ENGINEERING PHYSICS

Undergraduate Program Information

The Engineering Physics program is offered jointly by the Department of Physics and the College of Engineering. The faculty is drawn from the Departments of Physics, Chemical and Materials Engineering, Electrical and Computer Engineering, and Mechanical & Aerospace Engineering. The mission of the Engineering Physics program at New Mexico State University is to offer an accredited degree that combines high-quality engineering and physics programs to best prepare our graduating students for careers in state-of-the-art industry or to move on to advanced study in engineering physics.

The B.S. in Engineering Physics confers an engineering credential. Students in the program complete an engineering core curriculum, as well as a rigorous course of study in physics and mathematics. A strong laboratory component prepares students in experimental techniques and technology using state-of-the-art equipment. The program has the following educational objectives:

1. **Competitiveness.** Graduates are competitive in internationally recognized academic, government and industrial environments.
2. **Adaptability.** Graduates exhibit success in solving complex technical problems in a broad range of disciplines subject to quality engineering processes.
3. **Collaboration/Teamwork and Leadership.** Graduates have a proven ability to function as part of and/or lead interdisciplinary teams.

The Engineering Physics B.S. program is accredited by the Engineering Accreditation Commission (EAC) of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Engineering, General Engineering, Engineering Physics, Engineering Science, and Similarly Named Engineering Programs.

The student must choose one of four concentrations in

- Aerospace Engineering,
- Chemical Engineering,
- Electrical Engineering, or
- Mechanical Engineering.

Degrees for the Department

- Engineering Physics (Aerospace Engineering) - Bachelor of Science in Engineering Physics (https://catalogs.nmsu.edu/nmsu/engineering/engineering-physics/engineering-physics-aerospace-bachelor-science-engineering-physics/)
- Engineering Physics (Chemical Engineering) - Bachelor of Science in Engineering Physics (https://catalogs.nmsu.edu/nmsu/engineering/engineering-physics/engineering-physics-chemical-bachelor-science-engineering-physics/)
- Engineering Physics (Electrical Engineering) - Bachelor of Science in Engineering Physics (https://catalogs.nmsu.edu/nmsu/engineering/engineering-physics/engineering-physics-electrical-bachelor-science-engineering-physics/)
- Engineering Physics (Mechanical Engineering) - Bachelor of Science in Engineering Physics (https://catalogs.nmsu.edu/nmsu/engineering/engineering-physics/engineering-physics-mechanical-bachelor-science-engineering-physics/)

Professor, Stefan Zollner, Department Head

Professor, Boris Kiefer, Engineering Physics Program Head

Physics Courses

PHYS 1110. Explorations in Physics
1 Credit (1)
This course will introduce students to university resources, pre-professional student societies, learning strategies to help strengthen academic performance, and will explore career paths for graduates. Students will also discuss the roles of physicists in society, physics research being performed at and nearby NMSU, and what the latest discoveries in physics tell us about nature and the universe.
Learning Outcomes

1. Describe effective learning strategies for science/engineering classes.
2. Give examples of impactful scientists from groups underrepresented in physics and describe their career paths.
3. Research examples of positions open to physics majors.
4. Identify critical components of an effective resume.
5. Write a professional cover letter for an internship/undergraduate research application.
6. Discuss the boundaries of ethical science and give an example of an accidental breach of ethics.
7. Describe the societal impact of misinformation about scientific results or research.
8. Explore ways scientists can engage with the general public to shape the discourse of knowledge or the ways scientists are perceived.
9. List some of the burning questions current physicists are trying to answer. 1
10. Establish a sense of community within the department, the university, and the greater physics world. 1
11. Discover useful resources to help with academic success and avoid pitfalls while pursuing a physics degree. 1
12. Better understand the value of a physics degree, and what can be expected entering the workforce or academia. 1
13. Understand and discuss how the field of physics connects with the issues and problems facing society today.

PHYS 1111. Introductory Computational Physics
3 Credits (2+2P)
Introduction to computational techniques for the solution of physics-related problems.
Prerequisite: a C- or better in MATH 1220G or MATH 1250G or MATH 1511G.
Learning Outcomes

1. Use computers for visualizing and analyzing data.
2. Apply techniques of structured programming and software development.
3. Trouble shoot and debug programs.

PHYS 1112. Introductory Physics for the Health Sciences
3 Credits (3)
Algebra-level introduction to topics required for the Health Sciences including basic mechanics (including sound, mechanical waves and fluids), heat and thermodynamics, electricity and magnetism, optics and electromagnetic waves, atomic and nuclear physics and applications to medical imaging. Restricted to Community Colleges campuses only.
Prerequisite(s): MATH 1215 or Equivalent.

Learning Outcomes

1. The objective of the course is to familiarize the student with the concepts and methods used in the underlying physics associated with various Health Science disciplines.
2. The course will demonstrate how the basic principles of mechanics, thermodynamics, electricity, magnetism, electromagnetic waves and optics can be applied to solve particular problems in Health Sciences applications. Introduces the student to selected topics in modern physics including quantum physics, atomic and nuclear physics.

PHYS 1115G. Survey of Physics with Lab
4 Credits (3+3P)
Overview of the concepts and basic phenomena of physics. This course provides a largely descriptive and qualitative treatment with a minimum use of elementary mathematics to solve problems. No previous knowledge of physics is assumed. Includes laboratory.

Learning Outcomes

1. Apply concepts of classical mechanics (such as velocity, acceleration, force, inertia, momentum, torque, work, energy) to simple static and dynamic systems.
2. Apply concepts of thermodynamics (such as heat, temperature, internal energy, entropy) to simple processes.
3. Apply concepts of electricity and magnetism (such as fields, potential, charge conservation, static and dynamic induction) to simple circuits, motors, and other simple contrivances.
4. Apply simple geometric and wave optics in simple situations.
5. Test ideas using modern laboratory equipment.
6. Estimate experimental uncertainties.
7. Use computers to analyze and report laboratory results.
8. Draw appropriate conclusions from quantitative scientific observations.
9. Accurately and clearly communicate the results of scientific experiments.

PHYS 1125G. Physics of Music
4 Credits (3+2P)
Introduction for non-science majors to basic concepts, laws, and skills in physics, in the context of a study of sound, acoustics, and music.

