

# Physical Sciences

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General education courses in the Physical Sciences benefit from a rich tradition of scientific discovery at the University of Chicago. The late University of Chicago professor and Nobel laureate Subrahmanyan Chandrasekhar, who predicted the existence of black holes based on theoretical considerations, described well the importance of science in our lives when he said, "Science is a perception of the world around us. Science is a place where what you find in nature pleases you."

Under the designation PHSC, the Physical Sciences Collegiate Division offers several sequences of courses from the Astronomy and Astrophysics, Chemistry, Geophysical Sciences, and Physics departments, tailored to provide an interesting and useful education for non-scientists in their goal of satisfying their general education requirement in the physical sciences. The goal of general education in the physical sciences is to engender in the student the ability to understand and assess our understanding of the physical world. One can argue that the fundamental tenet of liberal education at the University of Chicago is to cultivate an appreciation for critical inquiry and the basis for judgement. The physical sciences contribute to this mission in teaching the principles of experimentation, observation, and the principles of scientific inquiry. Chemistry and physics are advanced through laboratory experiments that study the structure of nature and build models which we extrapolate from those observations. Astronomy and geophysical sciences develop methods to make inferences about the world around us based on observations which cannot always be recreated in a laboratory.

While the Mathematics, Statistics, and Computer Science Departments do not offer PHSC courses, these subjects are strongly connected to the physical sciences. Mathematics is the language of science and the only known way to make quantitative assessments about the experiments. Statistics teaches us how to interpret experimental results and how to assess a level of confidence in the conclusions derived from them, while computer science enables us to analyze large and complex data and simulate physical processes whose properties cannot be determined mathematically. The techniques developed and applied to scientific inquiry provide valuable tools to the basis of inquiry in any field, and indeed in our lives in general.

Students are required to take at least two courses in the physical sciences to satisfy the general education requirement. This requirement may be met by taking an introductory sequence in Chemistry, Geosciences, or Physics, or by taking any acceptable pairing of Physical Sciences (PHSC) courses, which generally have a broader focus than the disciplinary sequences. It is strongly recommended that the general education sequence in the physical sciences be completed in the first two years.

## General Education Sequences

The following introductory sequences may be used to satisfy the general education requirement in the physical sciences for all students, although these tend to be taken by sciences majors or by students who have a particular need for science (namely, premeds). The sequences are:

CHEM 10100-CHEM 10200

CHEM 11100-CHEM 11200\*

CHEM 12100-CHEM 12200

GEOS 13100-GEOS 13200

PHYS 12100-PHYS 12200\*#

PHYS 13100-PHYS 13200

PHYS 14100-PHYS 14200\*

\* For information, see the Placement Tests and Advanced Placement Credit sections elsewhere in this catalog.

# PHYS 12100 has the prerequisite of CHEM 11300 or CHEM 12300.

Beginning in the 2017–18 academic year, a 5 on the AP Chemistry exam will give credit for CHEM 11100. Students who have credit for CHEM 11100 by either taking the course or by AP credit and do not wish to take CHEM 11200 or 12200 may complete the general education requirement with either of the following two courses offered by the Chemistry Department:

PHSC 12400

PHSC 12500

Students with course or examination credit for PHYS 12100 or 12200 who do not wish to complete a second quarter of Physics must petition the master of the Physical Sciences Collegiate Division for approval to pair an alternate course with the Physics credit. This petition must be submitted *prior* to taking the course.

There are several sequences in the physical sciences, each of which introduces a different discipline and different aspects of scientific knowledge. Physical Sciences (PHSC) courses fall mainly into four general categories that we might conveniently label as "**Physics**," "**Astronomy and Astrophysics**," "**Geosciences**," and "**Chemistry**." As a general rule, courses from two different categories may not be combined to satisfy the two-quarter general education requirement in the

physical sciences. It is strongly recommended that the general education sequence in the physical sciences be completed in the first two years. Some PHSC courses restrict registration for students beyond the second year.

Students who seek to deviate from the combinations identified here must submit a petition to the master of the Physical Sciences Collegiate Division, Harper Memorial Library 235 (HM 235).

