

# Systems Science

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M.S.  
Ph.D.

Systems science is the study and application of general methods of problem solving and general principles governing systems of widely differing types. Systems concepts and techniques are used extensively for both applied and research purposes. In industry and government, considerable demand exists for professionals who are skilled in modern methods of decision making and systems design and who are capable of managing complex social and technical systems. In mathematics, engineering, business administration, and the natural and social sciences, systems theorists continue to make important contributions to the growth of knowledge within academic disciplines and to the application of knowledge across disciplinary boundaries. Indeed, the most exciting research in science and engineering today is outside the boundaries of traditional disciplines and is done at centers and institutes that study systems described as complex, artificial, adaptive, nonlinear, or intelligent. Such research can be viewed as the continuation and contemporary form of systems science, which crystallized after World War II around general systems theory, cybernetics, operations research, systems dynamics, systems engineering, and systems analysis.

The core curriculum includes courses in artificial life, computer simulation, discrete multivariate modeling, dynamical systems, game theory, information theory, neural networks, systems approach, system dynamics, systems theory, and other areas.

**Doctor of Philosophy in systems science.** There are two options for the Ph.D. in systems science.

**Core option:** The student pursues interdisciplinary studies with a strong emphasis on systems coursework. Examples of study topics appropriate for inclusion in such a program are: intelligent systems; information, structure and dynamics; organization, decision making and optimization; modeling and simulation; systems philosophy; systems approach; and related topics in the study of complex systems. To accommodate broader student interests, the Core option includes a Multidisciplinary track as well (see Program documents on web).

**Departmental option:** The student undertakes advanced academic preparation primarily in a single department or school. Discipline-oriented studies, augmented by systems coursework, lead to dissertation research that incorporates systems ideas and methods. This option has historically been available in the College of Liberal Arts and Sciences, the Maseeh College of Engineering and Computer Science, and the School of Business Administration.

Both of the options facilitate the design of curricula which are individually tailored to the needs and interests of the students.

**Master of Science in systems science.** The Systems Science M.S. program emphasizes the systems theories and methodologies taught in the current Systems Science Ph.D. program. Students choose a combination of systems science courses plus approved courses in associated disciplines. Concentration areas include (but are not limited to) the faculty research areas described in the document entitled Systems Science Research at PSU. Upon completion of the program, students will understand a wide variety of systems ideas, be able to use them in modeling and analysis, be able to tap methods and ideas from a variety of disciplines, and will gain expertise in problem solving and in being integrative thinkers.

## Graduate certificates

The Systems Science program offers graduate certificates in two specialty areas: computational intelligence and computer modeling and simulation. Please see the Graduate Studies section on for graduate certificate requirements.

## Admission requirements

**Master of Science in systems science.** Admission is based on the applicant's academic transcript, two letters of recommendation, a statement of interests and objectives, and other background material considered individually by an admissions committee, in line with general University admission policies. GRE scores are recommended but not required. Students admitted to the Ph.D. program (either option) need not apply separately for admission to the master's program, but must complete and submit a GO-19D form to the program.

**Doctor of Philosophy in systems science.** Students with high academic standing and with a baccalaureate and/or master's degree may apply for admission to the doctoral program. D. Applicants should have a combined GRE score of at least 1150

(quantitative plus verbal) taken within the last five years. (This is used to indicate student's national ranking.) For applicants to the SYSC: SBA departmental option, a GMAT score of at least 550 may be submitted instead of a GRE score. The Admissions Committee will consider exceptions to the five-year requirement if the GMAT score or both GRE scores are in the 90th percentile or higher.

In considering an applicant for admission, the admissions committee for Systems Science seeks evidence of demonstrated intellectual capacity, undergraduate and/or graduate training in an appropriate discipline (or disciplines), adequate preparation in mathematics (including calculus, statistics, and computer programming), and the potential to pursue advanced study and research for the Ph.D. Students are admitted to the program in Fall, Winter, and Spring terms. Prospective applicants should call or email the Systems Science Program for the information packet. It is also available online at [www.sysc.pdx.edu](http://www.sysc.pdx.edu). The Office of Admissions must receive: (1) the completed Application to Doctoral Program form, (2) the application fee, (3) one copy of all undergraduate and graduate transcripts to be sent by the institutions to Portland State University, and (4) TOEFL if a foreign student. The applicant must arrange for Systems Science to receive: (1) the completed Application to Doctoral Program form, (2) one copy of all undergraduate and graduate transcripts to be sent by the institutions, (3) GRE aptitude or GMAT scores, (4) three letters of recommendation from faculty and/or professionals acquainted with the applicant's abilities and record, (5) statement of the student's expectations of the program, and (6) TOEFL score of 575 or other evidence of English competency if a foreign student.

