimental Physics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 120</td>
<td>Physics in the 21st Century</td>
<td>1</td>
</tr>
<tr>
<td>or PHYS 309</td>
<td>Physics on the Back of an Envelope</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 355</td>
<td>Mathematical Methods of Physics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 413</td>
<td>Methods of Experimental Physics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 425</td>
<td>Electromagnetism I</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 499W</td>
<td>Senior Thesis **</td>
<td>3</td>
</tr>
<tr>
<td>or PHYS 489W &amp; PHYS 490W</td>
<td>Senior Thesis I and Senior Thesis II</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Hours 61

* CHEM 137N/CHEM 138N may be taken instead of CHEM 121N/CHEM 122N and CHEM 123N/ CHEM 124N

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

The Professional Education Core Courses and Requirements

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEM 101</td>
<td>Step 1 – Inquiry Approaches to Teaching STEM</td>
<td>1</td>
</tr>
<tr>
<td>STEM 102</td>
<td>Step 2 - Inquiry Based STEM Lesson Design</td>
<td>1</td>
</tr>
<tr>
<td>STEM 201</td>
<td>Knowing and Learning in STEM Education</td>
<td>3</td>
</tr>
<tr>
<td>STEM 202</td>
<td>Classroom Interactions in STEM Education</td>
<td>3</td>
</tr>
<tr>
<td>STEM 401</td>
<td>Project Based Instruction in STEM Education</td>
<td>3</td>
</tr>
<tr>
<td>STEM 485</td>
<td>Apprentice Teaching</td>
<td>9</td>
</tr>
<tr>
<td>STEM 402</td>
<td>Perspectives on STEM</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 468W</td>
<td>Research Methods in Mathematics and Sciences</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Hours 26

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

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

**Common Course Requirements**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit</th>
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</thead>
<tbody>
<tr>
<td>Approved Physics Seminar</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>CHEM 121N &amp; CHEM 122N</td>
<td>Foundations of Chemistry I Lecture and Foundations of Chemistry I Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>MATH 211</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>MATH 212</td>
<td>Calculus II</td>
<td>4</td>
</tr>
<tr>
<td>MATH 312</td>
<td>Calculus III</td>
<td>4</td>
</tr>
</tbody>
</table>

Physics 4
or MATH 285  Transfer Credit for Calculus III
MATH 307  Ordinary Differential Equations 3
or MATH 280  Transfer Credit for Ordinary Differential Equations
CS 150  Problem Solving and Programming I 4
PHYS 261N  Advanced University Physics I 4
PHYS 262N  Advanced University Physics II 4

Physics Course Requirements
CHEM 123N  Foundations of Chemistry II Lecture 4
& CHEM 124N  Foundations of Chemistry II Laboratory
Select one of the following:
MATH 316  Introductory Linear Algebra 3
MATH 401  Partial Differential Equations 3
MATH 421  Applied Mathematics II: Mathematical Modeling 3
MATH 422  Applied Complex Variables 3
PHYS 355  Mathematical Methods of Physics 3
PHYS 323  Modern Physics 3
PHYS 319  Analytical Mechanics 3
PHYS 303  Intermediate Experimental Physics 2-3
or ECE 287  Fundamental Electric Circuit Laboratory 3
PHYS 425  Electromagnetism I 3
PHYS 452  Introduction to Quantum Mechanics 3
PHYS 413  Methods of Experimental Physics 3
PHYS 454  Thermal and Statistical Physics 3
PHYS 420  Introductory Computational Physics 3
PHYS 453  Electromagnetism II 3
or ECE 322  Electromagnetics 3
PHYS 456  Intermediate Quantum Mechanics 3
PHYS 499W  Senior Thesis * 3
or PHYS 489W  Senior Thesis I
& PHYS 490W  and Senior Thesis II
Select one of the following:
PHYS 411  Introduction to Atomic Physics 3
PHYS 415  Introduction to Nuclear and Particle Physics 3
PHYS 416  Introduction to Solid State Physics 3
PHYS 417  Introduction to Particle Accelerator Physics 3

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 3
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 9
Approved Elective 1-3
Total Hours 129-132

