Physics and Engineering

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The purpose of the Physics and Engineering Department is to provide an educational experience within a Christian context that equips students with the ability to obtain knowledge and understanding about the physical world for use in research, graduate studies, and careers and to positively impact society. The Physics and Engineering Department offers instruction in physics, engineering, astronomy, and physical science. Theoretical high-energy physics, high temperature solar thermochemistry, non-destructive materials evaluation, advanced engineering instrumentation, smart grid technologies, power electronics, and microelectronics provide the major research interests in the department.

Departmental majors include: Physics, Engineering, Physics Science Education, and Physics/Mathematics Education.

Physics (BA)

The Bachelor of Arts degree with a major in Physics requires two years of one foreign language and 78-80 hours in the major. *All major courses must be completed with a grade of C- or better and are included in the major GPA.*

Major Requirements

PHY 211	5	University Physics I
PHY 212	5	University Physics II
PHY 311	4	Modern Physics
PHY 321	3	Electricity and Magnetism
PHY 322	4	Waves and Physical Optics
PHY 330	2	Advanced Lab
PHY 341	3	Math Methods in Physics and Engineering
PHY 342	3	Analytical Mechanics
PHY 350	4	Thermodynamics and Statistical Mechanics
PHY 412	3	Quantum Mechanics
PHY 493	3	Physics Senior Capstone

Electives

Select 8 hours from the following:

ENP 200-499	1-8	Engineering Physics Electives
MAT 245	4	Linear Algebra
PHY 201‡	4	Introductory Astronomy
PHY 313	2	Nuclear Radiation Experimental Methods
PHY 370	1-4	Selected Topics *(approved by advisor)*
PHY 393	2	Practicum
PHY 413	2	Quantum Mechanics II
PHY 441	3	Advanced Mathematical Methods in Physics
PHY 450	1-4	Directed Research
PHY 491	1	Preparation for the Physics GRE

Additional Major Requirements

CHE 211	4	College Chemistry I
CHE 212	4	College Chemistry II
ENP 104	3	Introduction to Engineering and Software Tools
MAT 151	4	Calculus I
MAT 230	4	Calculus II
MAT 240	4	Calculus III
MAT 251	4	Differential Equations

Select one course from the following:

COS 130	3	Computational Problem Solving for Engineers
SYS 120	4	Introduction to Problem Solving

Select one course from the following:

NAS 480	1	Seminar
IAS 231H	2	Issues in Science and Religion *(Honors)*

‡*Special lab section required. Please see catalog course description for more details.*

Physics (BS)

The Bachelor of Science degree with a major in Physics requires 91-95 hours in the major. *All major courses must be completed with a grade of C- or better and are included in the major GPA.*

Major Requirements

PHY 211	5	University Physics I
PHY 212	5	University Physics II
PHY 311	4	Modern Physics
PHY 321	3	Electricity and Magnetism
PHY 322	4	Waves and Physical Optics
PHY 330	2	Advanced Lab
PHY 341	3	Math Methods in Physics and Engineering
PHY 342	3	Analytical Mechanics
PHY 350	4	Thermodynamics and Statistical Mechanics
PHY 412	3	Quantum Mechanics
PHY 413	2	Quantum Mechanics II
PHY 441	3	Advanced Mathematical Methods in Physics
PHY 491	1	Preparation for the Physics GRE
PHY 493	3	Physics Senior Capstone

Select one course from the following:

PHY 393	2	Practicum
PHY 450	2-4	Directed Research

Technical Electives

Select at least 9 additional hours from the following:

CHE 431	4	Physical Chemistry I
CHE 432	4	Physical Chemistry II
COS 121	4	Foundations of Computer Science
ENP 200-499	1-9	Engineering Physics Electives
MAT 310	3	Mathematical Modeling with Numerical Analysis
MAT 340	4	Advanced Calculus
MAT 352	4	Mathematical Statistics
MAT 382	3	Advanced Statistical Methods
MAT 455	3	Abstract Algebra
MAT 456	3	Advanced Algebra
MAT 461	3	Real Analysis
PHY 201‡	4	Introductory Astronomy
PHY 300-499	1-9	Physics Electives

‡*Special lab section required. Please see catalog course description for more details.*

Additional Major Requirements

CHE 211	4	College Chemistry I
CHE 212	4	College Chemistry II
ENP 104	3	Introduction to Engineering and Software Tools
MAT 151	4	Calculus I
MAT 230	4	Calculus II
MAT 240	4	Calculus III
MAT 245	4	Linear Algebra
MAT 251	4	Differential Equations

