

COMPUTER SCIENCE DEPARTMENT

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INSTRUCTOR **Deborah S. Noonan** (M.S., William & Mary).

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ADJUNCT PROFESSORS **Rex K. Kincaid** (Ph.D., Purdue), and **Lawrence M. Leemis** (Ph.D., Purdue).

ADJUNCT ASSOCIATE PROFESSOR, **R. Michael Lewis** (Ph.D., Rice) and **Zia-ur Rahman**, (Ph.D., Virginia).

General Description

The Department offers a Master of Science (M.S.) in computer science and a Doctor of Philosophy (Ph.D.) in computer science. In conjunction with faculty from the Mathematics Department, the department also offers a M.S. with a specialization in computational operations research. As part of the Computational Science Cluster, the department offers a M.S. and a Ph.D. with a specialization in computational science. Well-qualified students who earn a M.S. with a specialization in computational operations research are encouraged to apply for admission to the Ph.D. program. Faculty are actively engaged in research in the following areas:

- Operating systems, networks, architecture, parallel and distributed computation, security, compiler construction, software engineering;
- Modeling and Simulation: discrete-event simulation, stochastic systems;
- Computational Science: serial and parallel numerical methods, numerical optimization;
- Foundations: analysis of algorithms, graph theory, cryptography; Operations Research: nonlinear programming, discrete optimization, metaheuristics, inventory theory, reliability, computational statistics, stochastic optimization.

Some faculty and graduate students participate in joint research activities with two nearby national research facilities: the NASA Langley Research Center and the Thomas Jefferson National Accelerator Facility (Jefferson Lab).

The department maintains several heterogeneous networks to support teaching and research. These networks include personal computers, Unix workstations, and multiprocessors. Additional information about the department can be found at the URL <http://www.cs.wm.edu>.

Admission

Applicants must submit test results for the aptitude portion of the Graduate Record Examination and are encouraged (but not required) to submit results from a suitable subject area. Students from non-English speaking countries must submit TOEFL results.

Admission requirements for the M.S. and Ph.D. in computer science

Students seeking the M.S. or Ph.D. degrees in computer science are expected to have a background that includes the following:

Mathematics: two calculus courses and one linear algebra course.

Computer Science: two introductory programming courses (CS1 and CS2 in the standard computer science curriculum) and one course in each of discrete mathematics, data structures, algorithms, and computer organization.

Applicants lacking this background may be admitted provisionally into the M.S. program. In that case, the department will establish a suitable set of qualifying courses at the time of admission. To achieve regular status, provisionally accepted students must earn at least a B in each qualifying course. There is no provisional admission into the Ph.D. program.

Admission requirements for the M.S. with a specialization in computational operations research

Students seeking the M.S. degree with a specialization in computational operations research are expected to have a background in mathematics, science or engineering and the ability to program in a high-level language. Students with insufficient background in computer science may be required to enroll in CSci 241 and CSci 303. Applicants lacking an appropriate background may be admitted provisionally.

Admission requirements for the M.S. with a specialization in computational science

Students seeking the M.S. degree with a specialization in computational science are expected to have a background in mathematics, science or engineering that includes the following:

Mathematics: two calculus courses and one linear algebra course

Computer Science: two introductory programming courses (CS1 and CS2 in the standard computer science curriculum).

Students with insufficient background in data structures, algorithms, computer organization, and systems programming may be required to enroll in CSci 241, CSci 303, CSci 304, and CSci 315.

Degree Requirements for the Master of Science

(See general College requirements in the section entitled 'Graduate Regulations' in this catalog.)

Students who have taken twelve or more credits in courses leading to a graduate degree must maintain a minimum grade point average of 3.0. Students with less than a 3.0 average may appeal in writing to the department's Committee on Admission, Retention, and Financial Aid to remain in the graduate program. The committee normally rejects appeals from students with less than a 2.75 grade point average.