The PHSC courses in the **Physics** category are PHSC 11100-11200 Modern Physics I-II, PHSC 11300 Everyday Physics, and PHSC 11400-11500 Life in the Universe I-II. The approved sequences among these courses are listed below. Other sequences are not permitted.

PHSC 11100-PHSC 11200

PHSC 11100-PHSC 11300

PHSC 11400-PHSC 11500

Students wishing to take a three-quarter Physical Sciences sequence may take PHSC 11100-11200-11300, although at present only one of PHSC 11200 and PHSC 11300 is offered in any given year.

The PHSC courses in the **Geosciences** category are PHSC 10100 Origin and Evolution of the Solar System and the Earth, PHSC 10800 Earth as a Planet: Exploring Our Place in the Universe, PHSC 10900 Ice-Age Earth, PHSC 11000 Environmental History of the Earth, PHSC 13400 Global Warming: Understanding the Forecast, PHSC 13500 Chemistry and the Atmosphere, and PHSC 13600 Natural Hazards. The only approved sequences among these courses are listed below. The courses in these sequences can be taken in any order. Under no circumstances may a student get credit for both PHSC 10100 and PHSC 10800. Please note: PHSC 13500 has been discontinued. The combinations listed are for students who completed PHSC 13500 in Autumn Quarter 2014 or earlier. Below is a summary of approved courses:

PHSC 10100-PHSC 11000

PHSC 10100-PHSC 13400

PHSC 10800-PHSC 11000

PHSC 10800-PHSC 13400

PHSC 10900-PHSC 11000

PHSC 10900-PHSC 13400

PHSC 10900-PHSC 13500

PHSC 10900-PHSC 13600

PHSC 11000-PHSC 13400

PHSC 11000-PHSC 13500

PHSC 11000-PHSC 13600

PHSC 13400-PHSC 13500

PHSC 13400-PHSC 13600

PHSC 13500-PHSC 13600

There is one sequence of PHSC courses with a focus on **Chemistry**, PHSC 12400 The Chemistry of Big Problems and PHSC 12500 Molecular Mechanisms of Human Disease.

PHSC 12400-PHSC 12500

Two new sequences are available that pair **Geosciences** and **Astronomy and Astrophysics** courses. The approved sequences are PHSC 10800 Earth as a Planet: Exploring Our Place in the Universe + PHSC 12720 Exoplanets, and PHSC 10100 The Origin and Evolution of the Solar System and the Earth + PHSC 12720 Exoplanets.

PHSC 10100-PHSC 12720

PHSC 10800-PHSC 12720

Students who wish to take a three-quarter sequence may enroll accordingly: PHSC 12700 Stars (Autumn Quarter) + PHSC 10100 The Origin and Evolution of the Solar System and the Earth (Winter Quarter) + PHSC 12720 Exoplanets (Spring Quarter).

PHSC 12700-PHSC 10100-PHSC 12720

The on-campus PHSC courses in the **Astronomy and Astrophysics** category are PHSC 12600 Matter, Energy, Space, and Time, PHSC 12610 Black Holes, PHSC 12620 The Big Bang, PHSC 12700 Stars, PHSC 12710 Galaxies, and PHSC 12720 Exoplanets. PHSC 12600-12610-12620 is a logical progression that applies physical principles based on terrestrial experiments to the cosmos at large. Similarly, PHSC 12700-12710-12720 is a logical progression that concerns observed

properties of important classes of astronomical objects. Thus, a two-quarter sequence can be built most naturally from 12600 + 12610 or 12600 + 12620, and similarly from 12700 + 12710, 12700 + 12720 or 12710 + 12720. It is also possible to make two-quarter sequences from 12600 + 12710 (galaxies are an example of structure that evolved from early conditions), from 12700 + 12610 (black holes are an end state of stellar evolution), and from PHSC 12600 + 12700.