Each applicant who has received formal notice of admission to the Systems Science Doctoral Program should contact the Program office for initial advising. Adviser(s) will be appointed to assist and consult with the admitted student regularly in planning the program of study and research. A comprehensive examination committee is appointed for each student to give required oral and written examinations. A dissertation committee supervises the research and preparation of the dissertation.

## Degree requirements

**Master of Science in systems science.** A discussion of general requirements for master's degrees is on page 67. In addition, students must meet the requirements below and submit the necessary Graduate Studies Office forms. All students will be required to complete 24 credits of graded courses (pass/no pass are not applicable) listed under Systems Science in the PSU catalog numbered SySc 510-599 or SySc 610-699. Up to 3 credits of SySc 507 (with a Pass grade) may be included to satisfy the 45 credit hour requirement. *Note: There is a seven-year limit on courses for the master's degree. This is not true for the Ph.D.* The master's program has two options:

**Thesis option:** An additional 12 credits of Systems Science courses (numbered as above) and/or approved courses from other departments (see document entitled, *Approved Resource Courses for the Master of Science Program in Systems Science*); and 9 thesis credits. A student selecting the thesis option must form a thesis committee of at least three faculty members (one of whom must be a Systems Science core faculty), and pass an oral thesis defense.

**Non-Thesis option:** An additional 21 credits of Systems Science courses (numbered as above) and/or approved courses from other departments (see document entitled, *Approved Resource Courses for the Master of Science Program in Systems Science*). Up to 4 credits of Systems Science by-arrangement credits may be used to satisfy this requirement.

A student selecting the non-thesis option will be required to pass two written comprehensive exams, each of which covers a minimum of 16 credit hours of coursework. The comprehensive exam requirement is to be successfully completed within 5 years of admission to the master's program. One of the examiners must be a Systems Science core faculty member. Students admitted to the Ph.D. program who pass their comprehensive exams meet this requirement automatically. Ph.D. students who do not pass their comprehensive exams meet this requirement if they pass at least two of their written exams, one of which must be a core systems science exam.

**Doctor of Philosophy in systems science.** A discussion of general requirements for doctoral degrees is on page 69. Minimum requirements specific to the Ph.D. in systems science include 72 course credit hours, organized as follows:

**Systems component.** Students in both the core and departmental options are required to complete 16 credits of systems science coursework as the minimum systems component of the program. All students must satisfy the first 8 credits by taking two of the following courses: SySc 511, SySc 512, SySc 513, SySc 514. Any combination of two of the courses, except SySc 512 and 514 is acceptable. SySc 511 and 512 explore systems concepts in more mathematical terms than SySc 513 and 514. Consequently students taking SySc 511 and 512 should have stronger mathematical background.

To fulfill the remaining 8 credits of the systems component, students must take two systems science courses numbered 515 through 599 or 610 and above, or approved 510 courses. These elective courses are either advanced systems science courses or integrative courses. The integrative courses have emerged from the interdisciplinary nature of the program. They are taught jointly by faculty from Systems Science and participating departments, and the topics covered illustrate specific applications of systems concepts.

**Additional coursework requirements.** Beyond the systems component described above, additional graduate courses are required to meet the 72 credit hour program minimum for advancement to candidacy. Participating departments may have

additional or more specific requirements. Core option students are required to take 3 credits of SySc 507 (offered at 1 credit per term) and an additional 9 credits in Systems Science beyond the 16 credit core requirement cited earlier. Design of the student's comprehensive exam and anticipated dissertation research should guide course selection.

Courses taken to satisfy the systems core and additional coursework requirements must be at the 500 or 600 level. Credit for graduate work done elsewhere (with a grade of B or better) may also be approved. However, at least 27 credits of coursework (not including dissertation credits) must be taken at Portland State University.

Decisions to transfer credits for core option students are made by the program director upon recommendation of the student's adviser(s); decisions for departmental option students are made by the department/school. There is no specific time limitation on when courses were taken; however, the student is expected to be familiar with, and may be examined on, material being given in current courses equivalent to those included in the comprehensive examination proposal.

**Enrollment.** Students are required to be enrolled continuously, except if a leave of absence is formally requested and approved by the Program director. Failure to take courses for a year, or failure to maintain continued progress after coursework is completed will result in a student being dropped from the program.

**Language requirement.** Foreign language competency may be required of departmental option students in some departments which also determine the level of competency and testing procedures. (Consult the appropriate department for further information.) There is no foreign language requirement for the core option. If required, the foreign language examination must be successfully completed before the student is allowed to take the comprehensive examinations.

**Comprehensive examinations.** Written and oral comprehensive examinations are required in appropriate areas to demonstrate the breadth and depth of the student's academic competence and expertise in research techniques pertinent to his/her intended dissertation area. Written exams cover four distinct areas, each including a minimum of 16 course credit hours. See the Systems Science Ph.D. Program Supplemental Rules for more details (available on the web).