Learning Outcomes

1. Demonstrate converting units and other aspects of dimensional analysis in the working of numerical problems.
2. Apply basic classical mechanics to static and dynamic fluids, including Archimedes'principle and Bernoulli's principle.
3. Apply the general properties of waves to simple models of musical instruments.
4. Demonstrate knowledge of basic operating principles of wind, string, and percussion instruments.
5. Demonstrate knowledge of how objectively measurable properties of sound waves correspond to the perceptions of pitch, loudness, and timbre.
6. Demonstrate understanding of the description of vibrations and waves in terms of Fourier's Theorem and normal modes.
7. Demonstrate understanding of vocalization in terms of physical principles such as resonance and fluid dynamics.
8. Demonstrate understanding of how the ear works.

PHYS 1230G. Algebra-Based Physics I
3 Credits (3)
An algebra-based treatment of Newtonian mechanics. Topics include kinematics and dynamics in one and two dimensions, conservation of energy and momentum, rotational motion, equilibrium, and fluids.

Learning Outcomes

1. Demonstrate converting units and other aspects of dimensional analysis in the working of numerical problems.
2. Apply principles of Newtonian mechanics to predict and account for simple phenomena modeled by the motion of particles in one and two dimensions.
3. Apply principles of Newtonian mechanics to predict and account for simple phenomena modeled by the motion of a rigid body in two dimensions.
4. Apply Newton's theory of gravitation to circular orbits and demonstrate understanding of how Kepler's laws of planetary motion provide the empirical foundation for Newton's theory.
5. Apply the mathematics of vectors to the principles of Newtonian mechanics.
6. Apply principles of Newtonian mechanics to the case of static and dynamic incompressible fluids, including Archimedes'and Bernoulli's principles.

PHYS 1230L. Algebra-Based Physics I Lab
1 Credit (1)
A series of laboratory experiments associated with the material presented in PHYS 1230G.
Prerequisite(s)/Corequisite(s): PHYS 1230G.

Learning Outcomes

1. Explain the scientific method.
2. Test ideas using modern laboratory equipment.
3. Estimate experimental uncertainties using statistical methods.
4. Use computers to analyze and report laboratory results.
5. Draw appropriate conclusions from quantitative scientific observations.
6. Accurately and clearly communicate the results of scientific experiments.

PHYS 1240G. Algebra-Based Physics II
3 Credits (3)
The second half of a two semester algebra-based introduction to Physics. This course covers electricity, magnetism and optics.
Prerequisite(s): a C- or better in PHYS 1230G or PHYS 2230G.

Learning Outcomes

1. Be able to state Coulomb's Law and Gauss's laws and apply them.
2. Apply the concepts of electric charge, electric field and electric potential to solve problems.
3. Analyze simple DC and AC circuits.
4. Apply the Lorentz force to solve problems.
5. Apply Faraday's law of induction (and Lenz's law) to solve problems.
6. Apply ray optics to practical lens systems such as microscopes and corrective lenses.
7. Apply the wave nature of light to the phenomena of reflection, refraction, and diffraction.

PHYS 1240L. Algebra-Based Physics II Lab
1 Credit (1)
A series of laboratory experiments associated with the material presented in PHYS 1240
Prerequisite(s)/Corequisite(s): PHYS 1240G.

Learning Outcomes

1. Explain the scientific method.
2. Test ideas using modern laboratory equipment.
3. Estimate experimental uncertainties using statistical methods.
4. Use computers to analyze and report laboratory results.
5. Draw appropriate conclusions from quantitative scientific observations.
6. Accurately and clearly communicate the results of scientific experiments.

PHYS 1310G. Calculus -Based Physics I
3 Credits (3)
A calculus level treatment of classical mechanics and waves, which is concerned with the physical motion concepts, forces, energy concepts, momentum, rotational motion, angular momentum, gravity, and static equilibrium.
Prerequisite: a C- or better in ENGR 190 or MATH 1511G or higher.
Learning Outcomes

1. Describe the relationships among position, velocity, and acceleration as functions of time.
2. Use the equations of kinematics to describe motion under constant acceleration.
3. Analyze linear motion using Newton's laws, force, and linear momentum.
4. Analyze rotational motion using torque and angular momentum.
5. Analyze motion using work and energy.

PHYS 1310L. Calculus -Based Physics I Lab
1 Credit (3P)
A series of laboratory experiments associated with the material presented in Calculus-based Physics I. Students will apply the principles and concepts highlighting the main objectives covered in coursework for Calculus-based Physics I.
Prerequisite(s)/Corequisite(s): PHYS 1310G.
Learning Outcomes

1. Develop a reasonable hypothesis.
2. Work effectively as part of a team.
3. Take measurements and record measured quantities to the appropriate precision.
4. Estimate error sources in experimental techniques.
5. Apply appropriate methods of analysis to raw data, including using graphical and statistical methods via computer-based tools.
6. Determine whether results and conclusions are reasonable.
7. Present experimental results in written form in appropriate style and depth.
8. Experience the relationship between theory and experiment.

PHYS 1311. Problems in Calculus-Based Physics I
0.5-1 Credits (.5-1)
This is a supplemental course for Calculus-based Physics I. May be repeated up to 1 credits.
Corequisite(s): PHYS 1310G.

PHYS 1320G. Calculus -Based Physics II
3 Credits (3)
A calculus level treatment of classical electricity and magnetism. It is strongly recommended that this course is taken at the same time as Calculus-based Physics II laboratory.
Prerequisite: a C- or better in (PHYS 2110 or PHYS 1310G) and (ENGR 190 or MATH 1521G or higher).

Learning Outcomes

1. Apply the concepts of electric charge, electric field and electric potential to solve problems.
2. Sketch the electric field in the vicinity of point, line, sheet, and spherical distributions of static electric charge.
3. Sketch the magnetic field in the vicinity of line, ring, sheet, and solenoid distributions of steady current.
4. Describe the relationship between electric field and electric potential.
5. Calculate the Lorentz force on a moving charge for simple geometries of the fields and use it to analyze the motion of charged particles.
6. Apply the integral forms of Maxwell's equations.
7. Calculate the energy of electromagnetic fields.
8. Analyze DC circuits.

PHYS 1320L. Calculus -Based Physics II Lab
1 Credit (3P)
A series of Laboratory experiments associated with the material presented in Calculus-Based Physics II. Students will apply the principles and concepts highlighting the main objectives covered in coursework for Calculus-Based Physics II.
Prerequisite(s)/Corequisite(s): PHYS 1320G. Prerequisite(s): A C- or better in PHYS 2110L or PHYS 1310L.
Learning Outcomes

1. Develop a reasonable hypothesis.
2. Work effectively as part of a team.
3. Take measurements and record measured quantities to the appropriate precision.
4. Estimate error sources in experimental techniques.
5. Apply appropriate methods of analysis to raw data, including using graphical and statistical methods via computer-based tools.
6. Determine whether results and conclusions are reasonable.
7. Present experimental results in written form in appropriate style and depth.
8. Experience the relationship between theory and experiment

PHYS 1321. Problems in Calculus-Based Physics II
0.5-1 Credits (.5-1)
This is a supplemental course for Calculus-based Physics II.
Corequisite(s): PHYS 1320G.