PHSC 12600 must be taken as the prerequisite before PHSC 12610 or PHSC 12620. Either PHSC 12700 or PHSC 12710 can be taken as the prerequisite before PHSC 12720. Three-quarter sequences may be created by adding any third of the six courses, subject to prerequisite restrictions. The approved sequences among these courses are:

PHSC 12600-PHSC 12610

PHSC 12600-PHSC 12620

PHSC 12600-PHSC 12700

PHSC 12600-PHSC 12710

PHSC 12700-PHSC 12710

PHSC 12700-PHSC 12720

PHSC 12700-PHSC 12610

PHSC 12710-PHSC 12720

Every Spring Quarter a three-course Astronomy program (<http://study-abroad.uchicago.edu/programs/paris-astronomy>) is offered in Paris, composed from the PHSC courses numbered in the 12600s and 12700s that are offered on campus. The Astronomy program in Paris satisfies the general education requirement in the physical sciences.

PHSC 11900 and PHSC 12000 were offered for the last time in academic year 2014–15. PHSC 11902 was offered for the last time in summer 2015. Students who have taken PHSC 11900 or PHSC 11902 may complete their general education requirement by taking PHSC 12600, PHSC 12620\*, PHSC 12710, or PHSC 12720. Students who have taken PHSC 12000 may complete their general education requirement by taking PHSC 12600, PHSC 12610, PHSC 12700, or PHSC 12720\*\*. For students who do not have a preference for a particular course, suggested pairings are PHSC 11900 with PHSC 12600 and PHSC 12000 with PHSC 12600 or 12700. Please note: PHSC 11900 may not be combined with PHSC 12610 or PHSC 12700, and PHSC 12000 may not be combined with PHSC 12620 or PHSC 12710.

\* Discouraged because PHSC 11900 may not provide adequate preparation for PHSC 12620.

\*\* Discouraged because PHSC 12000 may not provide adequate preparation for PHSC 12720.

Four other PHSC courses that fit into the Astronomy and Astrophysics category are PHSC 18100 The Milky Way, PHSC 18200 The Origin and Evolution of the Universe, PHSC 18300 Searching Between the Stars, and PHSC 18800 Philosophical Problems in Cosmology. These courses may only be used as a third Physical Sciences general education course and may be combined with any acceptable two-quarter sequence, including those outside of the Astronomy and Astrophysics category.

#### Note on General Education in the Sciences:

Along with one of these two-quarter sequences, students must register for at least two quarters of an approved biological sciences sequence and at least one quarter of an approved mathematical science. A sixth quarter must be taken in any one of the three areas: physical science, biological science, or mathematical science. NOTE: To receive general education credit for calculus, two quarters must be taken; this will count as two quarters towards meeting the general education requirement in the sciences.

#### General Education Courses

##### **PHSC 10100. Origin and Evolution of the Solar System and the Earth. 100 Units.**

This course examines the physical and chemical origins of planetary systems, the role of meteorite studies in this context, and a comparison of the Earth with neighboring planets. It then turns to chemical and physical processes that lead to internal differentiation of the Earth. Further topics include the thermal balance at the Earth's surface (glaciation and the greenhouse effect), and the role of liquid water in controlling crustal geology and evolution. (L)

Instructor(s): A. Davis Terms Offered: Winter

##### **PHSC 10800. Earth as a Planet: Exploring Our Place in the Universe. 100 Units.**

This course explores the diversity of bodies in our Solar System, and the physical and chemical processes that have shaped them over their histories. We will also discuss how these studies have carried us away from an Earth-centered view of the universe to one where Earth is just one of billions of planets that exist in our galaxy. Topics to be covered include: early observations of the Solar System and the laws of planetary motion, the formation and evolution of the Moon, the structure and geophysical evolution of the planets, and the search for habitable environments outside of Earth. (L)

Instructor(s): F. Ciesla Terms Offered: Autumn

**PHSC 10900. Ice-Age Earth. 100 Units.**

We examine the cause and effects of Earth's great ice ages, and use the knowledge so gained as a means to inform ourselves about the stability of Earth's climate system and its relationship to the life of humankind. The ice age also serves as the starting point for the exploration of Earth's history through deep time undertaken in PHSC 11000. The lab exercises deal with topographic maps that depict glacial landforms in various national parks such as Yosemite National Park in California and Glacier National Park in Montana. We also explore the glacial landforms in the Chicago vicinity through topographic maps and a day-long field trip. A day-long weekend field trip to ice-age sites is required. If a weekend date is not possible, the field trip will be run on the Wednesday prior to Thanksgiving recess. Students who register for this class must arrange to attend the field trip at one of the offered dates. (L)