**Advancement to candidacy.** All students must establish competency in appropriate research methodology before beginning their dissertation research. After this and all other requirements have been met, the student prepares a proposal for independent research leading to a significant and original contribution to knowledge in the systems field. When the proposal is accepted, the student is advanced to candidacy, and then focuses exclusively on research. Students must register for at least 27 credits of dissertation research after advancement to candidacy.

**Dissertation.** Completed research is presented in a dissertation which must be approved and successfully defended in a final oral examination. After Advancement to Candidacy, but prior to this examination, core students are required to present their research at the SySc 507 Seminar, a pre-announced 50-minute formal presentation.

The student can anticipate approximately four to five years of full-time study beyond the baccalaureate degree in order to satisfy the program requirements. Detailed additional information on requirements and procedures are contained in the document, "Systems Science Ph.D. Program Supplemental Rules," and should be obtained by visiting our Web site: [www.sysc.pdx.edu](http://www.sysc.pdx.edu) or contacting the Systems Science Ph.D. Program.

## Courses

Courses with an asterisk (\*) are not offered every year.

### SySc 501

#### **Research (Credit to be arranged.)**

Research which is normally not part of the thesis.

### SySc 503

#### **Thesis (Credit to be arranged.)**

All aspects of the thesis including research and its writing.

### SySc 505

#### **Reading and Conference (Credit to be arranged.)**

Scholarly examination of literature including discussion between student and professor.

### SySc 507

#### **Seminar (Credit to be arranged.)**

Discussion of recent and current research and/or presentation of progress and final reports.

### SySc 508

#### **Workshop (Credit to be arranged.)**

### SySc 510 Selected Topics (Credit to be arranged.)

### SySc 511

#### **Systems Theory (4)**

Surveys fundamental systems concepts and central aspects of systems theory. The course begins with an overview of the systems paradigm and the systems field as a whole. Topics then include introductions to set and information-theoretic multivariate relations and structures, discrete dynamic systems; model representation and simulation; decision analysis, optimization, game theory; artificial intelligence, complex adaptive systems. Readings drawn from mathematics, the natural and social sciences, and the professional disciplines (e.g., engineering, business).

Course content derives both from “classical” general systems theory, cybernetics, and operations research as well as from contemporary systems research, which is organized around the themes of nonlinear dynamics, complexity, and adaptation. Prerequisites: graduate standing, calculus, probability, computer programming.

#### **SySc 512**

##### **Quantitative Methods of Systems Science (4)**

An introduction to the quantitative representation and investigation of systems with a focus that emphasizes tools more than applications. Topics include linear dynamics, optimization, and uncertainty. The level of presentation assumes familiarity and facility with calculus. Notions from linear algebra unify the topics and those notions will be presented. Required coursework includes both calculations to be done on a computer and calculations to be done by hand. Prerequisites: one year of calculus, probability and familiarity with computers, graduate standing.

#### **SySc 513**

##### **Systems Approach (4)**

Provides practitioner-oriented definition of systems, including: importance of observer dependence and context, and ideas of meta-systems, subsystems; notion of value system and associated optimization/sub-optimization; aspects of life-cycle project management; the underlying notions of inquiring systems; and key aspects of learning (human) organizations. Qualitative tools for the system’s practitioner, including graphical tools, basic ideas of modeling/simulation and structural modeling. Also, the multiple perspectives aspect of the systems approach. Prerequisite: graduate standing.

#### **SySc 514**

##### **System Dynamics (4)**

Introduces concepts and a methodology for analyzing the behavioral dynamics of systems that consist of complex “webs” of feedback loops. Primary emphasis is on building computer models of these systems and using these models to enhance understanding, make predictions, and find ways to improve the performance of systems and processes. Models are defined in terms of a set of “rate” equations that are numerically integrated to simulate behavior over time. The process of applying this methodology to real world situations is discussed in detail. Prerequisite: graduate standing.

#### **SySc 521/621**

##### **Systems Philosophy (4)**

A study of ideas central to systems theory and philosophy. The course focuses on concepts rather than mathematics, and organizes systems ideas around the theme of the fundamental “difficulties” (problems, imperfections, modes of failure) encountered by systems of widely differing types. Though these systems ideas often come from the natural sciences and engineering, they are significant also for the social sciences, the professional fields, and even the arts and humanities.

#### **SySc 525/625**

##### **Agent Based Simulation (4)**

Introduction to simulation methods that impart simple rules to collections of “agents” that interact within an environment represented as a spatial grid. The properties of the agents and the environment vary dynamically, and often result in behavior patterns that are complex in ways that are not readily apparent from an examination of the rules that generated the behavior. Such behavior is often referred to as emergent, with examples including flocks of birds, traffic jams, ant colonies, crowd phenomena, etc. Of particular interest is the fact that such phenomena occur without centralized control. This approach is often used to study social systems, but may be used to study a variety of natural and non-natural systems.