PHYS 2110. Mechanics
3 Credits (3)
Newtonian mechanics.
Prerequisite/Corequisite: MATH 1511G or higher.
Learning Outcomes

1. Describe matter as particles or extended objects, analyze forces or torques acting on it, and apply Newton's laws to determine if the object is in equilibrium or predict any change in the motion of such an object.
2. Apply vector algebra to predict motion or analyze interactions in one or two dimensions.
3. Apply techniques of conservation laws (linear momentum, energy, angular momentum) to determine the effect of interactions that are internal or external to the system studied.
4. Analyze systems in simple harmonic motion and explain qualitatively under what condition a driven oscillating system shows the phenomenon of resonance.

5. Use multiple representations to build, interpret and communicate a model, including visual representations such as sketches or diagrams, mathematical expressions, graphs, or text.
6. Given two or more cases, perform a ranking task by evaluating the similarities (comparison) or differences (contrast) in the cases and applying physics principles.
7. Self-check reasonableness of assumptions and solutions, making use of limiting cases or symmetry arguments.
8. Analyze real-world phenomena by defining and formulating the question or problem, constructing simplified idealized models(and stating their limitations), and applying appropriate mathematical reasoning to make predictions or explain a phenomenon or function.
9. Communicate effectively with audiences of different scientific backgrounds by recognizing their needs and making the communication relevant and impactful. 1
10. Work collegially and collaboratively in diverse teams both as a leader and as a member in pursuing a common goal.

PHYS 2110L. Experimental Mechanics
1 Credit (3P)
Laboratory experiments associated with the material presented in PHYS 2110. Science majors.
Prerequisite/Corequisite: PHYS 2110.
Learning Outcomes
1. Test scientific questions or ideas using appropriate laboratory equipment.
2. Collect experimental data and evaluate the outcomes of an experiment qualitatively and quantitatively.
3. Estimate measurement uncertainty.
4. Apply appropriate methods of analysis to raw data, including graphical or statistical methods, and computer-based tools.
5. Draw appropriate conclusions from quantitative scientific data.
6. Communicate the process and the outcomes of an experiment and reflect on possible revisions in the procedure.
7. Work effectively as part of a team.
8. Demonstrate professional responsibility.

PHYS 2111. Supplemental Instruction to PHYS 2110
1 Credit (1)
This Optional workshop as a supplement to PHYS 2110. The tutorial sessions focus on reasoning and hands-on problem solving. May be repeated up to 1 credit.
Corequisite: PHYS 2110.
Learning Outcomes
1. Analyze real world phenomena by constructing simplified idealized models and appropriate mathematical reasoning to make predictions or explain a phenomena or function.
2. Use multiple representations to build, interpret and communicate the model, including visual representations such as sketches or diagrams, mathematical expressions, graphs, or text.
3. In the contexts of concepts and physical laws discussed in PHYS 2110, apply quantitative analysis to solve problems, including the use of scientific notation, unit conversion and vector algebra.
4. Self-check reasonableness of assumptions and solutions, making use of limiting cases or symmetry arguments.
5. Develop learning strategies and use metacognition to promote thinking in the discipline.

PHYS 2120. Heat, Light, and Sound
3 Credits (3)
Calculus-level treatment of thermodynamics, geometrical and physical optics, and sound.
Prerequisite: a C- or better in PHYS 2110 or PHYS 1310G, and MATH 1511G or higher.
Learning Outcomes
1. Analyze real world phenomena that meet specific needs and use scientific judgement to draw conclusions.
2. Use multiple representations to build, interpret and communicate scientific models, including visual representations such as sketches or diagrams, mathematical expressions, graphs, or text.
3. Analyze oscillations and wave phenomena.
4. Analyze properties of sound waves.
5. Analyze properties of light using interference and diffraction.
6. Analyze light propagation through media using index of refraction and optical apparatus.
7. Analyze optical systems using light propagation.
8. Analyze the laws of thermodynamics and use them to describe processes in gases and other states of matter.

PHYS 2120L. Heat, Light, and Sound Laboratory
1 Credit (3P)
Laboratory experiments associated with the material presented in PHYS 2120. Science majors.
Prerequisite: a C- or better in PHYS 2110L or PHYS 1310L.
Prerequisite/Corequisite: PHYS 2120.
Learning Outcomes
1. Develop a reasonable hypothesis.
2. Work effectively as part of a team.
3. Take measurements and record measured quantities to the appropriate precision.
4. Estimate error sources in experimental techniques.
5. Apply appropriate methods of analysis to raw data, including using graphical and statistical methods via computer-based tools.
6. Determine whether results and conclusions are reasonable.
7. Present experimental results in written form in appropriate style and depth.
8. Understand the relationship between theory and experiment.

PHYS 2121. Supplemental Instruction to PHYS 2120
1 Credit (1)
This optional workshop supplements PHYS 2120 "Heat, Light, and Sound". Students actively apply concepts and methods introduced in PHYS 2120 to problem solving and quantitative analysis. May be repeated up to 1 credit.
Corequisite: PHYS 2120.
Learning Outcomes
1. Analyze real world phenomena by constructing simplified idealized models and appropriate mathematical reasoning to make predictions or explain a phenomena or function.
2. Use multiple representations to build, interpret and communicate the model, including visual representations such as sketches or diagrams, mathematical expressions, graphs, or text.
3. In the contexts of concepts and physical laws discussed in PHYS 2121, apply quantitative analysis to solve problems involving wave propagation and interference, geometric optics, heat transfer and thermodynamics.