Select one course from the following:

COS 130	3	Computational Problem Solving for Engineers
SYS 120	4	Introduction to Problem Solving

Select one course from the following:

IAS 231H	2	Issues in Science and Religion (Honors)
NAS 480	1	Seminar

Engineering (BS)

The Bachelor of Science degree with a major in Engineering requires the completion of 104-106 hours. It is a general engineering degree which prepares students for industry practice and/or graduate study in a variety of engineering disciplines. Students select one or two* of seven concentrations to align with individual interests and career goals. This program is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; telephone (410) 347-7700. Courses may not be used to fulfill more than one major requirement: core, concentration, elective. *Engineering students may elect any double concentration, provided (1) they meet the requirements of both concentrations, (2) neither of the concentrations is General engineering, and (3) the total number of concentration credits (non-core) is at least 32. These restrictions mean that any double concentration will require at least 8 Tier B credit hours beyond the 24 credit hours required for a single concentration. *All major courses, including those in the concentration(s), must be completed with a grade of C- or better and are included in the major GPA.*

Program Objectives:

1. Prepare our graduates to serve others dependably, most importantly their employer, customers, and community.
2. Prepare our graduates to practice technical competence, producing reliable engineering designs.
3. Prepare our graduates to exercise creativity in their work, fostering innovative solutions.
4. Prepare our graduates to pursue growth, both knowledge and career, thus ensuring dependability in an ever changing world.

Engineering Core Requirements

COS 130	3	Computational Problem Solving for Engineers
ENP 104	3	Introduction to Engineering and Software Tools
ENP 231	4	Introduction to Electric Circuits
ENP 252	4	Principles of Engineering
ENP 301	3	Statics
ENP 332	4	Control Systems
ENP 351	3	Thermodynamics
ENP 352	3	Materials Science and Solid State Physics
ENP 392	3	Junior Engineering Project
ENP 393	2	Practicum
ENP 405	1	Engineering Ethics
ENP 491	1	Review of the Fundamentals of Engineering
ENP 492	2	Engineering Senior Capstone I
ENP 493	3	Engineering Senior Capstone II
ENP 494	1	Engineering Senior Capstone III

Science and Math Core Requirements

CHE 211	4	College Chemistry I
MAT 151	4	Calculus I
MAT 230	4	Calculus II
MAT 240	4	Calculus III
MAT 251	4	Differential Equations
PHY 211	5	University Physics I
PHY 212	5	University Physics II

Select <u>one</u> course from the following:

PHY 341	3	Math Methods in Physics and Engineering
SUS 231	4	Environmental Science, Society, and Sustainability

Select <u>one</u> course from the following:

NAS 480	1	Seminar
IAS 231H	2	Issues in Science and Religion

Additional Core Requirements

ECO 201	3	Principles of Microeconomics
SYS 330	3	Human Relations in Organizations

Select <u>one or two</u>* 24-hour concentration areas: Biomedical, Chemical, Electrical, Environmental, General, Mechanical, Physics

Biomedical

BIO 201	4	Biology I: Foundations of Cell Biology and Genetics
CHE 212	4	College Chemistry II
CHE 311	4	Organic Chemistry I
ENP 303	3	Dynamics

Select <u>5</u> additional hours from Tier A: Engineering Electives

Select <u>4</u> additional hours from Tier B: Mathematics, Science, and Engineering Electives

Chemical

CHE 212	4	College Chemistry II
CHE 311	4	Organic Chemistry I
CHE 431	4	Physical Chemistry I - Thermodynamics
ENP 357	3	Heat Transfer

Select <u>5</u> additional hours from Tier A: Engineering Electives

Select <u>4</u> additional hours from Tier B: Mathematics, Science, and Engineering Electives

Electrical

ENP 261	3	Digital Systems Design
ENP 321	2	Applied Electromagnetics
ENP 341	4	Microcomputer Interfacing
ENP 431	4	Advanced Electronics and Microcircuits
PHY 311	4	Modern Physics
PHY 321	3	Electricity and Magnetism

Select <u>4</u> additional hours from Tier B: Mathematics, Science, and Engineering Electives

Environmental

CHE 212	4	College Chemistry II
ENP 355	3	Fluid Mechanics and Water Flow
ENS 241	4	Physical Geology
ENS 361	4	Geomorphology
ENS 362	4	Hydrogeology

