Physics

Website: http://physics.wustl.edu

Courses

PHYSICS 1013 Basic Physics I
Credit 3 units.

PHYSICS 1014 Basic Physics II
Credit 3 units.

PHYSICS 1030 Principles and Practice of Physics
We will study and describe the motion of material objects, their symmetries and interactions, and the link with conservation/dissipation of certain quantities. While the concepts will be developed by focusing on concrete physical phenomena, the goal of the course is to provide a full appreciation of the logical structure underlying mechanics.
Credit 3 units. A&S IQ: NSM BU: SCI
Typical periods offered: Summer

PHYSICS 1100 First-Year Seminar: All About Black Holes
Black holes are the Universe's most extreme objects: they are so massive and compact that gravity bends space and time into a knot. The signature property of a black hole is that your can get in, but not out. In this first-year seminar, we discuss what is currently known about black holes, starting from Einstein's theories about space, time, and gravity, through the first observational evidence for black holes, to the latest images of the shadows cast by black holes taken with the largest telescopes on earth. This class is designed to bend your mind when figuring out why clocks run slower when approaching the edge of a black hole, what could be at the center of a black hole or even at the other side. At the same time, we will discuss the inner workings of the most advanced telescopes that astronomers have developed to study black holes, and the strategies astronomers employ to develop ever more sensitive instruments. Also expect a fair bit of astronomy in this class, when we discuss how black holes form, when and how they grow, and which roles they play in cosmic eco-systems such as the Milky Way Galaxy. This first-year seminar adopts a flipped class/socratic discussion structure. The students are asked to read a wide variety of texts, including texts from the current literature, and to present and to discuss some of the material in class. The class assumes no background in math; at the same time, we will discuss some of the math that brings Einstein's theories of space and time to life.
Credit 3 units. A&S IQ: NSM, AN Art: NSM
Typical periods offered: Fall

PHYSICS 1210 Ampersand: Gateway Expeditions Into Exoplanets
Discovery and characterization of planets beyond our Solar System have transformed our view of the cosmos and our home planet, Earth. These alien worlds, referred to as exoplanets, are opportune cosmic laboratories for improving our understanding of the formation of planets and the origin of life. Many of these worlds are highly dissimilar to those in our Solar System, requiring significant paradigm shifts in modeling the physical processes that govern them. In line with this rigorous exploration, exoplanet research has recently become a significant branch of astrophysics. Gateway Expeditions into Exoplanets is a new introductory, non-calculus course that provides an introduction to exoplanets, covering their formation and evolution, diverse properties, and potential to support life. The course includes assignments and a class project featuring data analysis and modeling in exoplanet research, a student-led tournament between exoplanets called ExoCup, occasional Socratic discussions in an inverted classroom setting, and a trip to Yerkes Observatory to witness the history of developments in astronomy leading to the exoplanet revolution. The course will function as the first part of a new Ampersand Program, Gateway Expeditions into Exoplanets and Black Holes. There is no prerequisite for taking this course.
Credit 3 units. A&S IQ: NSM, AN
Typical periods offered: Fall

PHYSICS 1211 Ampersand: Gateway Expeditions Into Exoplanets II
Black holes are the Universe's most extreme objects: they are so massive and compact that gravity bends space and time into a knot. The signature property of a black hole is that your can get in, but not out. In this second semesterr, we discuss what is currently known about black holes, starting from Einstein's theories about space, time, and gravity, through the first observational evidence for black holes, to the latest images of the shadows cast by black holes taken with the largest telescopes on earth. This class is designed to bend your mind when figuring out why clocks run slower when approaching the edge of a black hole, what could be at the center of a black hole or even at the other side. At the same time, we will discuss the inner workings of the most advanced telescopes that astronomers have developed to study black holes, and the strategies astronomers employ to develop ever more sensitive instruments. Also expect a fair bit of astronomy in this class,when we discuss how black holes form, when and how they grow, and which roles they play in cosmic eco-systems such as the Milky Way Galaxy.The course will function as the second part of a new Ampersand Program, Gateway Expeditions into Exoplanets and Black Holes. There is no prerequisite for taking this course. This course is only for first-year students admitted to the Ampersand Program.
Credit 3 units. A&S IQ: NSM, AN

PHYSICS 1410 Peer Led Team Learning: Physics
A 1-credit course that can only be taken concurrently with Physics 191. The purpose of the course is to encourage students to work in small groups, supervised by a mentor, on problems from the course that will enhance understanding. Students will enroll in PLTL through an online application, but have the option of signing up to take it for credit. They can drop the course at any time without penalty. Grading is Pass/Fail based on participation; a student must miss no more than two sessions to pass the course. In this course, student groups facilitated by a peer leader meet weekly and work together on a problem set building on topics covered in the parent course, with the aim of developing problem-solving, critical-thinking, and collaboration skills. Sign-ups for PLTL begin in Week 1 of the semester, with meetings beginning on the weekend of Week 2. Students must attend at least eight sessions during the semester to earn credit; those who do not reach the attendance threshold will be dropped from the course, and the course will be removed from their transcript. To receive credit for PLTL, a student must remain enrolled in the parent course. Please note the following exceptions to the enrollment and drop policy: (1) Students will not be able to enroll in PLTL if doing so would bring them above 21 credit units, but they will still be able to participate. (2) Students who wish to participate in PLTL but want to opt-out of receiving credit should contact their course's program manager. (3) If dropping PLTL would bring a student below 12 credit units, the drop will be entered as a withdrawal instead.
Credit 1 unit.
Typical periods offered: Fall