4. Self-checkreasonableness of assumptions and solutions, making use of limiting cases or symmetry arguments.
5. Develop learning strategies and use metacognition to promote thinking in the discipline

PHYS 2140. Electricity and Magnetism
3 Credits (3)
Charges and matter, the electric field, Gauss law, the electric potential, the magnetic field, Ampere's law, Faraday's law, electric circuits, alternating currents, Maxwell's equations, and electromagnetic waves.
Prerequisite: a C- or better in PHYS 2110 or PHYS 1310G, and MATH 1511G or higher.
Prerequisite/Corequisite: MATH 1521G.
Learning Outcomes
1. Analyze real-world phenomena by deciding what information is relevant and constructing simplified idealized models and appropriate mathematical reasoning to make predictions or explain a phenomenon or function.
2. Use multiple representations to build, interpret and communicate the model, including visual representations such as sketches or diagrams, mathematical expressions, graphs, or text.
3. Use a physics problem-solving strategy: i. Identify relevant concepts. ii. Introduce and study simplified models. iii. Use symmetry arguments. iv. Establish the relation between known and unknown quantities. v. Calculate a quantitative result using appropriate mathematical methods. vi. Self-check reasonableness of assumptions and solutions.
4. Analyze/predict the interaction of charged particles, dipoles, or conductors with electric or magnetic fields. Apply concepts of force, work, or energy.
5. Describe sources of electric fields or magnetic fields and calculate field vectors for a point in space.
6. Apply Gauss's law to calculate electric fields for symmetric charge distributions or to determine surface charges on conductors in electrostatic equilibrium.
7. Apply Ampere's law and the Law of Biot-Savart to calculate magnetic fields.
8. Evaluate if magnetic flux changes and if an electric field or electric current is induced. Determine the direction of the induced current or the non-Coulomb electric field by applying Lenz's law. Apply Faraday's law to relate the rate of change of magnetic flux with the magnitude of emf induced.
9. Calculate and discuss properties of electric circuits (dc) with resistors, capacitors, and inductors applying Kirchhoff's rules or Ohm's law. 1
10. Discuss how the presence of a capacitor or an inductor modifies the behavior of a (dc) circuit and determine the time dependence of the current. 1
11. For a series RLC-circuit (or RC, LC, RL) with an ac-voltage source apply the concept of impedance or reactance to calculate the current through or voltages across each of the circuit elements, especially in the low-frequency limit, high-frequency limit, or at the resonant frequency.

PHYS 2140L. Electricity & Magnetism Laboratory
1 Credit (3P)
Laboratory experiments associated with the material presented in PHYS 2140.
Prerequisite: a C- or better in PHYS 2110 or PHYS 1310G.
Prerequisite/Corequisite: PHYS 2140.
Learning Outcomes
1. Develop a reasonable hypothesis.
2. Work effectively as part of a team.
3. Take measurements and record measured quantities to the appropriate precision.
4. Estimate error sources in experimental techniques.
5. Apply appropriate methods of analysis to raw data, including using graphical and statistical methods via computer-based tools.
6. Determine whether results and conclusions are reasonable.
7. Present experimental results in written form in appropriate style and depth.
8. Understand the relationship between theory and experiment.

PHYS 2141. Supplemental Instruction to PHYS 2140
1 Credit (1)
Optional workshop as a supplement to PHYS 2140. The tutorial sessions focus on reasoning and hands-on problem solving.
Corequisite: PHYS 2140.
Learning Outcomes
1. Analyze real-world phenomena by constructing simplified idealized models and appropriate mathematical reasoning to make predictions or explain a phenomenon or function.
2. Use multiple representations to build, interpret and communicate the model, including visual representations such as sketches or diagrams, mathematical expressions, graphs, or text.
3. In the contexts of concepts and physical laws discussed in PHYS 2140, apply quantitative analysis to solve problems, including the use of symmetry to study electric and magnetic fields. Practice concepts of calculus applied to charge and current distributions.
4. Self-check reasonableness of assumptions and solutions, making use of limiting cases or symmetry arguments.
5. Develop learning strategies and use metacognition to promote thinking in the discipline.

PHYS 2230G. General Physics for Life Science I
3 Credits (3)
This algebra-based introduction to general physics covers mechanics, waves, sound, and heat. Special emphasis is given to applications in the life sciences. This course is recommended for students in the life sciences and those preparing for the physics part of the MCAT.
Prerequisite: A C- or better in MATH 1220G or higher.
Learning Outcomes
1. Modeling: analyze real-world phenomena by deciding what information is relevant and constructing simplified idealized models and appropriate mathematical reasoning to make predictions or explain phenomena or function; use multiple representations to build, interpret and communicate the model,including visual representations such as sketches or diagrams, mathematical expressions, graphs, or text; critique assumptions and determine how to test the validity of a model and use the comparison of experimental data and prediction to refine the model.
2. Conceptual understanding: describe the motion of any object in terms of displacement, velocity, and acceleration; analyze external forces acting on an object and determine if a system is in equilibrium or relate the net force to changes in motion; predict or analyze motion using conservation laws for energy and momentum; analyze forces and torques fora rigid object in static equilibrium; for a static fluid determine pressure and the buoyant force; apply idealized models of fluid flow to the circulatory system; describe the properties of pressure waves known as sound, apply the model of standing waves

to musical instruments and discuss how sound is used to sense the environment; predict qualitative changes in the internal energy of a thermodynamic system when energy has been transferred due to work or heat and justify those predictions using conservation of energy (First law of thermodynamics). Identify which heat transfer processes occur in a described situation.
3. Quantitative reasoning: use a physics problem-solving strategy (Identify relevant concepts; Introduce and study simplified models; Use symmetry arguments; Establish the relation between known and unknown quantities; Calculate a quantitative result using appropriate mathematical methods; Self-check reasonableness of assumptions and solutions); use scientific notation accurately and convert units if necessary.
4. Communicating scientific information: interpret or generate graphs or other visual representations and be able to switch between various representations including text,mathematical description, or diagrams.

PHYS 2230L. Laboratory to General Physics for Life Science I
1 Credit (1)
Laboratory experiments in topics associated with material presented in PHYS 2230G.
Prerequisite(s)/Corequisite(s): PHYS 2230G. Restricted to Las Cruces campus only.

PHYS 2231. Supplemental Instruction to General Physics for Life Sciences I
1 Credit (1)
This optional workshop supplements Physics for Life Sciences I. The tutorial sessions focus on reasoning and hands-on problem solving.
Corequisite: PHYS 2230G.
Learning Outcomes
1. analyze real world phenomena by constructing simplified idealized models and appropriate mathematical reasoning to make predictions or explain a phenomena or function.
2. use multiple representations to build, interpret and communicate the model, including visual representations such as sketches or diagrams, mathematical expressions, graphs, or text.
3. in the contexts of concepts and physical laws discussed in PHYS 2230, apply quantitative analysis to solve problems, including the use of scientific notation, unit conversion and vector algebra.
4. self-check reasonableness of assumptions and solutions, making use of limiting cases or symmetry arguments.
5. develop learning strategies and use metacognition to promote thinking in the discipline.