Select <u>5</u> additional hours from Tier A: Engineering Electives

General

Select <u>15</u> additional hours from Tier A: Engineering Electives

Select <u>9</u> additional hours from Tier B: Mathematics, Science, and Engineering Electives

Mechanical

ENP 302	3	Strength of Materials and Machine Design
ENP 303	3	Dynamics
ENP 355	3	Fluid Mechanics and Water Flow
ENP 357	3	Heat Transfer
ENP 359	2	Mechanical Engineering Laboratory

Select <u>10</u> additional hours from Tier B: Mathematics, Science, and Engineering Electives

Physics

PHY 311	4	Modern Physics
PHY 321	3	Electricity and Magnetism
PHY 322	4	Waves and Physical Optics
PHY 412	3	Quantum Mechanics I

Select <u>8</u> additional hours from Tier A: Engineering Electives

Select <u>2</u> additional hours from Tier B: Mathematics, Science, and Engineering Electives

<u>Tier A: Engineering Electives</u>

COS 121	4	Foundations of Computer Science
ENP 261	3	Digital Systems Design
ENP 302	3	Strength of Materials and Machine Design
ENP 303	3	Dynamics
ENP 321	2	Applied Electromagnetics
ENP 341	4	Microcomputer Interfacing
ENP 355	3	Fluid Mechanics and Water Flow
ENP 357	3	Heat Transfer
ENP 359	2	Mechanical Engineering Laboratory
ENP 394	1-4	Advanced Engineering Project
ENP 431	4	Advanced Electronics and Microcircuits

<u>Tier B: Mathematics, Science, and Engineering Electives</u>

BIO 201	4	Biology I: Foundations of Cell Biology and Genetics
BIO 203	4	Principles of Genetics
BIO 244	4	Human Anatomy and Physiology I
BIO 245	4	Human Anatomy and Physiology II
CHE 212	4	College Chemistry II
COS 121	4	Foundations of Computer Science
COS 230	3	Missions Technology
ENS 241	4	Physical Geology
MAT 245	4	Linear Algebra
BIO ___	1-10	*Any 300/400 electives not used in major*
CHE ___	1-10	*Any 300/400 electives not used in major*
COS ___	1-10	*Any 300/400 electives not used in major*
ENP ___	1-10	*Any 300/400 electives not used in major*
ENS ___	1-10	*Any 300/400 electives not used in major*
MAT ___	1-10	*Any 300/400 electives not used in major*
PHY ___	1-10	*Any 300/400 electives not used in major*
SYS ___	1-10	*Any 300/400 electives not used in major*

Computer Engineering

Computer Engineering is an interdisciplinary major offered jointly by the Physics and Engineering and the Computer Science and Engineering Departments. *For program details, refer to **Computer Engineering** on page 144.*

Physics/Mathematics Education (BS)

The Bachelor of Science degree with a major in Physics/Mathematics Education requires 61 hours in addition to education courses. *All major courses, including education curriculum courses, must be completed with a grade of C- or better and are included in the major GPA.*

Physics Core

ENP 231	4	Introduction to Electric Circuits
IAS 231H	2	Issues in Science and Religion *(Honors)*
PHY 211	4	University Physics I
PHY 212	5	University Physics II
PHY 311	4	Modern Physics
SYS 120	4	Introduction to Problem Solving

Select <u>one</u> course from the following:

PHY 493	3	Physics Senior Capstone
MAT 493	3	Mathematics Senior Capstone

Mathematics Core

MAT 151	4	Calculus I
MAT 230	4	Calculus II
MAT 240	4	Calculus III
MAT 245	4	Linear Algebra
MAT 251	4	Differential Equations
MAT 280	3	Mathematics in the Junior High/Middle School
MAT 312	4	College Geometry
MAT 352	4	Mathematical Statistics

Electives

Select <u>4</u> hours of electives from the following:

ENP 252	4	Principles of Engineering

ENP 300-/400-level courses
PHY 300-/400-level courses

Professional Education

EDU 150	3	Education in America
EDU 222	3	Reading in the Content Area for Secondary Teachers
EDU 260	3	Educational Psychology
EDU 307	2	Discipline and Classroom Management for Secondary Teachers
EDU 309	1	Teaching in Secondary, Junior High/Middle Schools—Special Methods
EDU 328	2	Assessment for Student Learning
EDU 332	2	The Junior High/Middle School
EDU 344	1	Educational Technology in Secondary Education
EDU 431	15	Supervised Internship in Secondary Schools
SED 220	3	Exceptional Children