#### **SySc 527/627**

##### **Discrete System Simulation (4)**

The primary focus is on the application of discrete system simulation to real world problems using the Arena simulation language. The mathematical basis for discrete system simulation is probability theory and queuing theory. It is used extensively in the fields of operations research, civil engineering, and industrial engineering. Students apply the tools to projects within their fields of interest. Prerequisite: graduate standing or consent of the instructor.

#### **SySc 529/629**

##### **Business Process Modeling and Simulation (4)**

The primary focus is on the application of system simulation to process flow problems. Extend, a special-purpose computer simulation language, is used to develop models to describe and analyze both continuous and discrete flow processes in order to better understand bottlenecks and how to alleviate them. Such models are used to study, for example, manufacturing systems, business systems, and engineering systems. Students apply the concepts to projects within their fields of interest. Prerequisite: graduate standing or consent of the instructor.

#### **SySc 541/641**

##### **Dynamic Systems I (4)**

The fundamental concepts of modeling time dependent deterministic systems, including applications of dynamic models to various types of systems including electrical, mechanical, economic, and ecological. Computer methods are used as illustrations and as tools for analysis. Prerequisites: familiarity with high-level computer languages, applied linear algebra, differential equations, and multivariable calculus.

#### **SySc 545/645**

##### **Information Theory I (4)**

Establishes theoretical limits on the performance of techniques for compression or error correction of signals. This course focuses on communications applications, specifically source coding and channel coding for discrete signals. Topics will include: Entropy and Mutual Information, Asymptotic Equipartition (the Ergodic Theorem of Information Theory), Entropy Rates of Information Sources, Data Compression, and Channel Capacity.

**SySc 551/651****Discrete Multivariate Modeling (4)**

This course focuses on information theory as a tool for modeling and multivariate analysis and as a general framework for the study of structure and organization. The course examines the use of set- and information-theoretic techniques for the analysis of constraints in qualitative, as well as quantitative, data. Also covered are software implementations, relations to log-linear methods, and applications in the natural and social sciences and the arts. Prerequisite: SySc 511/611 or consent of instructor.

**SySc 552/652****Game Theory (4)**

Study of cooperation, competition, and conflict in social systems and associated issues of rationality. Emphasis is on game-theoretic models, particularly of dilemmas of collective action, their possible solutions, and their applications to social, economic, and political phenomena. Also covered are social choice theory, and other systems-theoretic approaches to cooperation, competition and conflict. Prerequisite: SySc 511/611 or consent of instructor.

**SySc 553/653****Manufacturing Systems Simulation (4)**

Application of discrete systems simulation to manufacturing processes, including production cells, assembly operations, materials handling, and scheduling. Students also learn general systems modeling concepts, such as how to model random processes and probabilistic events, and how to use a specific simulation package that features realistic animation of the system under study. Prerequisites: basic knowledge of probability and statistics, and some exposure to manufacturing processes and terminology. This course is the same as ETM 553/653; course may only be taken once for credit.

**SySc 557/657****Artificial Life (4)**

Artificial life (ALife) encompasses mathematical and computational studies of phenomena such as replication, metabolism, morphogenesis, learning, adaptation, and evolution. Situated at the intersection of computer science and biology (also physics and chemistry) and focused on abstract, materiality-independent aspects of life, its purpose is two-fold: to understand biological phenomena and to develop computational technologies. ALife bears significantly also on the social sciences and philosophy. It is part of the research program into "complex adaptive systems". Emphasizes (1) cellular automata (and other discrete dynamical models), (2) ecological and evolutionary simulations, and (3) genetic algorithm optimization and adaptation. Other topics include artificial chemistry (metabolism and origins of life) and philosophical issues. Prerequisites: graduate standing, calculus, probability, computer programming.

**SySc 575****AI: Neural Networks I (4)**

Introduces approach for developing computing devices whose design is based on models taken from neurobiology and on notion of "learning." A variety of NN architectures and associated computational algorithms for accomplishing the learning are studied. Experiments with various available architectures are performed via a simulation package. Students do a major project on the simulator or a special programming project. Prerequisite: graduate standing.

**SySc 576****AI: Neural Networks II (4)**

Focuses on applications. Topics in fuzzy set theory, control theory, and pattern recognition are studied and incorporated in considering neural networks. A design project (using NN simulator) in selected application area is done by each student. Prerequisite: SySc 575.

**SySc 601****Research (Credit to be arranged.)****SySc 603****Dissertation (Credit to be arranged.)****SySc 605****Reading and Conference (Credit to be arranged.)****SySc 607****Seminar (Credit to be arranged.)****SySc 608****Workshop (Credit to be arranged.)****SySc 610****Selected Topics (Credit to be arranged.)**