PHYS 2240G. General Physics for Life Science II
3 Credits (3)
This algebra-based course covers electricity, magnetism, light, atomic physics, and radioactivity. Special emphasis is given to applications in the life sciences This course is recommended for students in the life sciences and those preparing for the physics part of the MCAT.
Prerequisite: a C- or better in PHYS 1230G or PHYS 2230G, and MATH 1220G or higher.
Learning Outcomes
1. Modeling: analyze real world phenomena by constructing simplified idealized models (an abstract description) that allow making predictions or explaining a phenomena or function; use multiple representations to build and communicate the model, including sketches, mathematical expressions, diagrams or graphs; decide what information is relevant and critique assumptions and models of others; determine how to test the validity of a model and use comparison of experimental data and prediction to refine the model.
2. Conceptual understanding: electric or magnetic fields can be used to describe interactions of objects that contain charges with their surroundings; changes that occur as a result of interactions are constrained by conservation laws (such as conservation of energy, conservation of charge or conservation of nucleon number); many macroscopic properties of materials can be described using microscopic models or related to their geometry; electromagnetic radiation can be modeled as a wave or as fundamental particles (photons); the direction of propagation of a wave may change when it encounters a boundary surface between two media of different properties (reflection or refraction); the spontaneous radioactive decay of nuclei is described by probability.
3. Quantitative reasoning: apply quantitative analysis and appropriate mathematical reasoning to describe or explain phenomena; use scientific notation accurately and convert units if necessary.
4. Communicating scientific information: interpretor generate graphs or other visual representations (e.g. field lines, equipotential lines) and be able to switch between various representations including text, mathematical description, or diagrams.

PHYS 2240L. Laboratory to General Physics for Life Science II
1 Credit (1)
Laboratory experiments in topics associated with material presented in PHYS 2240.
Prerequisite(s)/Corequisite(s): PHYS 2240G. Restricted to Las Cruces campus only.

PHYS 2241. Supplemental Instruction to General Physics for Life Sciences II
1 Credit (1)
This optional workshop is a supplement to Physics for Life Science II. The tutorial sessions focus on reasoning and hands-on problem solving. May be repeated up to 1 credits.
Corequisite(s): PHYS 2240G.
Learning Outcomes
1. analyze real world phenomena by constructing simplified idealized models and appropriate mathematical reasoning to make predictions or explain a phenomena or function.
2. use multiple representations to build, interpret and communicate the model, including visual representations such as sketches or diagrams, mathematical expressions, graphs, or text.
3. in the contexts of concepts and physical laws discussed in PHYS 2240, apply quantitative analysis to solve problems, including the use of scientific notation, unit conversion and vector algebra.
4. self-check reasonableness of assumptions and solutions, making use of limiting cases or symmetry arguments.
5. develop learning strategies and use metacognition to promote thinking in the discipline.

PHYS 2996. Special Topics
1,4 Credits
Topics to be announced in the Schedule of Classes. May be repeated up to 12 credits.
Learning Outcomes
1. Varies.

PHYS 2997. Independent Study
1-3 Credits
Individual analytical or laboratory studies directed by a faculty member. May be repeated for a maximum of 6 credits.

Prerequisite: consent of instructor.

Learning Outcomes

1. Varies

PHYS 303V. Energy and Society in the New Millennium
3 Credits (3)

Traditional and alternative sources of energy. Contemporary areas of concern such as the state of depletion of fossil fuels; nuclear energy, solar energy, and other energy sources; environmental effects; nuclear weapons; and health effects of radiation. Discussion of physical principles and impact on society. Focus on scientific questions involved in making decisions in these areas. No physics background required.

PHYS 304. Forensic Physics
4 Credits (3+3P)

Theories, laboratory, and field techniques in the area of forensic physics.

PHYS 305V. The Search for Water in the Solar System
3 Credits (3)

Examines the formation, abundance and ubiquity of water in our Solar System stemming from comets, Martian and Lunar poles, Earth's interior and into the outer reaches of the Solar System. Topics will include nuclear synthesis, Solar System formation, remote sensing, as well as past, present and future NASA missions for water.

Learning Outcomes

1. Learn how to apply scientific reasoning for understanding the evolution of the universe.
2. Learn the location of possible water resources in the solar system and beyond.
3. Learn how to use remote sensing to identify water in distant stellar objects and their atmospheres.
4. Acquire the ability to apply knowledge of mathematics, science and applied sciences (scientific expertise).
5. Recognize the need for an ability to engage in life-long learning (Life-long learning).

PHYS 315. Modern Physics
3 Credits (3)

An introduction to relativity and quantum mechanics, with applications to atoms molecules, solids, nuclei, and elementary particles.
Prerequisite: a C- or better in MATH 2530G and PHYS 2140 or PHYS 1320G.

Learning Outcomes

1. Communication: an ability to communicate effectively with a range of audiences.
2. Ethical and Professional Responsibilities: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
3. Ability to learn on your own: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

PHYS 316. Supplemental Instructions to PHYS 315
1 Credit (1)

This optional workshop supplements PHYS 315 "Modern Physics". Students actively apply concepts and methods introduced in PHYS 315 to problem solving and quantitative analysis.
Corequisite(s): PHYS 315.

PHYS 325. Intermediate Experimental Physics
3 Credits (1+6P)

An exploration of a variety of experimental techniques in physics with an emphasis on the proper determination of statistical and systematic uncertainties. Students will work in teams and prepare professional written and oral reports of their work. This course cannot be used to replace M E 345 for students majoring in engineering.
Prerequisite(s)/Corequisite(s): PHYS 315. Prerequisite(s): a C- or better in PHYS 2140L or PHYS 1320L.

Learning Outcomes

1. Design within constraints: an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
2. Communication: an ability to communicate effectively with a range of audiences.
3. Ethical and Professional Responsibilities: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
4. Teamwork: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
5. Collect, Analyze, and Interpret Data: an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

PHYS 350. Special Topics
1-3 Credits

Lectures, demonstrations, and discussions on such topics as lasers and holography, energy sources, clouds, and biophysics. May be repeated for a maximum of 12 credits under different subtitles.

PHYS 380. Individual Study
1-3 Credits

Individual analytical or laboratory studies directed by a faculty member. May be repeated for a maximum of 6 credits.
Prerequisite: consent of instructor.