Departmental Requirements for Concentration E (B.S. Physics and M.B.A.)
Students in this concentration must earn a minimum of 150 credit hours (120 for the undergraduate degree and 30 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:
MATH 316  Introductory Linear Algebra 3
MATH 401  Partial Differential Equations 3
MATH 421  Applied Mathematics II: Mathematical Modeling 3
MATH 422  Applied Complex Variables 3
CHEM 121N  Foundations of Chemistry I Lecture 4
& CHEM 122N  Foundations of Chemistry I Laboratory *
CHEM 123N  Foundations of Chemistry II Lecture 4
& CHEM 124N  Foundations of Chemistry II Laboratory *
Select one of the following:
CS 150  Problem Solving and Programming I 4
PHYS 261N  Advanced University Physics I 4
PHYS 262N  Advanced University Physics II 4
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 453  Electromagnetism II 3
or ECE 322  Electromagnetics 3
PHYS 456  Intermediate Quantum Mechanics 3
PHYS 499W  Senior Thesis * 3
or PHYS 489W  Senior Thesis I
& PHYS 490W  and Senior Thesis II
Approved Physics Seminar 1
Select one of the following:
PHYS 420  Introductory Computational Physics 3
PHYS 453  Electromagnetism II 3
PHYS 456  Intermediate Quantum Mechanics 3
PHYS 499W  Senior Thesis ** 3
or PHYS 489W  Senior Thesis I
& PHYS 490W  and Senior Thesis II

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

Upper-Division General Education
Satisfied by M.B.A. Pre-Core and Core Curriculum: These 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.

### B. S. Degree with Honors

Qualified students may receive the B.S. 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 for PHYS 111N-PHYS 112N (four credits each, for a total of eight credits) will be awarded for a score of 4 or 5 on the Physics B examination, advanced placement credit for PHYS 231N (four credits) will be awarded for a score of 4 or 5 on the Physics C (Mechanics) examination, and advanced placement credit for PHYS 232N (four credits) will be awarded for a score of 4 or 5 on the Physics C (Electricity and Magnetism) examination, each administered by the Advanced Placement Program of the College Board.

### 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.

### 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 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. Introductory 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, and both MATH 211 and MATH 212 with each grade of C or better.

PHYS 232N. Introductory 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 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 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 304. 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. This course is a continuation of PHYS 303. Prerequisite: PHYS 232N and PHYS 303.

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 313. Elements of Astrophysics. 3 Credits.
A one-semester course covering the important topics of modern astrophysics. The physical basis of stellar evolution and chemical element formation is derived from first principles. Observational details of white dwarfs, neutron stars, pulsars, and black holes are developed. Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N.

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 332. Physics of Music and Musical Reproduction. 3 Credits.
This course explores the topics of: the nature of sound, vibrations, resonance, the human ear, loudness, pitch, timbre, musical scales, dissonance and consonance, musical instruments, sound recording and reproduction, electronic music, noise, and acoustics. Prerequisite: MATH 102M.
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, tunable 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. (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. (Qualifies as a CAP experience) 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. (Qualifies as a CAP experience) Prerequisites: approval by the chief departmental advisor and Career Development Services.

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) Corequisite: CS 150. 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. Corequisite: MATH 307. Prerequisite: PHYS 452.

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.
Introduction to the historical development and applications of particle accelerators. Fundamentals of relativistic particle dynamics including particle acceleration; linear beam optics and particle transfers stability; weak and strong focusing; introduction to the statistical descriptions of particle beams; linear and non-linear synchrotron motion; 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. Pre- or corequisite: PHYS 355. Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N and MATH 312.

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. 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. 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. Prerequisites: PHYS 323 and PHYS 452 or permission of the instructor.

PHYS 460/560. 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. PHYS 489W plus PHYS 490W is equivalent to PHYS 499W. Prerequisite: 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.) Prerequisite: PHYS 489W.

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. (offered fall, spring, summer) (This is a writing intensive course.) Prerequisite: grade of C or better in ENGL 211C or ENGL 221C or ENGL 231C and permission of the instructor.