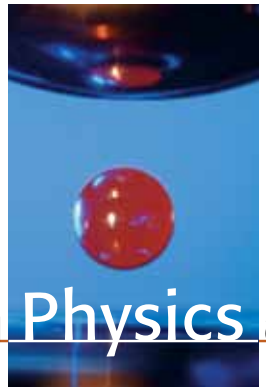
Undergraduate

Physics

Washington University in St. Louis



Studying Physics at Washington University

If you have a strong interest in the sciences, you will want to consider physics as a major. As the most fundamental of all the sciences, physics will lead you to a deeply fulfilling and rewarding undergraduate experience. Not only will a physics major provide you with the skills to excel in a professional career in scientific research and/or teaching, you can also apply your studies to a surprising variety of occupations. Physics majors from our department have seen rewarding lifelong careers in science, medicine, law, engineering, computer science, and business, among other professions. Washington University's strong biophysics and neurophysics programs can play an important role in premedical studies, and the opportunities for double majors assure that you can integrate other subjects you are passionate about into your course of study. Graduates of our department have been accepted into graduate school at every top university in the country, including our own.

Above: a 2.5-mm diameter sphere of liquid titanium-zirconium-nickel alloy at a temperature of over 800° C. Electrostatic forces are used to levitate the sphere in high vacuum between the electrodes at the top and bottom, for studies of crystalline growth.

On cover: Professor Mark Conradi explains quantum mechanical transitions in a two-level system to students in the quantum mechanics course.

Washington University's Department of Physics has a rich history that includes the fundamental X-ray scattering experiment of Nobel Prize-winner Arthur Holly Compton, as well as pioneering research in and major contributions to gravitational theory, nuclear magnetic resonance (NMR), quantum field theory, ultrasonics, superconductivity, cosmic rays, and quantum control. The American Physical Society has even named the department one of the five historic physics sites in the United States. Today, the department continues innovations in those areas, as well as in nanoparticles, broad areas of condensed-matter physics, high-energy astrophysics, biophysics, supercomputing, quark matter, and much more.

The department's 39 teaching and research faculty members enjoy facilities spread out over more than 100,000 square feet in Crow Hall, Compton Laboratory, and the Power House. As an undergraduate, you can work closely with the department's distinguished faculty members and attain significant research experience. Furthermore, you will be part of a supportive community of students, faculty, and staff that continue to learn from one another in and out of the classroom.

Ariel Leonard, '11 | Bethesda, Maryland
Physics Major.

"The physics department is such a welcoming environment. As a physics major I have met some amazing fellow students and have time after time come across professors who share the same wonderful qualities: a sincere eagerness to teach and a desire to make learning physics a fun experience."

"The physics majors form a community that is truly unique."

"Being a physics major at Washington University is such a rewarding experience. The material is fascinating, and the professors excellent. The physics majors form a sense of community that is truly unique. I love being a part of this group, and of course SPS—the school physics club."

Marieke Jager, '12 | Anchorage, Alaska
Physics major

Majoring in Physics

Your first two years are largely dedicated to building a firm foundation that will permit you to focus your advanced studies toward specific personal goals.

Whether you intend to pursue a career based on experiments and applications, on teaching and theoretical discovery, or outside of science, you will find the Department of Physics offers you the flexibility to shape your future. Interested students begin by taking Physics 197—a new, active-learning, discussion-based, problem-oriented introductory course that incorporates all of the major themes of contemporary physics.

As a physics major (or minor), you will have the opportunity to gain invaluable research experience as you prepare for your career or advanced study. The research areas in which undergraduates can play a *substantial* role include theoretical and observational astrophysics, mathematical physics, elementary particles and many-body systems, materials, solid state, high pressure, and ultrasonic physics, biophysics, and neurophysics—to name a few!

The Double Major: If you have a comparable dedication to another area of study, you can explore a double major in physics and another subject. Second majors that physics students have pursued include chemical and electrical engineering, computer science, biology and chemistry, history, English, mathematics, foreign languages, and philosophy.

The Department of Physics

Research is divided into four primary areas, with a variety of subgroups in each area.