PHYSICS 1412 Seminar in Academic Mentoring
A one-credit course that can only be taken concurrently with Physics 192. The purpose of the course is to encourage students to work in small groups, supervised by a mentor, on problems from the course that will enhance understanding. Students will enroll in PLTL through an online application, but have the option of signing up to take it for credit. They can drop the course at any time without penalty. Grading is Pass/Fail based on participation; a student must miss no more than two sessions to pass the course. In this course, student groups facilitated by a peer leader meet weekly and work together on a problem set building on topics covered in the parent course, with the aim of developing problem-solving, critical-thinking, and collaboration skills. Sign-ups for PLTL begin in Week 1 of the semester, with meetings beginning on the weekend of Week 2. Students must attend at least eight sessions during the semester to earn credit; those who do not reach the attendance threshold will be dropped from the course, and the course will be removed from their transcript. To receive credit for PLTL, a student must remain enrolled in the parent course. Please note the following exceptions to the enrollment and drop policy: (1) Students will not be able to enroll in PLTL if doing so would bring them above 21 credit units, but they will still be able to participate. (2) Students who wish to participate in PLTL but want to opt-out of receiving credit should contact their course's program manager. (3) If dropping PLTL would bring a student below 12 credit units, the drop will be entered as a withdrawal instead.
Credit 1 unit.
Typical periods offered: Spring

PHYSICS 1551 Physics I - First-Years Only
This section of Physics 191 is for rising first-years only. Any non-first-year student enrolled in this section will be removed from the course. Non-first-year students should enroll in Physics 191U. Calculus-based introduction to the concepts, laws, and structure of physics. Topics include kinematics, Newton's laws, energy, linear momentum, angular momentum, the conservation laws, gravitational force, harmonic motion, wave motion and interference, sound, and special relativity. Two evening exams required, followed by a required final exam. Prerequisite: previous or concurrent enrollment in Calculus I (Math 131) is required; previous or concurrent enrollment in Calculus II (Math 132) strongly recommended. Taking Physics 191 as a first-year student is compatible with on-time completion of all pre-health requirements.
Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 1553 Physics I - Sophomores, Juniors, and Seniors Only
This section of Physics 191 is for rising seniors, juniors, and sophomores only. Any first-year student enrolled in this section will be removed from the course. First-year students should enroll in Physics 191F. Calculus-based introduction to the concepts, laws, and structure of physics. Topics include kinematics, Newton's laws, energy, linear momentum, angular momentum, the conservation laws, gravitational force, harmonic motion, wave motion and interference, sound, and special relativity. Two evening exams required, followed by a required final exam. Prerequisite: previous or concurrent enrollment in Calculus I (Math 131) is required; previous or concurrent enrollment in Calculus II (Math 132) strongly recommended. Combination of Physics 191 and Physics 191L is a replacement for Physics 197. Students may not receive credit for more than one of Physics 117A, Physics 191, and Physics 197.
Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 1625 Solar System Astronomy
Designed for the nonscience major, this course deals with the planets, their moons and rings, comets, meteorites and interplanetary dust particles. In order to understand both classical astronomy and the results obtained from modern telescopes and the space program, basic scientific ideas (including optics and the laws of motion) are reviewed first. There will also some discussion of astronomical history to show how we have arrived at our present ideas of the structure and evolution of the solar system. Prerequisite: High school algebra and trigonometry or concurrent enrollment in Math 131
Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 1626 Stars, Galaxies, and Cosmology
Intended as a general survey for the nonscience major. Topics include the structure and evolution of stars, such as red giants, white dwarfs, neutron stars, pulsars, and black holes; galaxies and quasars, cosmology and the big bang theory. Prerequisite: high school algebra and trigonometry, or concurrent enrollment in Math 131.
Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI
Typical periods offered: Spring

PHYSICS 1630 Introduction to Mathematical and Computational Methods in Physics
This is a learning by doing course whose objective is for the students to learn practical methods for solving physics problems using mathematical and computational tools. The course gives an introduction to applied mathematics and basic computational tools and techniques used in contemporary scientific fields of research. The format of the course is highly interactive. Each course unit will be devoted to a specific activity, including a lecture from the instructor, working groups on solving analytical problems, and working groups on coding with Python. Prerequisite: Previous or concurrent Calculus I is recommended.
Credit 3 units. A&S IQ: NSM, AN Art: NSM
Typical periods offered: Fall, Spring

PHYSICS 1673 Physics of Sustainable Energy
Introduction to the physics of climate change and sustainable energy. This course is intended for students with little previous exposure to science or math. We will learn about the value of rough estimates and simple calculations. We will apply this approach to energy and power; atoms and heat; the history and basic modeling of earth's climate; energy sources including fossil fuels, nuclear, and renewables. No prerequisites.
Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 1680 Focused Physics II
Physics 194 is the second part of a two-semester calculus-based introduction to physics, with a co-requisite of Calculus III (Math 233 or its equivalent). The course is an advanced first-year course in electricity and magnetism, taught at a more sophisticated level than Physics 192. The approach is that of an upper-division physics course, with more emphasis on the underlying formal structure, rather than breadth of topics. The main goal is to provide an in-depth coverage of electromagnetism, DC and AC circuits using complex variables, and optics. The course is particularly addressed to students considering a physics or mathematics heavy science/engineering majors. Taking Physics 194 as a first-year student is compatible with on-time completion of all pre-health requirements.
Credit 4 units. A&S IQ: NSM, AN BU: SCI
Typical periods offered: Spring