PHYS 395. Intermediate Mathematical Methods of Physics
3 Credits (3)

Introduction to the mathematics used in intermediate-level physics courses. Topics include vector calculus, curvilinear coordinates, matrices, linear algebra, function spaces, partial differential equations, and special functions. This course cannot be used to replace M E 228 or M E 328 for students majoring in engineering. May be repeated up to 3 credits.
Prerequisite(s)/Corequisite(s): MATH 3160. Prerequisite(s): a C- or better in MATH 2530G.

Learning Outcomes

1. Problem solving: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. Ability to learn on your own: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

PHYS 400. Undergraduate Research
1-3 Credits

May be repeated for a maximum of 6 credits.
Prerequisite: consent of instructor.

PHYS 420. Capstone Project I
3 Credits (3P)

Application of engineering physics principles to a significant design project. Includes teamwork, written and oral communication and realistic technical, economic and public safety requirements.

PHYS 421. Capstone Project II
3 Credits (3P)
Continuation of PHYS 420.

PHYS 450. Selected Topics
1-3 Credits
Readings, lectures or laboratory studies in selected areas of physics. May be repeated for a maximum of 12 credits.

PHYS 451. Intermediate Mechanics I
3 Credits (3)
Newtonian mechanics, including an introduction to the Lagrangian formulation. Topics include central force motion, rigid body motion, noninertial reference frames, oscillating systems, and classical scattering.
Prerequisite(s)/Corequisite(s): MATH 3160. Prerequisite(s): a C- or better in PHYS 2110 or PHYS 1310G, and MATH 2530G.
Learning Outcomes

1. Set up equations of motion for classical mechanical systems and solve them.
2. Identify conserved quantities and understand the circumstances under which they arise (symmetries); in particular, know how to use conservation of energy, momentum, angular momentum to solve problems.
3. Fluently use three-dimensional calculus as a language to do the above; be able to use spherical and cylindrical coordinates.
4. Understand the paradigmatic examples of the harmonic oscillator, central force (in particular, gravitational) motion and rigid body motion, which serve as starting points for investigating more complicated realistic problems.

PHYS 454. Intermediate Modern Physics I
3 Credits (3)
Introduction to quantum mechanics, focusing on the role of angular momentum and symmetries, with application to many atomic and subatomic systems. Specific topics include intrinsic spin, matrix representation of wave functions and observables, time evolution, and motion in one dimension.
Prerequisite: a C- or better in PHYS 315.
Prerequisite/Corequisite: MATH 3160 and PHYS 395.
Learning Outcomes

1. Problem solving: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. Ability to learn on your own: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

PHYS 455. Intermediate Modern Physics II
3 Credits (3)
Continuation of subject matter of PHYS 454. Specific topics include rotation and translation in three dimensions, solution of central potential problems, perturbation theory, physics of identical particles, scattering theory, and the interaction between photons and atoms.
Prerequisite: a C- or better in PHYS 454, MATH 3160, and PHYS 395.
Learning Outcomes

1. Problem solving: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. Ability to learn on your own: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

PHYS 461. Intermediate Electricity and Magnetism I
3 Credits (3)
The first part of a two-course sequence in classical electrodynamics. Covered topics include static electric and magnetic fields, Laplace's and Poisson's equations, electromagnetic work and energy, Lorentz force, Gauss's, Biot-Savart, and Ampere's laws, Maxwell's equations, as well as electric and magnetic fields in matter.
Prerequisite: a C- or better in PHYS 2140 or PHYS 1320G or equivalent and a C- or better in MATH 2530G.
Prerequisite/Corequisite: MATH 3160 and PHYS 395.
Learning Outcomes

1. Problem solving: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. Ability to learn on your own: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

PHYS 462. Intermediate Electricity and Magnetism II
3 Credits (3)
Continuation of subject matter of PHYS 461. Covered topics include Maxwell's equations and their applications, electromagnetic waves, reflection, refraction, dispersion, radiating systems, interference and diffraction, as well as Lorentz transformations and relativistic electrodynamics.
Prerequisite: a C- or better in PHYS 461, MATH 3160, and PHYS 395.
Learning Outcomes

1. Problem solving: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. Ability to learn on your own: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

PHYS 468. Intermediate X-ray Diffraction
3 Credits (3)
Introduction to x-ray diffraction and reflectivity spectra. Topics include X-ray sources and detectors, atomic spectra, characteristic x-rays, thermionic emission, synchrotron radiation, instrument components, and beam conditioners. Prerequisite(s): a C- or better in PHYS 315 and PHYS 325
Learning Outcomes

1. Knowledge of structural properties of materials
2. Experimental x-ray characterization techniques
3. Presentation and writing skills in the discipline
4. Ethics, teamwork, and career opportunities

PHYS 471. Modern Experimental Optics
3 Credits (1+6P)
Cumulative experience course in experimental optics.
Prerequisite: a C- or better in PHYS 315 and PHYS 325.
Learning Outcomes

1. Design within constraints: an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
2. Communication: an ability to communicate effectively with a range of audiences.
3. Ethical and professional responsibilities: an ability to recognize ethical and professional responsibilities in engineering situations

and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
4. Teamwork: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
5. Collect, analyze, and interpret data: an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

PHYS 475. Advanced Laboratory Practices for Materials
3 Credits (1+6P)
Cumulative experience course in advanced laboratory practices involving experiments in atomic, molecular, and condensed matter physics.
Prerequisite: a C- or better in PHYS 315 and PHYS 325.
Learning Outcomes
1. Design within constraints: an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
2. Communication: an ability to communicate effectively with a range of audiences.
3. Ethical and Professional Responsibilities: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
4. Teamwork: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
5. Collect, Analyze, and Interpret Data: an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

PHYS 476. Computational Physics
3 Credits (3)
Scientific visualization, numerical differentiation and interpolation, numerical integration, root finding, linear algebra, eigensystems, ODE's, Boundary value problems, PDE's, Monte-Carlo calculations, data description and analysis, Fast Fourier Transforms, and applications to advanced physics problems. Recommended is the knowledge of a programming language.
Prerequisite: a C- or better in PHYS 1111 or equivalent and MATH 3160.
Learning Outcomes
1. learn how to use computers for solving problems in the physical sciences,
2. obtain skills to implement numerical simulation and modeling strategies,
3. learn how to monitor and analyze data graphically, during and after computation,
4. obtain workflow organization skills needed for the solution of complicated systems.