ASTROPHYSICS AND SPACE SCIENCE: As part of the McDonnell Center for the Space Sciences, members of the physics department explore the origin of cosmic rays, energetic processes in galactic and extra-galactic objects, the properties of matter and spacetime near black holes, phase transitions inside neutron stars, the search for dark matter, the synthesis of heavy elements in nature, the formation of dust around stars, and the history of the lunar surface and of meteorites.

High Energy Astrophysics: Students work with, and sometimes design and build, instruments that are flown on spacecraft and high-altitude balloons or are used at ground-based observatories to detect cosmic-ray nuclei, gamma rays, and X-rays.

Extraterrestrial Materials: Three different types of materials are studied: meteorites, interplanetary dust from comets and asteroids, and lunar samples.

An array of telescopes for TeV gamma-ray detection, built by the VERITAS consortium, of which Washington University is a strong part

Physicists Make a Difference in the World

Physicists have impacted our lives in fundamental and everyday ways, from space exploration to laying the foundation of modern electronics and computers. NMR imaging, or MRI, a standard diagnostic tool in hospitals, was derived from physicists' techniques for studying nuclear and atomic structure. One of our professors, James G. Miller, has contributed significantly to the technology used in medical cardiac ultrasound. The Global Positioning System uses atomic clocks developed by physicists, as well as Einstein's relativity theory (and Cliff Will, another of our professors, was part of the team that incorporated relativity into the GPS). The World Wide Web was developed by particle physicists at CERN (the European Organization for Nuclear Research) who needed a way to transmit data from accelerators to the home universities of the researchers. And the structure of DNA was co-discovered by a physicist.

One of the exciting things about physics is its unpredictability: Most new discoveries are unexpected. And the "basic" physics discoveries of one generation often have prodigious practical consequences in the next—as a Washington University physics major you will be part of this exciting continuum.

Directed assembly of ordered Co "dots" for nanotechnology applications. Each dot is around 70 nanometers across.

Gravitational Physics: Studies the observable aspects of general relativity, including gravitational waves.

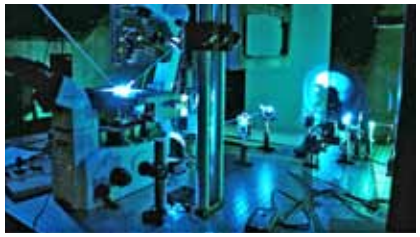
Theoretical Astrophysics: Uses the fundamental laws of physics, ranging from particle physics to gravitational theory, to investigate observable astronomical phenomena.

CONDENSED MATTER AND MATERIALS PHYSICS: This area includes the Laboratory for Magnetic Resonance, the Laboratory for High-Pressure Physics, the Laboratory for Materials Physics, and the recently established Center for Materials Innovation.

Quasicrystals and Metallic Materials: Explores nucleation and growth processes in condensed phases, relations between liquid structures and the nucleation barrier, formation of metallic glasses, and their crystallization to consolidated nanostructured materials.

Magnetic Resonance: The study of magnetic resonance can be used to explore the structure and atomic motions of solids and liquids. Nuclear magnetic resonance is an ideal tool for the study of metal-hydrides, potentially important in the storage of hydrogen fuel for clean-burning automobiles and buses of the future.

High-Pressure Superconductors: Studies of the superconducting and magnetic properties of matter under variation of the lattice parameters allow a quantitative comparison with theoretical predictions.



Professor Wang has developed a new molecular imaging method using the laser system above, for single-particle tracking in biological systems. Her group aims at a better understanding of biological mechanisms at the level of single molecules by the investigation of protein-nonspecific DNA interactions at the base-pair level.

Thin Film Physics: A major research area of this group is the manipulation of atoms during the deposition of thin films and nanostructures (image on preceding page).

Materials Physics: Researches the fabrication, characterization, and application of new materials. The recently established Center for Materials Innovation allows collaborators from across the University to make basic and applied advances in materials research such as nanosynthesis, magnetics, and biomedical materials.

Microstructure and Electronic Structure: Uses the transmission electron microscope with its electron-energy-loss and energy-dispersive X-ray spectrometers to investigate a wide variety of materials.