PHYSICS 1730 General Physics I
This course is the first semester of a two-semester, calculus-based introductory physics course. In this semester, we will study the principles of Newtonian mechanics and their application to various physical systems. The material we learn this semester will serve

as a basis for topics we will study in the second semester, such as electromagnetism. The aim of this course is to give you a robust introduction to the fundamentals of physics. Studying physics will also give you a better insight into other subjects like chemistry. The analytic techniques we develop will have a wide range of availability. Prerequisite: previous or concurrent enrollment in Calculus I.

Credit 3 units. A&S IQ: AN BU: SCI

Typical periods offered: Fall

PHYSICS 1731 General Physics I Lab

The laboratory experience is an integral component of Introductory Physics. It is designed to provide a hands-on opportunity to explore concepts introduced in the lecture course and to develop careful measurement and documentation skills. Prerequisite or Corequisite: Physics 205.

Credit 1 unit.

Typical periods offered: Fall

PHYSICS 1732 General Physics II

Phys 206 is the second semester of a two semester, calculus-based introductory physics course. In this semester, we build on what we learned in the first semester to explore more advanced topics like electromagnetism and optics. A strong understanding of the topics covered in Phys 205 is essential for this semester. The aim of this course is to give you a robust introduction to the fundamentals of physics. Studying physics will also give you a better insight into other subjects like chemistry. The analytic techniques we develop will have a wide range of availability. Prerequisite - Physics 205. Previous or concurrent in Calc II is recommended.

Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI

Typical periods offered: Spring

PHYSICS 1733 General Physics II Lab

Laboratory experience is an integral component of Introductory Physics. It is designed to provide a hands-on opportunity to explore concepts introduced in the lecture course and to develop careful measurement and documentation skills. Required prerequisite or co-requisite: General Physics II.

Credit 1 unit. Art: NSM BU: SCI

Typical periods offered: Spring

PHYSICS 1740 Physics I

Calculus-based introduction to the concepts, laws, and structure of physics. Topics include kinematics, Newton's laws, energy, linear momentum, angular momentum, the conservation laws, gravitational force, harmonic motion, wave motion and interference, sound, and special relativity. A daily regimen of homework and reading as well as weekly homework assignments, small-group problem-solving exercises, and active class participation are integral parts of this course. Evening exams, at which attendance is required, will be given from 6-9 p.m. on Prerequisite: previous or concurrent enrollment in Calculus I (Math 131) is required; previous or concurrent enrollment in Calculus II (Math 132) strongly recommended. Taking Physics 191 as a first-year student is compatible with on-time completion of all pre-health requirements.

Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI

Typical periods offered: Fall, Summer

PHYSICS 1741 Physics I Laboratory

Laboratory experience is an integral component of Introductory Physics. It is designed to provide a hands-on opportunity to explore concepts introduced in the lecture course and to develop careful measurement and documentation skills. Students may not receive credit for Physics 191L if they have already received credit for 117A or 197

Credit 1 unit.

Typical periods offered: Fall, Summer

PHYSICS 1742 Physics II

Continuation of Physics 191. Calculus-based introduction to concepts, laws, and structure of physics. Topics include electromagnetic forces and fields, direct current circuits, capacitance and inductance, electromagnetic radiation, light, physical optics, interference and diffraction, early quantum theory, and nuclear physics. A daily regimen of homework and reading as well as weekly homework assignments, small-group problem-solving exercises, and active class participation are integral parts of this course. Prerequisite: Physics 191, Physics 193 and Calculus I (Math 131); previous or concurrent enrollment in Calculus II (Math 132) is very strongly recommended. Taking Physics 192 as a first-year student is compatible with on-time completion of all pre-health requirements.

Credit 3 units. A&S IQ: NSM, AN BU: SCI

Typical periods offered: Spring, Summer

PHYSICS 1743 Physics II Laboratory

Laboratory experience is an integral component of Introductory Physics. It is designed to provide a hands-on opportunity to explore concepts introduced in the lecture course and to develop careful measurement and documentation skills. Prerequisite/Corequisite: Physics 192. Students who have taken Physics 118 or Physics 198 may not receive credit for Physics 192L.

Credit 1 unit.

Typical periods offered: Spring, Summer

PHYSICS 1760 Focused Physics I

Physics 193 is the first part of a two-semester calculus-based introduction to physics. The course is an advanced first-year course in classical mechanics, taught at a more sophisticated level than Physics 191. The approach is that of an upper-division physics course, with more emphasis on underlying formal structure rather than breadth of topics. The main goal is to provide in-depth coverage of the physical laws that govern the motion of objects, forces, and forms of energy in mechanical systems as well as an introduction to special relativity. The course is particularly addressed to students considering a physics- or mathematics-heavy science or engineering major. Corequisite: Math 132 or equivalent. Taking Physics 193 as a first-year student is compatible with on-time completion of all pre-health requirements.