Select <u>one</u> course from the following:

NAS 309	2	Science Education Methods
MAT 309	2	Teaching Math in Secondary Schools

Additional Education Requirements

CAS 110	3	Public Speaking
PSY 340	3	Adolescent Psychology

Physics Science Education (BS)

The Bachelor of Science degree with a major in Physics Science Education requires 56 hours in addition to education courses. *All major courses, including education curriculum courses, must be completed with a grade of C- or better and are included in the major GPA.*

Major Requirements

CHE 211	4	College Chemistry I
ENP 231	4	Introduction to Electric Circuits
IAS 231H	2	Issues in Science and Religion *(Honors)*
SYS 120	4	Introduction to Problem Solving

Additional Major Requirements

MAT 151	4	Calculus I
MAT 230	4	Calculus II
MAT 240	4	Calculus III
PHY 211	4	University Physics I
PHY 212	5	University Physics II
PHY 311	4	Modern Physics
PHY 330	2	Advanced Lab
PHY 493	3	Physics Senior Capstone

Electives

Select <u>12</u> hours of electives from the following:

ENP 252	4	Principles of Engineering

ENP 300-/400-level courses
PHY 300-/400-level courses

Professional Education

EDU 150	3	Education in America
EDU 222	2	Reading in the Content Area for Secondary Teachers
EDU 260	3	Educational Psychology
EDU 307	2	Discipline and Classroom Management for Secondary Teachers
EDU 309	1	Teaching in Secondary, Junior High/Middle Schools—Special Methods
EDU 328	2	Assessment for Student Learning
EDU 332	2	The Junior High/Middle School
EDU 344	1	Educational Technology in Secondary Education
EDU 384	1	Perspectives on Diversity
EDU 431	15	Supervised Internship in Secondary Schools
NAS 309	2	Science Education Methods
SED 220	3	Exceptional Children

Additional Education Requirements

CAS 110	3	Public Speaking
PSY 340	3	Adolescent Psychology

Physics Minor

A minor in Physics consists of 20 hours. This minor may not be awarded with a major from within the department. *All minor courses must be completed with a grade of C- or better and are included in the minor GPA.*

Minor Requirements

PHY 211	4-5	University Physics I
PHY 212	5	University Physics II

Electives

Select enough elective credit hours of upper-division (300- or 400-level) physics and engineering courses to reach <u>20</u> credit hours. ENP 231 and 252 may also meet elective hours.

Engineering Courses

ENP 104 **3 hours**
Introduction to Engineering and Software Tools
This course introduces the students to the engineering discipline, providing a hands-on overview of the tools they will acquire and use over the course of their major. These tools include process and methodology tools, analytical tools, software tools, and hardware tools. A goal of the course is to provide the students with a framework for their engineering studies along with a practical 'hands-on' example of what engineering might "look like." This framework should help the student better understand the role, need, and benefit of each successive course in their major. A group hardware project will be carried out as part of the course, helping to engage the students' learning and interest, and re-enforcing the concepts taught in class. *Offered January interterm. Prerequisite: PHY 211.*

ENP 170 **1-4 hours**
Selected Topics
A course offered on a subject of interest but not listed as a regular course offering.

ENP 231 **4 hours**
Introduction to Electric Circuits
First course in electric circuits, where DC, time-dependent, and AC circuits are each introduced. Network analysis, network reduction techniques, time-domain solutions to simple 1st and 2nd order circuits, and steady-state analysis of sinusoidally excited circuits are each developed. Weekly lab introduces breadboarding, debugging, and testing of basic electric and electronic circuits using common test equipment. An introduction and use of basic electronic devices such as op-amps, the Shockley diode and BJT or MOSFET transistors is also included. An emphasis is placed on SPICE circuit simulation throughout the semester. A course project introduces students to ECAD software, where they create, build, and test a custom printed circuit board (PCB) circuit. *Prerequisites: PHY 212 and ENP 104, or permission of instructor. Offered fall semester.*

ENP 252 **4 hours**
Principles of Engineering
The course focuses on the mathematical modeling and analysis of lumped-element physical systems—translational and rotational mechanical systems, electrical systems, heat transfer systems, and fluid systems. Unifying concepts of flow, effort, and impedance are emphasized, along with the use of transfer function descriptions, frequency domain analysis, and Laplace Transform analysis. Labs focus on modeling and simulation, design of experiments, directed design process, and software skill development, including MATLAB and Simulink. *Prerequisite: ENP 231. Corequiste: MAT 251. Offered spring semester.*