PHYS 480. Thermodynamics
3 Credits (3)
Thermodynamics and statistical mechanics. Basic concepts of temperature, heat, entropy, equilibrium, reversible and irreversible processes. Applications to solids, liquids, and gases.
Prerequisite: a C- or better in PHYS 2120, PHYS 315, and MATH 2530G.
Learning Outcomes
1. Problem solving: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. Ability to learn on your own: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

PHYS 485. Independent Study
1-3 Credits
Individual analytical or laboratory studies directed by a faculty member. May be repeated for a maximum of 6 credits.
Prerequisite: consent of instructor.

PHYS 488. Introduction to Condensed Matter Physics
3 Credits (3)
Crystal structure, X-ray diffraction, energy band theory, phonons, cohesive energy, conductivities, specific heats, p-n junctions, defects, surfaces, and magnetic, optical, and low-temperature properties.
Prerequisite: a C- or better in PHYS 315.
Learning Outcomes
1. Learn the fundamental concepts of solid-state physics: classification of solids, crystal structure, band structure of solids, lattice vibrations, optical and magnetic properties of solids.
2. Develop an ability to formulate and solve complex problems in solid state physics by applying the fundamental principles of physics and mathematics.
3. Develop and ability to acquire and apply new knowledge using appropriate learning strategies.

PHYS 489. Introduction to Modern Materials
3 Credits (3)
Structure and mechanical, thermal, electric, and magnetic properties of materials. Modern experimental techniques for the study of material properties.
Prerequisite: a C- or better in PHYS 315.
Learning Outcomes
1. Learn the fundamental concepts of the physics of modern materials, such as crystal structure, properties of materials, and experimental techniques.
2. Develop an ability to formulate and solve complex problems in the area of physics of modern materials by applying the principles of physics and mathematics.
3. Develop an ability to acquire and apply new knowledge using appropriate learning strategies.

PHYS 493. Experimental Nuclear Physics
3 Credits (1+6P)
Cumulative experience course in nuclear physics such as measurement of radioactivity, absorption of radiation, nuclear spectrometry.
Prerequisite: a C- or better in PHYS 315 and PHYS 325.
Learning Outcomes
1. Design within constraints: an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
2. Communications: an ability to communicate effectively with a range of audiences.
3. Ethical and professional responsibilities: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

4. Teamwork: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
5. Collect, analyze, and interpret data: an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

PHYS 495. Mathematical Methods of Physics I
3 Credits (3)
Applications of mathematics to experimental and theoretical physics. Topics include vector analysis, Fourier series and transforms, Green's functions, special functions, complex variables, tensor algebra and analysis.
Prerequisite: a C- or better in MATH 3160 and PHYS 395.

Learning Outcomes

1. Deploy the tools of vector analysis and expansion into complete sets of functions to treat problems arising, e.g., in electrodynamics.
2. Understand the elements of functional analysis underpinning, e.g., quantum mechanics, such as representations, operators and their inverses and spectra.
3. Evaluate integrals of analytic functions using the calculus of residues.
4. Take advantage of the transformation behavior, under symmetry operations, of representations of physical quantities, by casting physical relations in tensor language.

PHYS 500. Special Topics Seminar
1-2 Credits
Treatment of topics not covered by regular courses. Graded S/U. May be repeated.

PHYS 511. Mathematical Methods of Physics I
3 Credits (3)
Applications of mathematics to experimental and theoretical physics. Topics include vector analysis, Fourier series and transforms, Green's functions, special functions, complex variables, tensor algebra and analysis.

Learning Outcomes

1. Deploy the tools of vector analysis and expansion into complete sets of functions to treat problems arising, e.g., in electrodynamics.
2. Understand the elements of functional analysis underpinning, e.g., quantum mechanics, such as representations, operators and their inverses and spectra.
3. Evaluate integrals of analytic functions using the calculus of residues.
4. Take advantage of the transformation behavior, under symmetry operations, of representations of physical quantities, by casting physical relations in tensor language.

PHYS 520. Selected Topics
1-3 Credits
This is a lecture/laboratory course designed to present the basic concepts, the techniques and the tools to synthesize and characterize nanometer scale materials, and the latest achievements in current and future nanotechnology applications in engineering, materials, physics, chemistry, biology, electronics and energy. It is intended for a multidisciplinary audience with a variety of backgrounds. This course should be suitable for graduate students as well as advanced undergraduates. Topics covered will include: nanoscience and nanotechnology, nanofabrication, self-assembly, colloidal chemistry, sol-gel, carbon nanotubes, graphene, thin film, lithography, physical vapor deposition, chemical vapor deposition, quantum dots, lithium batteries, X-ray diffraction, scanning electron microscopy, transmission electron microscopy, nanoelectronics, nanophotonics and nanomagnetics, etc. Students must also have completed (EH&S Safety training to include the courses: (1) Employee & Hazard Communication Safety (HazCom); (2) Hazardous Waste Management; and (3) Laboratory Standard) trainings to enroll. Crosslisted with: CHME 467 . May be repeated up to 3 credits.
Prerequisite: (CHEM 1226 or CHEM 1215G), (PHYS 1230G or PHYS 1310G).

PHYS 521. Individual Study
1-3 Credits
Individual analytical or laboratory studies directed by a faculty member. May be repeated for a maximum of 6 credits.
Prerequisites: graduate standing, consent of instructor, and selection of a specific topic prior to registration.

PHYS 528. Fundamentals of Photonics
4 Credits (3+3P)
Ray, wave and guided optics, lasers and thermal sources, radiometry, photon detection and signal-to-noise ratio. Elements of photonic crystals, polarization, acousto-optics, electro-optics, and optical nanostructures. Recommended foundation (PHYS 1320G or PHYS2120) and (E E 473 or PHYS 473), Taught with E E 478. Crosslisted with E E 528.

Learning Outcomes

1. Describe the fundamental properties of light.
2. Formulate the concepts of ray, wave, and photon optics mathematically.
3. Represent and incorporate basic elements of an optical system.
4. Perform an analysis of a simple photonic/optical system mathematically by hand and with computer tools such as MATLAB.
5. Discuss ethical, societal, and professional issues related to photonics and optics.

PHYS 551. Classical Mechanics
3 Credits (3)
Lagrangian and Hamiltonian formulation of dynamics. Advanced treatments of most topics listed under PHYS 451, plus canonical transformations and Hamilton-Jacobi theory. PHYS 451 strongly recommended.

PHYS 554. Quantum Mechanics I
3 Credits (3)
Wave function, indeterminacy, classical limit. Schrodinger equation. Atomic and nuclear systems. Angular momentum, intrinsic spin, identical particles. Scattering theory. Mathematical formalism, symmetry and conserved quantities. Perturbation theory. Dirac theory, introduction to quantized fields. PHYS 451 and PHYS 454 strongly recommended.