Instructor(s): D. Rowley Terms Offered: Not Offered 2017-18

**PHSC 11000. Environmental History of the Earth. 100 Units.**

This course considers how physical and biological processes determine environmental conditions at the surface of the Earth, and how environments have changed over the 4.5 billion-year history of Earth. Topics include the methods of historical inference in geology; major transitions in the history of life, including the origin of life, the evolution of oxygen-producing photosynthesis, the origin of animals, and the series of massive extinctions that have repeatedly re-set ecosystems both on land and in the sea; and ecosystem evolution, including the environmental effects of human evolution. Labs involve hands-on study of rock and fossil specimens, and analysis and interpretation of datasets drawn from the scientific literature and/or faculty research programs.

Instructor(s): M. Webster; S. Kidwell Terms Offered: Spring

**PHSC 11100. Modern Physics I: Modern Physics in the Everyday World. 100 Units.**

This course will introduce key concepts in classical and quantum physics and will relate them to things we encounter everyday, such as lasers, microwaves, and magnetic levitation. It will also discuss some of the recent developments in chaos, nanotechnology, and quantum computing, and how they will change the world we live in. (L)

Terms Offered: Autumn

Note(s): Must be taken with either PHSC 11200 or PHSC 11300

**PHSC 11200. Modern Physics II: Paradoxes in Modern Physics. 100 Units.**

Physics advancements are often the result of conflict between, on the one hand, existing ideas and speculations, and on the other, observations and measurements. In this course, we explore historical and modern paradoxes in physics including quantum phenomena, elementary particle physics, and others. We match common sense and sensibility with scientific abstraction to broaden our understanding of the physical world. (L)

Terms Offered: Winter

Prerequisite(s): PHSC 11100

Note(s): Must be taken with PHSC 11100

**PHSC 11300. Everyday Physics. 100 Units.**

This course will be a walking tour through various topics in physics. It is not organized in the traditional way—mechanics, heat, electromagnetism, quantum mechanics, and relativity—but rather will look at real-world phenomena and try to figure out what is going on. Relying somewhat on knowledge gained in PHSC 11100, we will ask questions about the world around us. No formulas will be used. Questions might include, "Which draws more water from Lake Michigan, evaporation or the city of Chicago?" and "How does my cellphone work and what can I do to improve its reception?" The course will also address more substantial topics such as measuring the density of air, figuring out whether airplanes should be able to fly, estimating the density of the Sun, and determining the size of molecules. (L)

Terms Offered: Not offered in 2017-18

Prerequisite(s): PHSC 11100 or consent of instructor

**PHSC 11400. Development of Life on Earth. 100 Units.**

Starting with the big bang theory of the early universe, students study how the laws of physics guided the evolution of the universe through the processes most likely to have produced life on earth as it exists today. Physics topics include the fundamental interactions and the early universe; nuclear, atomic, and molecular structure; Newton's laws and the formation of stars, galaxies, and planetary systems; thermonuclear fusion in stars; the physical origin of the chemical elements; the laws of electricity and magnetism and electromagnetic radiation; the laws of thermodynamics; atmospheric physics; and physical processes on primordial earth. (L)

Terms Offered: Not offered in 2017-18

**PHSC 11500. Extraterrestrial Life. 100 Units.**

Building upon the topics in PHSC 11400, this course goes on to consider what the laws of physics has to say about life elsewhere in the universe. We begin with an analysis of the prospects for life on other bodies in the solar system, especially Mars. This is followed by a treatment of the physics behind the search for extraterrestrial intelligence and the feasibility of human interstellar and intergalactic spaceflight. We conclude with a critical examination of speculative ideas in the popular media such as the suggestion that the universe itself is a living organism. Physics topics include extended applications of topics from PHSC 11400, optics and electromagnetic communication, rocket propulsion and advanced propulsion systems, theories of special and general relativity, quantum physics, complexity, and emergence. (L)