Credit 4 units. A&S IQ: NSM, AN Art: NSM BU: SCI

Typical periods offered: Fall

PHYSICS 1941 Selected Topics in Physics I

Topics of special interest (e.g., superconductivity, quasicrystals, neural networks, chaos, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars, or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure consent to undertake direction of the course from a faculty member and apply for approval using the Physics independent study web form https://physics.wustl.edu/independent-study

Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI

Typical periods offered: Fall

PHYSICS 1942 Selected Topics in Physics I
Topics of special interest (e.g., holography, relativity, nuclear power, computer applications in physics, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars, or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure the instructor's consent to undertake direction of the course from a faculty member andapply for approval using the Physics independent study web form https://physics.wustl.edu/independent-study
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI
Typical periods offered: Spring

PHYSICS 1970 Physics I
Calculus-based introduction to the central concepts, laws, and structure of physics, presented in an active learning environment. The course is structured around three themes that are treated in depth: conservation laws, Newtonian physics, and special relativity. A daily regimen of homework and reading, as well as weekly homework assignments, small group problem-solving exercises, and active class participation are integral parts of this course. Concurrent registration in a Physics 197 lab section is required. Prerequisite: Previous or concurrent enrollment in Calculus I (Math 131) is required; previous or concurrent enrollment in Calculus II (Math 132) strongly recommended.. Credit may not be obtained for both Physics 117A and Physics 197 and students may not simultaneously enroll in both courses.
Credit 4 units. A&S IQ: NSM, AN Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 1972 Physics I - Lecture Only
Lecture-only version of L31 Physics 197 Lecture-only version of L31 Physics 197. Calculus-based introduction to the central concepts, laws, and structure of physics, presented in an active learning environment. The course is structured around three themes that are treated in depth: conservation laws, Newtonian physics, and special relativity. A daily regimen of homework and reading, as well as weekly homework assignments, small group problem-solving exercises, and active class participation are integral parts of this course. Prerequisite: Previous or concurrent enrollment in Calculus I (Math 131) is required; previous or concurrent enrollment in Calculus II (Math 132) strongly recommended.
Credit 3 units. BU: SCI

PHYSICS 1980 Physics II
Continuation of Physics 197. An advanced, calculus-based introduction to central concepts in physics for students who desire to major in physics or another physical science, or who have a special interest in physics. The course is structured around three themes that are treated in depth: electricity and magnetism, quantum physics, and statistical and thermal physics. A daily regimen of homework and reading as well as active class participation are integral parts of the course. Prerequisites: Physics 197 and Calculus II. Students who have not taken Physics 197 may not register for Physics 198. Concurrent registration in a Physics 198 lab section is required. Credit may not be obtained for both Physics 118 and Physics 198.
Credit 4 units. A&S IQ: NSM, AN Art: NSM BU: SCI

PHYSICS 1996 Physics Elective - 100 Level
Credit 0 units.

PHYSICS 2001 Honors Problem Solving 1
This is a problem solving course for students considering a physics or mathematics heavy major. The problems we will focus on will be more difficult and sophisticated than those encountered in Physics 197. However, the content will be tightly linked to the weekly schedule of physics 197, and the course will be taught by a 197 instructor. This course is for incoming Freshmen and rising Sophomores. Prerequisite: Concurrent enrollment in 197, AP physics, and permission of the instructor.
Credit 1 unit.
Typical periods offered: Fall

PHYSICS 2004 Honors Problem Solving II
This is the second semester of a problem-solving course for students considering a physics- or mathematics-heavy major. The problems we will focus on will be more difficult and sophisticated than those encountered in Physics 192. However, the content will be tightly linked to the weekly schedule of Physics 192, and the course will be taught by a Physics 192 instructor. This course is for incoming first-year students and rising sophomores. Prerequisite: previous enrollment in Physics 201, concurrent enrollment in Physics 192, or permission of the instructor.
Credit 1 unit.
Typical periods offered: Spring

PHYSICS 2010 Energy and Climate
This course will explain the physical principles underlying our energy systems and climate change, at a level suitable for an informed citizen who wishes to understand the natural world and the issues of the day. No prerequisites
Credit 3 units.

PHYSICS 2160 Introduction to Relativity: The Special Theory
Introduction to the special and general theories of relativity. Einstein's postulates of the principle of relativity and the constancy of the speed of light. Simple kinematics and dynamics: simultaneity, time dilation, space-time diagrams, twin and other paradoxes, E = mc^2, laws of motion. Elements of general relativity; curved spacetime, experimental tests, black holes, gravitational waves. Prerequisite: Phys 191, Phys 193, Phys 197, or permission of the instructor.
Credit 1 unit. A&S IQ: NSM Art: NSM BU: SCI
Typical periods offered: Spring

PHYSICS 2170 Introduction to Quantum Physics
Theoretical and experimental basis for quantum mechanics, following the historical development of 20th-century physics. Failure of classical physics; the Bohr theory of the atom; the Heisenberg uncertainty principle; the Schroedinger equation; atomic and molecular structure.Prerequisites: Phys 191-192 or Phys 193-194 or Phys 197-198 or Phys 205 - 206.
Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 2941 Selected Topics in Physics II
Topics of special interest (e.g., superconductivity, quasicrystals, neural networks, chaos, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars, or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure consent to undertake direction of the course from a faculty member and apply for approval using the Physics independent study web form https://physics.wustl.edu/independent-study
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 2942 Selected Topics in Physics II
Topics of special interest (e.g., holography, relativity, nuclear power, computer applications in physics, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars, or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure the instructor's consent to undertake direction of the course from a faculty member and apply for approval using the Physics independent study web form https://physics.wustl.edu/independent-study
Credit 3 units. A&S IQ: NSM Art: NSM BU: IS
Typical periods offered: Spring