ENP 261 **3 hours**
Digital Systems Design
Digital Systems are explored, including combinational (e.g., multiplexors and decoders) and sequential (e.g., flip-flops and registers) logic. Circuit minimization techniques such as boolean algebra and Karnaugh maps are examined. Mealy and Moore finite state machines will be developed to model systems. Designs will culminate in projects that simulate circuits with a hardware description language and then synthesized on an FPGA. *Offered spring semester of even years.*

ENP 270 **1-4 hours**
Selected Topics
A course offered on a subject of interest but not listed as a regular course offering.

ENP 301 **3 hours**
Statics
This course is a one-semester introduction to the statics of particles and rigid bodies. Topics include: forces, moments, equilibrium, and structures in equilibrium. Course makes applications to engineering and uses software tools for engineering mechanics. *Prerequisites: PHY 211 and MAT 230. Offered fall semester.*

ENP 302 **3 hours**
Strength of Materials and Machine Design
Course investigates the fundamentals of strength of materials and machine design. The strength of materials section covers stress—strain relationships, axial loading, torsion, beam loading, and linear buckling. The machine design portion applies the fundamental knowledge of statics, dynamics and strength of materials to mechanical components and integration of components into systems. *Prerequisite: ENP 301. Offered spring semester of even years.*

ENP 303 **3 hours**
Dynamics
This course covers the basic principles of dynamic mechanical systems, as derived from Newtonian mechanics. The main topics covered include kinematics of particles, kinetics of particles (using both force and energy/momentum methods), kinetics of systems of particles, kinematics of rigid bodies, and 2-D kinetics (plane motion) of rigid bodies (using both force and energy/momentum methods). *Prerequisite: ENP301. Offered spring semester of odd years.*

ENP 321 **2 hours**
Applied Electromagnetics
The course considers the application and technology of electromagnetic field theory to computing and communications systems. Topics may include wave propagation, transmission lines, fiber optics, high frequency communication networks, antennas, and satellite communications. *Prerequisites: ENP 252, MAT 251, and ENP 231. Offered spring semester of odd years.*

ENP 332 **4 hours**
Control Systems
This is an introductory course in Signals, Systems and Controls. A selection of topics is chosen from a conventional two-course sequence of "Signals and Systems" and "Automatic Control". Mathematical tools for studying linear time invariant (LTI) continuous time systems are developed. These include describing and analyzing LTI systems according to their 1) differential equation, 2) impulse response, 3) state-space representation, and 4) frequency response representation. Transform methods including Fourier series, Fourier Transform, and Laplace Transform are also developed as needed. The Controls portion of the course includes time-domain transient response, steady-state response, and stability tests. Frequency domain analysis such as root-locus and Nyquist stability are also introduced. *Prerequisites: ENP 252 and MAT 251. Offered spring semester of odd years.*

ENP 341 **4 hours**
Microcomputer Interfacing
Course develops the student's ability to design, build and test embedded systems. Hardware architecture and software programming of microcontrollers and other embedded system devices are studied. Operation and use of LCDs, A to D and D to A converters, keypads and other interface devices are investigated. Serial communication through 12C, OneWire, USB and RS232 are used. In addition, networking and RF techniques and protocols are studied. *Prerequisite: ENP 231 or permission of instructor. Offered fall semester of even years.*

ENP 345 **3 hours**
Fundamentals of Space Systems
Course is an introduction to space systems, the atmosphere, and astronomy. Course includes study and lab experiments coupled to the atmospheric and space environments, atmospheric and space sensors, orbits, nanosatellites, remote sensing, and penetrating nuclear radiation. Two hours lecture and two hours of lab. *Meets foundational core earth science requirement. Prerequisite: PHY 212. Offered as needed.*

ENP 351 **3 hours**
Thermodynamics
Course develops engineering thermodynamics including use of the first and second law, phase diagrams, properties, heat transfer, second law consequences, power and refrigeration cycles as well as other selected topics. *Prerequisites: MAT 251, PHY 212, and ENP 252. Offered spring semester of even years.*