Terms Offered: Not offered in 2017-18

Prerequisite(s): PHSC 11400

**PHSC 11902. The Secret Lives of Stars. 100 Units.**

This course fulfills the general education requirement in physical sciences for non-majors. As of Fall of 2015, PHSC 11900, 11902 and 12000 are no longer offered. Students who have taken 11902 but have not taken 12000 may complete a two-quarter Physical Sciences requirement by taking PHSC 12600, 12610, 12710 or 12720, although 12710 is recommended as the best fit with 11902 among these options. This course may not be combined with PHSC 11900.

Terms Offered: Not Offered in 2017-18

Note(s): This course is no longer offered as of Autumn Quarter 2015

**PHSC 12300. Chemistry for an Alternative Energy Economy. 100 Units.**

This course will cover the chemistry of alternative energy technologies and the potential for science to provide climate change solutions. Topics will include alternative energy production (photovoltaics, solar fuels, bio fuels and geothermal), storage and conversion (batteries and fuel cells), and climate change mitigation (carbon capture and geoengineering).

Discussion of these topics will be enriched by an understanding of the basic chemical principles behind energy production and conversion. Students will gain an appreciation of the pivotal role chemistry can play in an alternative energy economy and a foundation to better understand energy issues. The lab component will provide experiential support of the lecture material through hands on experiments and exploratory projects. (L)

Instructor(s): Jessica Swanson Terms Offered: Spring

Prerequisite(s): No formal prerequisite, but some previous background in Chemistry is recommended.

Note(s): In order to satisfy the general education requirements in the physical sciences PHSC 12300 may be combined with PHSC 12400 The Chemistry of Big Problems, PHSC 12500 Molecular Mechanisms of Human Disease, PHSC 13400 Global Warming. If a student does not wish to continue with CHEM 10100 Introductory General Chemistry, CHEM 11100 Comprehensive General Chemistry, or CHEM 12100 Honors General Chemistry, they may take PHSC 12300 as the second course.,

**PHSC 12400. The Chemistry of Big Problems. 100 Units.**

This course will discuss the chemistry of big problems that impact human life and society, such as the future accessibility of personal genetic sequence information, genetically modified organisms, or plastics and polymers and alternative sources of energy. We will use each of these topics as a window to grasp the underlying chemistry, reaction mechanisms, analytical methods, and quantitative chemical principles applied to major scientific issues that impact the world around us. Relevant examples will be considered in a discussion-oriented format to bring out chemical and analytical principles associated with big problems. The course will have a classroom lecture component as well as a laboratory component. The laboratory component will involve case studies and problem solving by application of analytical principles and independent work or teams of students. (L)

Instructor(s): Y. Krishnan Terms Offered: Winter

Prerequisite(s): Some previous background in Chemistry is recommended.

**PHSC 12500. Molecular Mechanisms of Human Disease. 100 Units.**

This course will examine the molecular basis for a few specific instances of human disease. We will use each of these molecular case studies as a vehicle to demonstrate quantitative chemical principles such as thermodynamics, chemical equilibrium, chemical kinetics, diffusive dynamics, and DNA damage and repair. The goal of the course will be to use well-understood biological and medical examples to illustrate chemical principles and to give students a toolbox and techniques to understand molecular systems more broadly. The course will have a classroom lecture component as well as a laboratory component. The laboratory component will involve specific case studies and mechanistic proposals that represent exploratory independent work by teams of students. (L)

Instructor(s): G. Engel Terms Offered: Spring

Prerequisite(s): Some previous background in Chemistry recommended

**PHSC 12600. Matter, Energy, Space, and Time. 100 Units.**

This course is a comprehensive survey of how the physical world works, and how matter, energy, space, and time evolved from the beginning to the present. We will explore current theories of the evolution of the Universe and see how these four concepts give us remarkable insight into how our world came to be. Beginning with a brief survey of the historical development of mathematics, physics, and astronomy, we then focus on the modern theory of the physical universe, space and time in relativity, the quantum theory of matter and energy, and the evolution of cosmic structure and composition. The lab component for the class will be aimed at understanding some of the tools astronomers and physicists have used to make the observations that led to our picture of the Universe. Although quantitative analysis will be an important part of the course, students will not be expected to employ mathematics beyond algebra. (L)

Instructor(s): S. Meyer Terms Offered: Autumn

Note(s): Approved Sequences Warning! PHSC 12600 can only be combined as follows to form an approved PHSC sequence: PHSC 12600-12610, PHSC 12600-12620, PHSC 12600-12700, or PHSC 12600-12710.