PHYSICS 2996 Physics Elective - 2000 Level
This course is used to transcribe 2000-level PHYSICS elective units.
Credit 0 units.
Typical periods offered: Fall, Spring, Summer

PHYSICS 3068 Introduction to Quantum Information
A general introduction to the field of quantum information: physics of information processing, quantum logic, quantum algorithms, physical hardware for quantum computation, quantum communications, quantum error corrections, quantum sensing. Prerequisites: Math 131, Math 132 or equivalent, Math 429 (Linear Algebra) or equivalent.
Credit 3 units. A&S IQ: NSM, AN Art: NSM
Typical periods offered: Spring

PHYSICS 3180 Introduction to Quantum Physics II
Application of elementary quantum principles to atomic and molecular physics, solid-state physics, and nuclear and particle physics. Prerequisite: Physics 217.
Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI
Typical periods offered: Spring

PHYSICS 3190 Quantum Theory of Matter
Students will learn how to apply quantum mechanics principles to atomic and molecular physics, solid-state physics, nuclear physics, and particle physics. A portion of the course will also be devoted to introducing Dirac notation and discussing its applications to simple systems.
Credit 3 units. A&S IQ: NSM, AN
Typical periods offered: Spring

PHYSICS 3321 Electronics Laboratory
Elements of linear and nonlinear circuits, amplifiers, feedback, with applications in experimental physics. Prerequisite: Phys 192 or Phys 194 or Phys 198 or Phys 206 or permission of instructor. Two three-hour laboratories and two one-hour lectures a week.
Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 3322 Physical Measurement Laboratory
A variety of classical and modern experiments in physics, including five experiments in nuclear radiation. Use of computers in experiment control, data acquisition, and data analysis. Development of skills in writing lab notebooks and formal reports and giving short oral presentations on experiments. Two laboratory periods each week. Prerequisite: Physics 217 or permission of instructor; junior or senior level standing
Credit 3 units. A&S IQ: NSM, AN, WI Art: NSM BU: SCI
Typical periods offered: Fall, Spring

PHYSICS 3323 Optics and Wave Physics Laboratory
Introduction to optics and to treatment of experimental data. Experiments and lectures on refraction, interference, diffraction, polarization, and coherence properties of waves with emphasis on light. Data analysis using statistical methods. Prerequisite: Physics 117A-118A or Physics 197-198.
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI
Typical periods offered: Fall, Spring

PHYSICS 3324 Biophysics Laboratory
This laboratory course consists of table-top experiments in biological physics that are designed to introduce the student to concepts, methods, and biological model systems in biophysics. Most experiments combine experimentation with computer simulations. The list of available experiments includes electrophysiology, human bioelectricity, optical tweezers, ultrasonic imaging, mass spectrometer, and viscosity measurements.Prior completion of Prerequisite: Physics 191 - 192 or Phys 193 - 194 or Physics 197-198 or Phys 205 - 206 or permission of instructor.
Credit 3 units. A&S IQ: NSM, AN Art: NSM
Typical periods offered: Fall

PHYSICS 3330 Planets and Life in the Universe
In this course, we will explore the history, methods, outcomes, and broad impacts of exoplanet research and how these are connected to our search for life beyond planet Earth. Following an engaging contextual introduction at the beginning of the lectures, topics will be presented with an accessible mathematical treatment (e.g., geometrical derivations of the two-body transit problem). Prerequisite: Physics 191 and 192 or Physics 193 and 194.
Credit 3 units. A&S IQ: NSM, AN Art: NSM
Typical periods offered: Fall

PHYSICS 3331 Introduction to Astrophysics
This course covers the physics needed for higher level astrophysics courses, and is a requirement for those courses. Furthermore, it gives a first introduction to several topics in modern astrophysics, including stars (stellar structure and evolution), compact objects (neutron stars and black holes), galaxies (galactic structure), and cosmology. The course should be taken by everybody interested in astrophysics. Prerequisite: Physics 191 and 192 or Physics 193 and 194 or Physics 197 and 198 or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI
Typical periods offered: Fall, Spring

PHYSICS 3350 Physics of the Brain
Concepts and techniques of physics are applied to study the functioning of neurons and neuronal circuits in the brain. Neurons and neural systems are modeled at two levels: (i) at the physical level, in terms of the electrical and chemical signals that are generated and transmitted and (ii) at the information-processing level, in terms of the computational tasks performed. Specific topics include: neuronal electrophysiology, neural codes, neural plasticity, sensory processing, neural network architectures and learning algorithms, and neural networks as dynamical and statistical systems. Course grade is based primarily on an individualized term project. Prerequisite: Phys 191-192 or Phys 193-194 or Phys 197-198 or Phys 205-206, or permission of the instructor.
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI
Typical periods offered: Fall, Spring