ENP 352 **3 hours**
Materials Science and Solid State Physics
The structure, processing, and properties of engineering materials are studied, with an emphasis on metallic systems. This includes: crystal structure, defects, diffusion, phase transformations, deformation mechanisms, strength, and fracture toughness. Also covered are material selection, linear elastic fracture mechanics, and dislocation theory. Course contains a significant research component. *Prerequisite: ENP 252. Offered fall semester of odd years.*

ENP 355 **3 hours**
Fluid Mechanics and Water Flow
An introduction to the basic properties of fluids in motion. Topics include: Differential fluid equations, streamlines, continuity, energy and linear angular momentum, incompressible viscous flow, potential flow, Navier-Stokes equations, open channel flow, pipe flow, laminar and turbulent boundary layers. *Prerequisite: ENP 252. Corequisite: MAT 251. Offered fall semester of even years.*

ENP 357 **3 hours**
Heat Transfer
Course investigates the fundamentals of heat transfer and applies those fundamentals to engineering applications. Topics covered include modeling of conduction, convection, radiation, and mixed mode heat transfer problems. Course covers both steady state and transient response and make applications to satellite thermal control and cooling of electrical devices. *Prerequisite: ENP 252. Offered fall semester of odd years.*

ENP 359 **2 hours**
Mechanical Engineering Laboratory
In this course, laboratory experiments reinforce key concepts encountered in mechanical engineering. Topics include materials science, fluid mechanics, thermodynamics, heat transfer, dynamics, and mechanics of materials. Students actively participate in the configuration of sensors and build data acquisition programs as they develop familiarity with various aspects of experimental measurements. Laboratory exercises include elements of data analysis, assessment of experimental uncertainty, and technical writing. *Prerequisite: ENP 252. Offered fall semester of even years.*

ENP 360 **1-4 hours**
Independent Study
An individualized, directed study involving a specified topic.

ENP 370 **1-4 hours**
Selected Topics
A course offered on a subject of interest but not listed as a regular course offering.

ENP 392 **2-4 hours**
Junior Engineering Project
In the context of completing an engineering project, students learn and practice: elements of the design process, the ability to be innovative and think creatively, the ability to acquire new knowledge and skills, the ability to solve engineering problems, the application of analytical and software tools to engineering problems, and the ability to communicate effectively. Focus on the "thoughtful design process" is particularly emphasized. *Prerequisite: ENP 252. Offered spring semesters.*

ENP 393 **1-4 hours**
Practicum
Supervised learning involving a first-hand field experience or a project. Generally, one hour of credit is awarded for a minimum of 40 hours of practicum experience. *Practicum must involve a significant engineering work experience and preference is given to an experience away from the Taylor campus. Offered primarily during summer. Prerequisite: ENP 252 and junior or senior status.*

ENP 394 **1-4 hours**
Advanced Engineering Project
Students complete an open-ended project, laboratory experiment or research project. The individual project depends on student and faculty interest. Many projects are externally funded. Specific learning outcomes vary depending on faculty, student, and project selected. *Prerequisite: ENP 252.*

ENP 405 **1 hour**
Engineering Ethics
Course introduces students to the ethical requirements of the engineering profession and the ethical issues associated with living in a technological intense digital society. Through the course, students should: appreciate the ethical use of computers and dangers of computer misuses, have knowledge of professional codes of ethics, be aware of the impact of technology on society, have an appreciation for the needs of society and how engineering can meet those needs, and begin developing an understanding of how their Christian faith integrates with their engineering practice. *Prerequisite: ENP 492.*

ENP 431 **4 hours**
Advanced Electronics and Microcircuits
Modeling and analysis of basic electronic devices—primarily diodes and transistors. Applications are made to various analog and digital circuits, including single and multi-stage amplifiers. *Prerequisites: ENP 231 and ENP 252. Offered fall semester of odd years.*

ENP 450 **1-4 hours**
Directed Research
Investigative learning involving closely directed research and the use of such facilities as the library or laboratory.

ENP 480 **1-4 hours**
Seminar
A limited-enrollment course designed especially for upper-class majors with emphasis on directed readings and discussion.

ENP 490 **1-2 hours**
Honors
Individualized study or research of an advanced topic within a student's major. Open to students with at least a 3.00 GPA in the major field.