Equivalent Course(s): ASTR 12600

**PHSC 12610. Black Holes. 100 Units.**

Black holes are the most exotic, extreme and paradoxical systems in the universe. They are the densest concentrations of energy, yet they convert all matter that falls in to a pure vacuum with extreme space-time curvature; they radiate more power than anything else, even though most of their radiation may not even be made of light; they are mathematically the most perfectly understood of any physical structure, but their enigmatic behavior is still the subject of a disagreement, even among experts, that highlights our ignorance of how quantum physics relates to gravity. This course will survey the physics of space and time, the nature of black holes, their effects on surrounding matter and light, the astrophysical contexts in which they are observed, and their importance in such frontier areas of research as quantum gravity and gravitational waves. Quantitative analysis will be an important part of the course, but mathematics beyond algebra will not be required. (L)

Instructor(s): C. Hogan Terms Offered: Winter

Prerequisite(s): PHSC 12600 or PHSC 12700. Prerequisites are required when the course is to be taken as part of an approved sequence to satisfy the PHSC general education requirement. If the course is to be taken as an elective, the prerequisite is recommended but not required.

Note(s): Approved Sequences Warning! PHSC 12610 can only be combined as follows to form an approved PHSC sequence: PHSC 12600-12610 or PHSC 12700-12610.

Equivalent Course(s): ASTR 12610

**PHSC 12620. The Big Bang. 100 Units.**

How old is the universe? How big is it? What is it made of? Why is there a universe? Will it last forever? Are there other universes? These questions have been asked for millennia. The answers involve our modern theory for the origin of the universe, The Big Bang, a model that can account for much of what we observe. It provides a framework for understanding the last 14 billion years over which our Universe expanded, cooled, and evolved from the simple, formless fog of the primordial soup, into a universe of galaxies, stars, planets, people, poodles, protozoa, pond scum, and politicians. The course will explore the history of scientific cosmology and the evidence for the Big Bang model, its consequences for the earliest moments after the Big Bang, and its predictions for the eventual fate of the Universe. Quantitative analysis will be an important part of the course, but prior experience with mathematics beyond algebra will not be required. (L)

Instructor(s): M. Turner Terms Offered: Spring

Prerequisite(s): PHSC 12600 must be taken before PHSC 12620 to form an approved sequence that will satisfy the PHSC general education requirement. If the course is to be taken as an elective, the prerequisite is recommended but not required.

Note(s): Approved Sequences Warning! PHSC 12620 can only be combined as follows to form an approved PHSC sequence: PHSC 12600-12620.

Equivalent Course(s): ASTR 12620

**PHSC 12700. Stars. 100 Units.**

Elements such as carbon and oxygen are created in fusion reactions at high temperatures and pressures in the deep interiors of stars, conditions that naturally arise in stars like the Sun. This course will outline the physical principles at work and the history of the development of key ideas: how nuclear physics and the theory of stellar interiors account for how stars shine, why they live for such long times, and how the heavy elements in their cores are dispersed to seed a new generation of stars. Gravity assembles stars out of more diffuse material, a process that includes the formation of planetary systems. The course shows how, taken together, these physical processes naturally lead to the ingredients necessary for the emergence of life. The course features quantitative analysis of data; any tools needed beyond pre-calculus algebra will be taught as part of the course. (L)

Instructor(s): D. Fabrycky Terms Offered: Autumn

Note(s): Approved Sequences Warning! PHSC 12700 can only be combined as follows to form an approved PHSC sequence: PHSC 12700-12710, PHSC 12700-12720 or PHSC 12700-12610.