PHYSICS 3352 Physics of Biomolecules
This course emphasizes the application of physical laws and concepts in understanding biomolecules and their interactions, and in developing tools to investigate their biological properties and functionalities. Topics include (1) a general introduction to biomolecules and cells, (2) physics of biopolymers as modeled by stochastic analyses, (3) transport processes in biological systems including diffusion, reaction kinetics, and life at low Reynolds number, and (4) the physics of fluorescence and its contemporary applications to dynamics of biomolecules, such as optical tweezers.Prerequisite: Prerequisite: Physics 191 - 192 or Phys 193 - 194 or Physics 197-198 or Phys 205 - 206. Some familiarity with thermodynamics; Chemistry 111A-112A recommended.
Credit 3 units. A&S IQ: NSM, AN

PHYSICS 3354 Physics of Living Systems
One of the grand challenges in contemporary biophysics is placing our understanding of cellular systems on a firm quantitative footing. How does the collective activity of molecules enable the cell to sense its environment, make decisions, grow and develop? This course, aimed at physical and life science students, will serve as an introduction to the physical principles and mathematical techniques underlying the analysis of systems and synthetic biology. Topics will include modeling gene and signaling networks, the regulation of intracellular structures, and pattern formation in development. Students in this course can expect to learn both analytical and computer simulation approaches to fundamental problems in biology, biophysics, and biotechnology. Graduate students will explore the subject in more depth. Pre-requisites: Prerequisite: Physics 191 - 192 or Phys 193 - 194 or Physics 197-198 or Phys 205 - 206. or Math 217 or Math 309, or permission of instructor. 3 units
Credit 3 units. A&S IQ: NSM BU: SCI
Typical periods offered: Fall, Spring

PHYSICS 3355 Physics of Vision
How do the eyes capture an image and convert it to neural messages that ultimately result in visual experience? This lecture and demonstration course will cover the physics of how we see. The course is addressed to physics, premedical, and life-sciences students with an interest in biophysics. Topics include physical properties of light, evolution of the eyes, image formation in the eye, image sampling with an array of photoreceptors, transducing light into electrical signals, color coding, retinal organization, computing with nerve cells, compressing the 3-D world into optic nerve signals, inferring the 3-D world from optic nerve signals, biomechanics of eye movement, engineered vision in machines. The functional impact of biophysical mechanisms for visual experience will be illustrated with psychophysical demonstrations. Corequisite: Phys 117A, Phys 197 or permission of instructor. 3 units.
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 3440 Energy and Environmental Physics
This intermediate-level course applies basic physics principles to this increasingly important area. It is designed for all science and engineering majors with an interest in energy and environmental issues. Topics to be covered include population trends, fossil fuel use, renewable energy sources, energy storage strategies and climate change. Particular emphasis will be given to the use of the fundamental laws of physics, such as energy conservation, as well as more general concepts such as local and global stability, chaotic behavior, probability and risk. The aim of the course is the development of analytical skills and familiarity with important concepts, in order to enable an independent and informed view of environmental problems and possible solutions. A one-year introductory physics class on the level of Phys 191 and 192, Phys 193 and 194 or 197-198 is required. This course may also be taken as Physics 444, which requires an additional independent project.
Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 3941 Selected Topics in Physics III
Topics of special interest (e.g., superconductivity, quasicrystals, neural networks, chaos, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars, or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure consent to undertake direction of the course from a faculty member and apply for approval using the Physics independent study web form https://physics.wustl.edu/independent-study
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 3942 Selected Topics in Physics III
Topics of special interest (e.g., holography, relativity, nuclear power, computer application in physics, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars, or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure the instructor's consent to undertake direction of the course from a faculty member and apply for approval using the Physics independent study web form https://physics.wustl.edu/independent-study
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI
Typical periods offered: Spring

PHYSICS 3996 Physics Elective
Credit 0 units.

PHYSICS 4011 Mechanics
Motion of a point particle, rotational motion, oscillation, gravitation and central forces, Lagrangian and Hamiltonian formulation. Prerequisite: Prerequisite: Physics 191 - 192 or Phys 193 - 194 or Physics 197-198 or Phys 205 - 206, Math 217, or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM
Typical periods offered: Spring

PHYSICS 4021 Electricity and Magnetism
Starting from Coulomb's law, the Biot-Savart law, and Faraday's law, the electrical and magnetic fields are defined and applied. Maxwell's equations are derived and their consequences, such as electromagnetic waves and relativity, are explored. Prerequisites: Prerequisite: Physics 191 - 192 or Phys 193 - 194 or Physics 197-198 or Phys 205 - 206., Math 217, or permission of instructor.
Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 4022 Electricity and Magnetism II
The second course in a two part series covering the classical theory of electricity and magnetism leading to the derivation and application of Maxwell's equation. Topics in electrodynamics including Faraday's law, the displacement current and Maxwell's equations in vacuum and in matter are covered. Electromagnetic waves and radiation, special relativity and relativistic electrodynamics will also be discussed. Prerequisites: Phys 421 or permission of instructor.
Credit 3 units. A&S IQ: NSM, AN Art: NSM
Typical periods offered: Spring

PHYSICS 4027 Introduction to Computational Physics
What does it mean to solve a research problem using a computer? What is the difference between someone ran a simulation and an interesting research result? And what skills does it take? Familiarity with a programming language is, of course, essential, but that is only the beginning. This course will focus on the methodology of computational research, touching also on topics in numerical analysis, statistics and visualization. The format will combine lectures and hands-on experience, with emphasis on research-style small-group projects. Prerequisites:Prerequisite: Physics 191 - 192 or Phys 193 - 194 or Physics 197-198 or Phys 205 - 206, Calculus, and familiarity with a programming language.
Credit 3 units. A&S IQ: NSM Art: NSM
Typical periods offered: Fall, Spring