ENP 491 **1 hour**
Review of the Fundamentals of Engineering
Course reviews the fundamentals of engineering and prepares students to enter the engineering profession. Depending on students' incoming ability, the course will review subjects from chemistry, computers, dynamics, electric circuits, engineering economics, ethics, fluid mechanics, materials science, mathematics, mechanics of materials, statics, and thermodynamics. *Prerequisite: Senior status. Offered spring semester.*

ENP 492 **2 hours**
Engineering Senior Capstone I
Course is the first of a three-course culminating experience which prepares students for engineering practice through a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic, environmental, sustainability, manufacturability, ethical, health and safety, social and political. *Prerequisite: Senior status. Offered fall semester.*

ENP 493 **3 hours**
Engineering Senior Capstone II
Course is the second of a three-course culminating experience which prepares students for engineering practice through a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic, environmental, sustainability, manufacturability, ethical, health and safety, social and political. Course also prepares students to serve God and humanity through active service to their family, church, employer and global community. *Prerequisite: ENP 492. Offered January interterm.*

ENP 494 **1 hour**
Engineering Senior Capstone III
Course is the third of a three-course culminating experience which prepares students for engineering practice through a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic, environmental, sustainability, manufacturability, ethical, health and safety, social and political. Course focuses mainly on documenting and presenting work completed in the first two courses of the capstone experience. *Prerequisite: ENP 493. Offered spring semester.*

Physics Courses

PHY 120 **4 hours**
Renewable Energy Principles
Intended for non-science majors. The continuum of energy use drives society to consider renewable and sustainable resource models based on physical principles, chemistry, and Earth science while connecting to theology and the "big picture" of the universe. *Three hours of lecture and two hours of lab (focusing on renewable energy) each week. Meets foundational core physical science requirements.*

PHY 170 **1-4 hours**
Selected Topics
A course offered on a subject of interest but not listed as a regular course offering.

PHY 201 **3-4 hours**
Introductory Astronomy
A descriptive course about the solar system, stars and stellar evolution, and galaxies and the universe. Recent findings of space exploration and radio astronomy are included. Telescopes are provided for viewing sessions. Two or three hours of lecture and two hours of lab. *Physics majors wishing to take PHY 201 for elective credit must take the "majors-only" lab section that is offered intermittently. Students interested in this option should consult with the department chair to determine availability of this special lab section. Students taking PHY 201 for elective credit should also check to ensure that they maintain the required minimum number of upper-division credit hours. Meets foundational core earth science requirement.*

PHY 203 **4 hours**
General Physics I
A study of mechanics, thermodynamics, waves and sound, electricity, magnetism, and optics. Assumes mathematics at the algebra-trigonometry level. For majors that do not require a calculus-based treatment of physics. *Meets foundational core physical science requirement. Three hours of lecture and two hours of lab. Offered annually.*

PHY 204 **4 hours**
General Physics II
See PHY 203.

PHY 211 **4-5 hours**
University Physics I
A calculus-based study of mechanics, waves and sound, electricity and magnetism, optics, fluids, and the structure of matter. The 4 hour course consists of four hours of lecture (for three-quarters of the term) and two hours of lab (for the entire term). The five-hour version also incorporates the study of thermodynamics and consists of four hours of lectures and two hours of lab. *Meets foundational core physical science requirement. Corequisite: MAT 146 or 151. Offered annually.*

PHY 212 **5 hours**
University Physics II
Four hours of lecture and two hours of lab. See PHY 211. Prerequisite: PHY 211. Corequisite: MAT 230.

PHY 270 **1-4 hours**
Selected Topics
A course offered on a subject of interest but not listed as a regular course offering.

PHY 311 **4 hours**
Modern Physics
An introduction to modern physics, including special relativity, quantum effects of radiation and particles, atomic structure, and elementary particles. *Three hours of lecture and two hours of lab per week. Prerequisites: PHY 211 and 212. Offered fall semester.*

PHY 313 **2 hours**
Nuclear Radiation Experimental Methods
A study of nuclear radiation and detection and experimental methods of measuring nuclear radiation. *One hour of lecture and two hours of lab per week. Prerequisites: PHY 211 and 212. Offered intermittently.*

PHY 321 **3 hours**
Electricity and Magnetism
The vector field approach to electromagnetic theory. Includes electrostatics, magnetostatics, induction, dielectric and magnetic materials, and Maxwell's equations. *Co-requisites: MAT 251 and PHY 341. Prerequisites: PHY 211, 212. Offered fall semester of even years.*

PHY 322 **4 hours**
Waves and Physical Optics
Applications of Maxwell's equations, including electromagnetic waves, wave guides, diffraction, and Fourier optics. *Three hours of lecture and three hours of lab per week. Prerequisites: PHY 211, 212, and 321. Offered spring semester of odd years.*