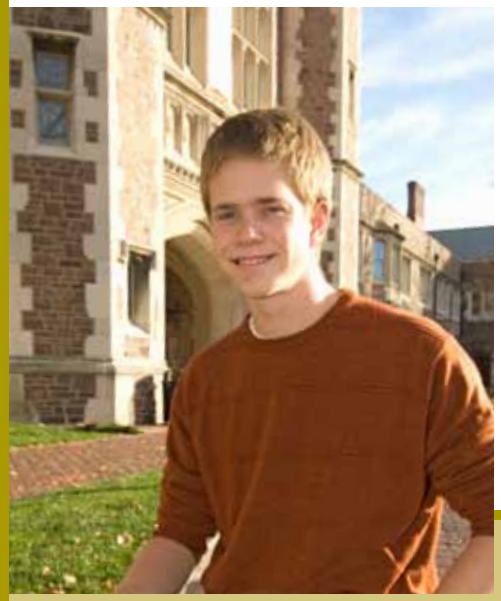
BIOLOGICAL AND BIOMEDICAL PHYSICS: Several experimental research groups work at the interface between physics and biology or medicine. Many of these programs involve active collaboration with research and clinical faculty at Washington University's renowned School of Medicine.

"Ever since I can remember, I have wanted to be an astronaut. The Department of Physics here at Washington University is helping me realize this dream. My four-year advisor has provided wonderful guidance and insight, and all of my physics classes have both interested and challenged me."

Michael Ingber, '12 | Owings Mills, Maryland
Physics major

Ultrasonics: Explores the physics underpinning echocardiographic imaging as a step toward characterizing normal and diseased hearts.

Magnetic Resonance Imaging: Develops techniques for magnetic resonance imaging of human lung ventilation and structure with "hyperpolarized" gases, or noble gases with high, nonequilibrium magnetizations. Recent collaborations are attempting to help and improve the diagnosis and treatment of lung diseases such as asthma and emphysema.



Dan Cole, '12 | Wilton, Connecticut
Physics major

"One of the greatest aspects of my experience as a physics major has been the professors. Their passion for physics really comes through in their teaching, and I can tell that they are eager to pass that passion on. When I first came to Washington University, I hadn't made up my mind about my major, and it was Professor Bernatowicz's enthusiasm in my introductory physics course that helped me make my decision."

Neurophysics: The brain computes! Any brain takes incoming sensory data, encodes them into biophysical variables, and subsequently performs a number of operations on these variables to extract and interpret relevant features of the input. This group focuses on one specific question: What are the biophysical mechanisms responsible for the computation of visual motion?

Theoretical Biophysics: Examines neural systems as complex statistical and dynamical networks; researches the biophysics of cell motion using computational and analytic methods.

HIGH ENERGY AND NUCLEAR PHYSICS: In addition to the study of nuclear structure and dynamics, research in this area concentrates on topics in quantum field theory, including lattice gauge theory, chiral symmetry breaking, properties of quark matter, and applications of quantum field theory to address problems in fundamental physics, statistical mechanics, and phase transitions.

Lattice Gauge Theory: Calculates fundamental properties of the strong interactions between elementary particles, which can lead to stringent tests of the standard model of particle physics and thereby point the way to new fundamental physical laws.

Quark Matter: Quark matter is the densest form of matter our current theories can describe and is conjectured to exist in the core of neutron stars. One major area of focus is "color superconductivity," where quarks pair up and form a state analogous to that formed by electrons in superconducting metals.

Quantum Field Theory: Complex quantum mechanics is used to examine the nature of antiparticles, offering the possibility that a particle and its corresponding antiparticle need not have identical masses. It also provides a setting for exploring the physics of the Higgs particle and the origin of mass.

Quantum-Mechanical Many-Body Theory: Explores the properties of strongly interacting quantum many-particle systems under realistic conditions of interaction, density, and temperature. The diverse target systems of this research activity include atomic nuclei, nuclear and neutron-star matter, hyper-nuclei, and strongly correlated quantum fluids and electron systems.

Nuclear Physics: Focuses on reaction mechanisms involving heavy ions that reveal fundamental properties of nuclei, as well as the behavior of nuclei under cosmic-ray bombardment.