PHYS 555. Quantum Mechanics II
3 Credits (3)
Continuation of topics in PHYS 554.
Prerequisites: PHYS 554 or consent of instructor.

PHYS 561. Electromagnetic Theory I
3 Credits (3)
Detailed advanced treatments of most topics listed under PHYS 461, PHYS 462, plus multipole radiation, collisions of charged particles and bremsstrahlung, scattering, and radiation reaction. PHYS 461 and PHYS 462 strongly recommended.

PHYS 562. Electromagnetic Theory II
3 Credits (3)
Continuation of topics in PHYS 561.
Prerequisites: PHYS 561 or consent of instructor.

PHYS 568. Elements of X-ray Diffraction
3 Credits (3)
Same as PHYS 468, but additional work required. Crosslisted with: CHME 588.

PHYS 571. Advanced Experimental Optics
3 Credits (1+6P)
Taught with PHYS 471 with additional work required at the graduate level.

Learning Outcomes

1. Design within constraints: an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
2. Communication: an ability to communicate effectively with a range of audiences.
3. Ethical and professional responsibilities: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
4. Teamwork: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
5. Collect, analyze, and interpret data: an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

PHYS 575. Advanced Physics Laboratory
3 Credits (1+6P)
Selected experiments in atomic, molecular, nuclear and condensed-matter physics.

Learning Outcomes

1. Design within constraints: an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
2. Communication: an ability to communicate effectively with a range of audiences.
3. Ethical and Professional Responsibilities: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
4. Teamwork: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
5. Collect, analyze, and interpret data: an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

PHYS 576. Advanced Computational Physics I
3 Credits (3)
Advanced treatment of topics listed under PHYS 476 plus additional work. Applications of numerical methods to advanced physics problems. Recommended is the knowledge of a programming language.

Learning Outcomes

1. learn to numerically solve problems that require higher mathematical and theoretical analysis,
2. experience how graduate research will be advanced and accelerated by the use of scientific computing skills.

PHYS 584. Statistical Mechanics
3 Credits (3)
Thermodynamics review. Probability, entropy, equilibrium. Canonical and grand canonical ensembles. Classical and quantum statistics. Degenerate and classical gases. Application to the equilibrium properties of solids, liquids, and gases. Kinetic theory and transport processes.

PHYS 589. Modern Materials
3 Credits (3)
Same as PHYS 489 with differentiated assignments for graduate students. PHYS 554 recommended.

Learning Outcomes

1. Learn the fundamental concepts of the physics of modern materials, such as crystal structure, properties of materials, and experimental techniques.
2. Develop an ability to formulate and solve complex problems in the area of physics of modern materials by applying the principles of physics and mathematics.
3. Develop an ability to acquire and apply new knowledge using appropriate learning strategies.

PHYS 591. Advanced High-Energy Physics I
3 Credits (3)
Taught with PHYS 491 with additional work required at the graduate level.
Prerequisite(s): PHYS 555 or consent of instructor.

PHYS 593. Advanced Experimental Nuclear Physics
3 Credits (1+6P)
Advanced experimental investigation of topics such as measurement of radioactivity, absorption of radiation, and nuclear spectrometry.

Learning Outcomes

1. Design within constraints: an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
2. Communication: an ability to communicate effectively with a range of audiences.
3. Ethical and Professional Responsibilities: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
4. Teamwork: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
5. Collect, analyze, and interpret data: an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

PHYS 597. Space Plasma Physics
3 Credits (3)
Same as PHYS 497 but with added requirements.

PHYS 599. Master's Thesis
1-15 Credits (1-15)
Thesis.

PHYS 600. Research
1-15 Credits

Doctoral research. May be repeated.

PHYS 620. Advanced Topics in Physics
1-3 Credits
Advanced formal treatment of topics not covered in regular courses. May be repeated for a maximum of 9 credits.
Prerequisite: consent of instructor.

PHYS 650. General Relativity I
3 Credits (3)
Basic foundations and principles of general relativity, derivation of the Einstein field equations and their consequences, the linearized theory, the Bel-Petrov classification of the curvature tensor, derivation of the Schwarzschild solution and the four basic tests of general relativity.
Prerequisite(s): PHYS 511 or PHYS 561 or consent of instructor.

PHYS 680. Independent Study
1-3 Credits
Individual analytical or laboratory studies directed by a faculty member. May be repeated for a maximum of 6 credits.
Prerequisite: graduate standing or consent of instructor.

PHYS 688. Advanced Condensed Matter Physics
3 Credits (3)
Continuation of the advanced condensed matter physics presented in PHYS 588. Topics include electronic structure methods, optical, magnetic, and transport properties of solids, semiconductors, crystalline defects, nanostructures, and noncrystalline solids. PHYS 588 strongly recommended.

Learning Outcomes

1. Learn the fundamental concepts of advanced condensed state physics: band theory of solids, electronic structure methods, optical and magnetic properties of solids, bulk semiconductors, and properties of nano-structured materials.
2. Develop an ability to formulate and solve complex problems in advanced condensed matter physics.
3. Develop an ability to to study independently and acquire new knowledge using appropriate learning strategies.

PHYS 689. Advanced Modern Materials
3 Credits (3)
Advanced topics in the physics of modern materials, such as crystalline, amorphous, polymeric, nanocrystalline, layered, and composite materials and their surfaces and interfaces. PHYS 555, PHYS 588, and PHYS 589 recommended.

Learning Outcomes

1. Learn the fundamental concepts of the physics of modern materials, such as crystalline, amorphous, polymeric, nanostructured, layered, and composite materials.
2. Develop an ability to formulate and solve complex problems in the area of advanced physics of modern materials.
3. Develop an ability to to study independently and acquire new knowledge using appropriate learning strategies.

PHYS 691. Quantum Field Theory I
3 Credits (3)
Path integrals, gauge invariance, relativistic quantum mechanics, canonical quantization, relativistic quantum field theory, introduction to QED.
Prerequisites: PHYS 555 and PHYS 562, or consent of instructor.

PHYS 692. Quantum Field Theory II
3 Credits (3)
QED, running coupling constant, QCD, electroweak theory, asymptotic freedom, deep inelastic scattering, basic QCD phenomenology, path integrals in quantum field theory, lattice QCD.
Prerequisite: PHYS 691 or consent of instructor.

PHYS 700. Doctoral Dissertation
1-15 Credits (1-15)
Dissertation.

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