PHY 330 **1-2 hours**
Advanced Lab
Students complete an open-ended project, laboratory experiment or research project. The individual project depends on student and faculty interests. Specific learning outcomes vary depending on faculty, student and project selected. *Prerequisites: ENP 252 or 301 or PHY 311 and junior classification. Offered as needed for physics and engineering physics majors.*

PHY 341 **3 hours**
Math Methods in Physics and Engineering
An application of analytical and computational methods to various mathematical topics, including linear algebra, matrices, eigenequations, vector field theory, partial differential equations, Fourier series and transforms, orthogonal functions, and complex analysis. Use of a computer application such as MATLAB is required. *Prerequisite: PHY 212. Corequisite: MAT 251. Offered spring semesters.*

PHY 342 **3 hours**
Analytical Mechanics
A formal treatment of mechanics covering harmonic motion, the translation and rotation of rigid bodies, noninertial reference frames, and gravitation. The course concludes with the Hamiltonian and Lagrangian formulations of mechanics. *Prerequisites: PHY 211, 212, 341. Offered spring semester of even years.*

PHY 350 **4 hours**
Thermodynamics and Statistical Mechanics
Develops thermal physics and statistical mechanics, with application to solid state physics. In the thermal physics portion of the course, the three laws of thermodynamics are developed and applied to problems. In the statistical mechanics portion, the development of the partition function is accomplished through the microcanonical formalism. The partition function is then applied to various problems, such as: Bose-Einstein and Fermi-Dirac statistics, Bose-Einstein condensation, blackbody radiation, and the behavior of electrons and phonons in solid materials. *Prerequisite: PHY 341.*

PHY 360 **1-4 hours**
Independent Study
An individualized, directed study involving a specified topic.

PHY 370 **1-4 hours**
Selected Topics
A course offered on a subject of interest but not listed as a regular course offering.

PHY 393 **1-4 hours**
Practicum
Supervised learning involving a first-hand field experience or a project. Generally, one hour of credit is awarded for a minimum of 40 hours of practicum experience. *Offered primarily during summer.*

PHY 412 **3 hours**
Quantum Mechanics
A quantum mechanical treatment of the free particle, harmonic oscillator and hydrogen atom. Includes creation and annihilation operators and an introduction to angular momentum. *Prerequisites: PHY 211, 212, 311 and 341. Offered spring semester of odd years.*

PHY 413 **2 hours**
Quantum Mechanics II
An in-depth treatment of several advanced topics in quantum mechanics. Topics covered include spin, angular momentum, three-dimensional problems, matrix mechanics, the density matrix, and perturbation theory. *Prerequisite: PHY 412. Offered fall semester of odd years.*

PHY 441 **3 hours**
Advanced Mathematical Methods in Physics
Application of analytical and computational methods to various advanced mathematical topics in physics, such as: group theory, complex analysis, partial differential equations, Green's functions, the Gamma function, Bessel functions, Legendre functions, and Fourier analysis. *Prerequisite: PHY 341. Offered fall of even years.*

PHY 450 **1-4 hours**
Directed Research
Investigative learning involving closely directed research and the use of such facilities as the library or laboratory.

PHY 480 **1-4 hours**
Seminar
A limited-enrollment course designed especially for upper-class majors with emphasis on directed readings and discussion.

PHY 490 **1-2 hours**
Honors
Individualized study or research of an advanced topic within a student's major. *Open to students with at least a 3.00 GPA in the major field.*

PHY 491 **1 hour**
Preparation for the Physics GRE
A review of topics covered in the undergraduate physics curriculum. The purpose of the course is to help students prepare for the GRE Subject Test in Physics. Topics reviewed include: Classical Mechanics (including the Lagrangian formalism), Modern Physics (including Quantum Mechanics and Special Relativity), Electricity and Magnetism, Optics, Thermodynamics, and Electronics. *Prerequisite: junior or senior status.*

PHY 493 **3 hours**
Physics Senior Capstone
A capstone course in which each senior's technical, analytical, and laboratory skills, along with coursework knowledge, are applied to an intensive physics or engineering project. Three weeks are devoted to the completion of the project, and the remainder of the term is spent off-campus, strengthening interpersonal relationships, integrating faith and learning, and examining topics critical to post-baccalaureate life. *Prerequisite: Senior status.*

Notes