Equivalent Course(s): ASTR 12700

**PHSC 12710. Galaxies. 100 Units.**

Galaxies have been called "island universes," places where stars are concentrated, where they are born, and where they die. These collections of stars, gas, and dust form much of the visible structures in the Universe. Using extensive modern observational data from a wide range of telescopes, we will trace the modern understanding of the formation and evolution of galaxies and the stars in them. Galaxies will then be used as markers of yet larger-scale structures, in order to examine the influence of gravity over cosmic time. Our explorations will highlight the profound discovery that most of the mass in galaxies (and the Universe as a whole) is in fact an exotic form of matter—dark matter—that we cannot directly see. Observationally oriented labs will allow students to directly experience how some of the modern understanding of galaxies has arisen. Quantitative analysis will be an important part of the course in both laboratory work and lectures, but mathematics beyond algebra and some geometric understanding will not be required. (L)

Instructor(s): M. Gladders Terms Offered: Winter

Prerequisite(s): PHSC 12600 or PHSC 12700 must be taken before PHSC 12710 to form an approved sequence that will satisfy the PHSC general education requirement. If the course is to be taken as an elective, the prerequisite is recommended but not required.

Note(s): Approved Sequences Warning! PHSC 12710 can only be combined as follows to form an approved PHSC sequence: PHSC 12600-12710, PHSC 12700-12710 or PHSC 12710-12720.

Equivalent Course(s): ASTR 12710

**PHSC 12720. Exoplanets. 100 Units.**

The past two decades have witnessed the discovery of planets in orbit around other stars and the characterization of extra-Solar (exo-) planetary systems. We are now able to place our Solar System into the context of other worlds and a surprising conclusion that most planetary systems look nothing like our own. A challenging next step is to find planets as small as the Earth in orbit around stars like the Sun. The architecture of planetary systems reflects the formation of the parent star and its protoplanetary disk, and how these have changed with time. This course will review the techniques for discovery of planets around other stars, what we have learned so far about exoplanetary systems, and the driving questions for the future, including the quest for habitable environments elsewhere. Although quantitative analysis will be an important part of the course, students will not be expected to employ mathematics beyond algebra. (L)

Instructor(s): L. Rogers Terms Offered: Spring

Prerequisite(s): PHSC 10800, PHSC 10100, PHSC 12700 or PHSC 12710 must be taken before PHSC 12720 to form an approved sequence that will satisfy the PHSC general education requirement. If PHSC 12720 is to be taken as an elective, the prerequisite is recommended but not required.

Note(s): Approved Sequences Warning! PHSC 12720 can only be combined as follows to form an approved PHSC sequence: PHSC 12700-12720, PHSC 12710-12720, PHSC 10800-12720 or PHSC 10100-12720.

Equivalent Course(s): ASTR 12720

**PHSC 13400. Global Warming: Understanding the Forecast. 100 Units.**

This course presents the science behind the forecast of global warming to enable the student to evaluate the likelihood and potential severity of anthropogenic climate change in the coming centuries. It includes an overview of the physics of the greenhouse effect, including comparisons with Venus and Mars; an overview of the carbon cycle in its role as a global thermostat; predictions and reliability of climate model forecasts of the greenhouse world. (L) This course is part of the College Course Cluster program, Climate Change, Culture, and Society.

Instructor(s): D. Archer, D. MacAyeal Terms Offered: Autumn, Spring

Prerequisite(s): Some knowledge of chemistry or physics helpful.

Equivalent Course(s): ENST 12300, GEOS 13400, ENSC 13400

**PHSC 13500. Chemistry and the Atmosphere. 100 Units.**

This course focuses on aspects of chemistry as they apply to the Earth's atmosphere. The first half considers atmospheric structure and fundamental chemical principles, while the second half presents examples of chemical systems that operate in the atmosphere. Topics include the chemical composition of the atmosphere, the structure of atoms and molecules, the nature of chemical reactions, the interaction of solar radiation with atmospheric gases, the properties of the water molecule, formation of an ozone layer, and the chemistry of urban air pollution.