PHYSICS 4063 Statistical Mechanics and Thermodynamics
Basic methods of classical and quantum statistical mechanics, thermodynamics, and transport theory. Prerequisite: Phys 217 or permission of instructor.
Credit 3 units. A&S IQ: NSM, AN Art: NSM
Typical periods offered: Fall

PHYSICS 4071 Quantum Mechanics
Origins of quantum theory, wave packets and uncertainty relations, Schroedinger's equation in one dimension, step potentials and harmonic oscillators, eigenfunctions and eigenvalues, Schroedinger's equation in three dimensions, the hydrogen atom, symmetry, spin and the periodic table, approximation methods for time independent problems, quantum statistics. Prerequisite: Math 217, Physics 217, or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM
Typical periods offered: Fall

PHYSICS 4072 Solid State Physics
Crystal structures, binding energies, thermal properties, dielectrics, magnetism, free electron theory of metals, band theory, semiconductors, defects in solids. Prerequisite: Phys 471.
Credit 3 units. A&S IQ: NSM Art: NSM
Typical periods offered: Spring

PHYSICS 4074 Introduction to Particle Physics
Introduction to the standard model of particle physics, including symmetries, conservation laws, the weak interaction, the strong interaction, quark confinement, and some more exotic ideas such as grand unified theories. Prerequisite: Phys 217.
Credit 3 units. A&S IQ: NSM, AN Art: NSM
Typical periods offered: Spring

PHYSICS 4077 Physics of Finite and Infinite Nuclear Systems
Quantum mechanics of finite and infinite systems of protons and neutrons. Interaction between nucleons. Independent-particle model of nuclei and shell structure. Contrast with atomic shell model. Isospin symmetry. Information from weakly and strongly interacting probes of nuclei. Nuclear decay properties and some historical context. Many-particle description of nuclear systems. Single-particle versus collective phenomena. Properties of excited states. Bulk properties of nuclei. Nuclear and neutron matter. Role of different energy scales in determining nuclear properties: influence of long-range, short-range, and medium-induced interactions. Pairing correlations in nuclear systems. Relevance of nuclear phenomena and experiments for astrophysics and particle physics. Prerequisites: Phys 318 or Phys 471, or permission of instructor
Credit 3 units. A&S IQ: NSM
Typical periods offered: Spring

PHYSICS 4080 Artificial Intelligence and Machine Learning Methods With Applications to Physics
The course will introduce key ideas of AI and machine learning from a statistical physics perspective. Essentials of statistical distributions, kernel methods, neural networks, large language models, diffusion models, and many other tools will be presented from this physics based approach. Students will apply these techniques to problems in physics. Apart from the very first assignments, nearly all homework problems will assume the use of Python. If you do not know Python, there will be an additional very brief introduction to Python that the instructor will give in addition to the course lectures. Prerequisites: L24 132 (Calculus III) and L24 429 (Linear Algebra)
Credit 3 units. A&S IQ: NSM, AN
Typical periods offered: Fall

PHYSICS 4081 Critical Analysis of Scientific Data
Data science is most commonly associated with topics in computer science. However, efficient algorithms, specific software packages, neural nets, and so on are only tools, and they are easily misused. In a research setting, working with data is primarily an exercise in critical thinking. The purpose of this interactive, hands-on course is to learn from mistakes by making them in a safe environment. After covering/reviewing probability theory, Bayesian inference, elements of information theory, and random matrix theory, the course will focus on case studies of real-world biological data, such as quantitative imaging data, nextgeneration sequencing (metagenomics), and neural recordings. These modules will involve the critical reading of research papers and working through puzzle-based assignments. The primary modules will be supplemented by shorter presentations on topics chosen by students. Fair warning: This is explicitly not a course on big data or machine learning, although students may choose to explore some of these topics in their presentations (required for credit). Experience with MatLab or Python strongly encouraged or will need to be acquired during the course. Open to undergraduates with prior programming experience and a quantitative background (Phys 197/198, Math 203 or similar; contact instructor if unsure). Experience with data or statistics not required. Course mimics a research environment, and undergraduates considering an academic research track are especially encouraged.
Credit 3 units. Art: NSM BU: SCI
Typical periods offered: Fall, Spring

PHYSICS 4082 Research Seminar
Designed to introduce students to current developments in physics and to research carried out by faculty. Topics vary each year. Each member of the department addresses their particular specialty. Interested undergraduates may take this seminar in their junior or senior year. Must be taken pass/fail.
Credit 1 unit. A&S IQ: NSM Art: NSM

PHYSICS 4500 Physics of the Brain
Contents are the same as Phys 350. Also intended for graduate students. Includes a more sophisticated term project than Phys 350. Prerequisite: Prerequisite: Physics 191 - 192 or Phys 193 - 194 or Physics 197-198 or Phys 205 - 206 or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI
Typical periods offered: Fall, Spring

PHYSICS 4520 Advanced Laboratory II
Applications of analog and digital electronics and microprocessor techniques, followed by projects in modern physics with concurrent lectures on methods of experimental physics. Prerequisite: Phys 322 or permission of instructor. Two laboratories a week.
Credit 3 units. A&S IQ: NSM, WI Art: NSM
Typical periods offered: Spring