Depiction of a neutron star, with a possible quark matter core. Professor Alford's group performs calculations of the properties of quark matter and searches for signatures of the presence of quark matter in neutron stars.

What Can You Do with a Bachelor's Degree in Physics?

An undergraduate degree in physics provides you with skills to pursue a wide variety of careers. Many people continue to explore physics as they go on to complete master's or Ph.D. degrees. Physics bachelor's degree graduates who choose to go directly into full-time employment readily find jobs in industry, with very competitive starting salaries. Five years after obtaining their degrees, Washington University physics graduates have careers in diverse fields, from top-level physics research to the software industry to management, medicine, law, finance, education, and the government. Our programs are designed to give you, in addition to the fundamentals of physics, a broad range of skills in laboratory techniques, critical thinking, computer use, and teamwork, which will serve you well in any chosen career.

Professor Ken Kelton works with undergraduate physics major Austin Hope on structural studies of supercooled high temperature liquids using a novel electrostatic levitation technique.

"We have designed a physics curriculum that gives students the broadest possible exposure to key topics and problems in classical and modern physics, while also providing opportunities to participate in cutting-edge research outside of the classroom. We want students to be able to be actively engaged with physics at all levels, from uncovering the complexity of familiar phases such as liquids and glasses, to participating in the design of a superconducting magnet, and ultimately experiencing the thrill of discovering something new about the universe that we inhabit. I believe that this is the best way for students to develop a passion for physics, to see it not simply as a collection of mathematical formulas but as a dynamic, living and breathing subject."

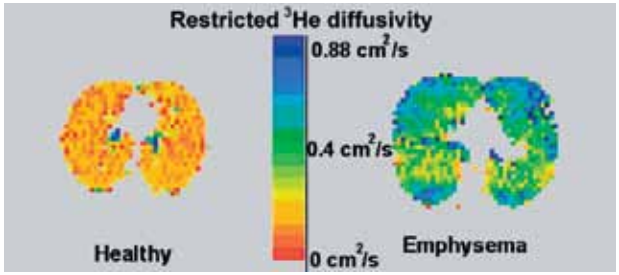
Ken Kelton, chair,
Department of Physics

Student Opportunities

You will have many opportunities to utilize your knowledge of physics and interact with other students throughout your course of study. You can participate in Washington University's chapter of the Society of Physics Students, a group that holds meetings during the year for discussion between students, faculty, and outside speakers. Physics majors also help run the astronomical observatory, which is open to the public.

A number of physics students take part in the prestigious Putnam Mathematical Competition. Of the hundreds of colleges and universities that participate, the Washington University team has been one of the top teams for nearly three decades.

The Department of Physics also awards a number of prizes and research fellowships to undergraduates. In addition, many undergraduate research fellowships are given every year for summer research.



MRI map of restricted diffusivity of hyperpolarized ^{3}He gas in healthy and diseased lungs. Techniques largely developed in the department are now being used to help characterize lung alveoli, and acinar connectivity.

You will also have extensive access to the Pfeiffer Physics Library, located on the third floor of Compton Hall. With subscriptions to some 200 journals, a first-rate collection of books, and a qualified librarian to help you in your searches, the library is a vital resource for your study of physics.

You may also, after your freshman year, enjoy being a leader of a peer-led student group in which you can formally lead and facilitate problem-solving sessions and discussions with students in the introductory courses.

Joining a Research Group

The excellent ratio of physics faculty to physics majors provides many exciting research opportunities. Students report their work at various meetings of the American Physical Society or other academic conferences, or as co-authors on papers published in refereed journals.

To join a research group, look for postings in the department, visit with professors whose work interests you, ask your instructors and advisors about possibilities, and circulate your résumé (the department office will do the copying and delivering to the faculty mailboxes). At the start of your sophomore year, the department can assist you in finding a research group that fits your interests.



Getting started

Faculty advisors are accessible and ready to help if you have questions about pursuing a major in physics. If you would like to set up an appointment with an advisor, please call the department office or e-mail us.

phone: (314) 935-6276
e-mail: getstarted@physics.wustl.edu

For additional information, or to schedule a visit to the University, contact:

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St. Louis, MO 63130-4899

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