Terms Offered: Not offered 2017-18

Note(s): As of Fall 2015 this course will no longer be offered.

Equivalent Course(s): ENST 12100

**PHSC 13600. Natural Hazards. 100 Units.**

This course presents the current understanding of high-impact weather and geologic events and an introduction to risk assessment and mitigation. Topics include an overview of geography, statistics, and societal impacts of the world's natural hazards; physics and forecasts of hurricanes, extratropical cyclones, tornadoes, earthquakes, tsunamis, volcanic eruptions, droughts, floods, wildfires, and landslides; climate change and weather events; quantifying risks; and successful examples of community- and national-level disaster prevention programs. (L)

Instructor(s): N. Nakamura Terms Offered: Winter

**Elective Courses**

Any of the following can be used only as a third course in physical sciences to meet the general education requirement (of six courses total in the biological, physical, and mathematical sciences).

**PHSC 18100. The Milky Way. 100 Units.**

Within a largely empty universe, we live in a vast stellar "island" that we call the Milky Way. As we survey the stellar and interstellar components of the Milky Way—the distribution and motions of stars and interstellar gas, and how these dynamic, ever-changing components interact with each other during their life cycles inside the Milky Way—we will follow the path of ancient astronomers, wonder at their mistakes and prejudices, and form our own understanding.

Instructor(s): N. Gnedin Terms Offered: Autumn

Prerequisite(s): Any two-course 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.

Equivalent Course(s): ASTR 18100

**PHSC 18200. The Origin and Evolution of the Universe. 100 Units.**

This course provides a comprehensive introduction to modern cosmology for students wishing to delve deeper into the subject than PHSC 12620 (which is not a prerequisite) but at a similar mathematical level. It will discuss how the fundamental laws of physics allow us to understand the origin, evolution, and large-scale structure of the universe. After a brief review of the history of cosmology, the course will cover the expansion of the universe, Newtonian cosmology, Einstein's Special and General Relativity, black holes, dark matter, dark energy, the Cosmic Microwave Background radiation, Big Bang nucleosynthesis, the early universe, primordial inflation, the origin and evolution of large-scale structure in the universe, and cosmic surveys that are probing inflation and cosmic acceleration.

Instructor(s): Josh Frieman Terms Offered: Winter

Prerequisite(s): Any two-course 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.

Equivalent Course(s): ASTR 18200

**PHSC 18300. Searching Between the Stars. 100 Units.**

With the advent of modern observational techniques (e.g., radio, satellite astronomy), it has become possible to study free atoms, molecules, and dust in the vast space between the stars. The observation of interstellar matter provides information on the physical and chemical conditions of space and on the formation and evolution of stars.

Instructor(s): D. Harper Terms Offered: TBD

Prerequisite(s): Any two-course 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.

Equivalent Course(s): ASTR 18300

**PHSC 18800. Philosophical Problems in Cosmology. 100 Units.**

In this course, we will undertake a comparison of the philosophical underpinnings of the Aristotelian and Copernican cosmologies, including a comparison of mechanistic and teleological approaches to the natural world. The epistemological foundations of the scientific method, in particular as applied to cosmology (from Galileo to the modern context) will be examined, as will positivist vs. realistic outlooks on cosmology. (For example, what does science say—or not say—about the inside of a black hole, or the space beyond the Hubble horizon?) We will ponder questions such as: *Do the epistemological foundations of science require us to be able to repeat relevant experiments? If so, does this disqualify cosmology as a science? If not, why? Might our universe be part of a computer simulation? What information could possibly convince us that this is true or false?*

Instructor(s): Dan Hooper Terms Offered: Spring

Prerequisite(s): Any two-course 10000-level general education sequence in chemistry, geophysical sciences, physical sciences, or physics.

Equivalent Course(s): ASTR 18800







#### Font Notice

This document should contain certain fonts with restrictive licenses. For this draft, substitutions were made using less legally restrictive fonts. Specifically:

Times was used instead of Trajan.

Times was used instead of Palatino.

The editor may contact Leepfrog for a draft with the correct fonts in place.