PHYSICS 4540 Physics of Living Systems
Contents are the same as Phys 354. Graduate students will explore the subject in more depth. Pre-requisites: Prerequisite: Physics 191 - 192 or Phys 193 - 194 or Physics 197-198 or Phys 205 - 206. or Math 217 or Math 309, or permission of instructor. 3 units
Credit 3 units. A&S IQ: NSM
Typical periods offered: Fall, Spring

PHYSICS 4550 Physics of Vision
Contents are the same as Phys 355. Also intended for graduate students. Includes a more sophisticated term project than Phys 355. Corequisite:Prerequisite: Physics 191 or Phys 193 or Phys 197 or Phys 206 or permission of instructor. 3 units.
Credit 3 units. A&S IQ: NSM Art: NSM
Typical periods offered: Fall

PHYSICS 4553 Topics in Theoretical Biophysics
Application of a range of physical models to biological systems. Topics include protein folding, self-assembling molecular systems, and mechanical properties of biological materials. Background material will be provided, but some exposure to statistical mechanics or thermodynamics is necessary. Prerequisite: experience with ordinary differential equations (as in Mathematics 217).
Credit 3 units. A&S IQ: NSM BU: SCI
Typical periods offered: Spring

PHYSICS 4646 Galactic Astrophysics
In these lectures, the focus is on the dynamics and statistical mechanics of a collection of stars, which is treated as a collisionless system. The course begins with a discussion of potential theory and proceeds to discuss the density and phase distributions of stars in star clusters and galaxies, thus leading to an understanding of the equilibria and stability of these systems. Topics such as Chandrasekhar's dynamical friction, galaxy formation and dark matter will constitute the final topics of discussion.
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 4660 X-Ray & Gamma-Ray Astrophysics
Observers started to use X-ray and gamma-rays in the sixties and seventies to explore the cosmos with high-energy photons. The sky looks dramatically different at these energies with bright flares from mass accreting black holes and gamma-ray bursts and large diffuse emission from supernova remnants and cosmic rays interacting with galactic matter and magnetic fields dominating the emission. This course gives a comprehensive overview of the underlying physics and observable phenomenology. Topics that will be covered include the history of X-ray and gamma-ray astronomy, high- energy radiation processes, particle heating and acceleration, accretion physics, blast waves and shocks, black holes, neutron stars, supernova remnants, gamma-ray bursts, and galaxy clusters. Prerequisite L31 312.
Credit 3 units. A&S IQ: NSM
Typical periods offered: Fall

PHYSICS 4676 Astrophysics
This Astrophysics course focuses on cosmic rays.Victor Hess discovered in 1912 that ionizing radiation impinges on the top of Earth's atmosphere. Even though physicists have been studying cosmic rays (the ionizing radiation) for more than 100 years now with a fantastic repertoire of experimental and theoretical tools, cosmic rays never stop to surprise us and cosmic ray physicists are still pushing the frontier of cosmic exploration in many ways. This course gives an introduction into this exciting topic covering historical and recent cosmic ray measurements at all energies, particle and antiparticle observations, and neutrino observations. The presently favored models of cosmic ray acceleration and transport are discussed in detail, and some topics of current interest are highlighted (including the production of particles and antiparticles by dark matter). The course also covers radio astronomy and highlights the clues about the origin of the cosmic rays that can be obtained from radio observations. Prerequisite Physics 312 or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM

PHYSICS 4678 From Black Holes to the Big Bang
An introduction to general relativity. The goal will be to illustrate important features of general relativity without the full-blown mathematics of Einstein's equations by restricting attention to spherically symmetric spacetimes. Topics will include: principle of equivalence; curved spacetime; spherical stars and black holes; the Big Bang model, observational cosmology. Prereq: Physics 411 or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM
Typical periods offered: Spring

PHYSICS 4680 Astrostatistics
The course will be centered on astrostatistics and explore fundamental concepts in statistics and computer science, using astrophysics as the basis of application. The course will introduce the essential principles and techniques of astrostatistics, equipping students with the necessary tools to analyze and interpret data from various astrophysical phenomena, while the methods covered will also apply to problems outside of astronomy.
Credit 0 units.

PHYSICS 4941 Selected Topics in Physics IV
Topics of special interest (e.g., holography, relativity, nuclear power, computer applications in physics, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars, or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure the instructor's consent to undertake direction of the course from a faculty member and apply for approval using the Physics independent study web form https://physics.wustl.edu/independent-study
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI
Typical periods offered: Fall

PHYSICS 4942 Selected Topics in Physics IV
Topics of special interest (e.g., holography, relativity, nuclear power, computer applications in physics, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars, or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure the instructor's consent to undertake direction of the course from a faculty member and apply for approval using the Physics independent study web form https://physics.wustl.edu/independent-study
Credit 3 units. A&S IQ: NSM Art: NSM
Typical periods offered: Spring, Summer

PHYSICS 4996 Physics Elective
Credit 0 units.

PHYSICS 4998 Honors Program
Prerequisites: junior standing, an average grade of B or better, and apply for approval using the Physics independent study web form https://physics.wustl.edu/independent-study. Program and credit to be determined; maximum 6 units.
Credit 3 units.
Typical periods offered: Fall, Spring