Degree Requirements for the Master of Science

Students may choose to write a thesis or not. Students who do not choose the thesis option must complete 32 graduate credits, including CSci 710, Research Project. Students who choose the thesis option must complete 24 graduate credits including Csci 700, M.S. Thesis, and defend their thesis at an oral examination, open to the faculty and to whomever else the department may invite. CSci 710, Research Project can not be applied to the 24 credits. In either case, students can apply at most 12 credits in courses numbered below 600 and must satisfactorily complete CSci 653 and two of the following three courses: CSci652, CSci654, CSci664.

A student can not use courses taken in another department, nor CSci courses designated as Computational Operations Research courses (last digit in the course number is an 8), to satisfy degree requirements without prior written approval of the student's advisor and the Graduate Admissions Committee.

Students must submit a 2-year plan of study at the beginning of their first semester in the M.S. program, which must be endorsed by their faculty advisors and then approved by the Graduate Admission Committee.

Degree Requirements for the Master of Science with a Specialization in Computational Operations Research

Students must complete 32 graduate credits, including one of either CSci 698, Simulation and Modeling Project in Computational Operations Research, CSci 708, Research Project in Computational Operations Research, or CSci 710, Research Project. There is no thesis option for this specialization. In addition, students must satisfactorily complete at least seven courses from the following list of courses in the computational operations research area: CSci 608, 618, 628, 638, 648, 658, 668, 678, 688, 698, and 708.

Degree requirements for the Master of Science with a Specialization in Computational Science

Students must complete 32 graduate credits, including CSci 710, Research Project. Students may apply at most 12 credits in course numbered below 600 and must satisfactorily complete CSci 653, CSci 654, and CSci 674. In addition students must also satisfactorily complete two graduate courses from outside the Computer Science Department. Each student will have a three-person computational science advisory committee within the department to advise the student about what is needed to meet the certification requirements of the Computational Science Cluster. Students must submit a two year plan of study at the beginning of their first semester in the M.S. with a specialization in computational science program, which must be endorsed by their computational science advisory committee and then approved by the Graduate Admissions Committee. There is no thesis option for this specialization.

Degree Requirements for the Doctor of Philosophy

(See general College requirements in the section entitled 'Graduate Regulations' in this catalog.)

Students seeking the Ph.D. in computer science must complete a seven-course requirement with at least a 3.7 grade point average in the seven courses, and with no individual grade lower than B-. All seven courses must be taken at William and Mary.

All Ph.D. students must take:

- Csci 653 Analysis of Algorithms
- Ccsi 654 Advanced Computer Architecture
- Csci 664 Advanced Operating Systems

The remaining four courses may be chosen from the 600 or 700 level courses in the department, excluding: 670, Colloquium; 690, Readings; 695, Research; 700, M.S. thesis; 708, Research Project in Computational Science; 710, Research Project; 770, Colloquium; 790, Readings; and 795, Research. At least three of these four courses must be at the 700 level, and at most two may be taken outside the Computer Science Department. A student may not use courses taken in another department nor CSci course designated as Computational Operations Research courses (last digit in the course number is an 8), to satisfy degree requirements without prior written approval of the student's advisor and the Graduate Admissions Committee.

For the Degree of Doctor of Philosophy with a specialization in computational science the student must satisfy all of the department's requirements for the degree of Doctor of Philosophy, including the seven-course requirement. In support of the specialization in computational science, the student must take at least three graduate courses from outside the department. Of these three courses, at most two can also be used to satisfy the department's seven-course requirement.

Each computational science student will have a three-person computational science advisory committee within the department to advise the student about what is needed to meet the certification requirements of the Computational Science Cluster. The committee will approve the three graduate courses from outside the department, and insure that the dissertation topic incorporates computation in a creative way, either by developing an enabling computational technology, or by using such technologies to obtain a significant scientific result.

Doctoral students must complete a year of continuous residence as a full-time student at William & Mary. Students who obtain a M.S. or M.A. degree must complete their residency requirement after satisfying the requirements for a M.S. or M.A. degree (at William & Mary or elsewhere). Students who do not obtain a M.S. or M.A. degree must complete their residency requirement after satisfying the department's seven course requirement. There is no foreign language requirement.

In addition to required course work, doctoral students will identify a principal research advisor, form a doctoral advisory committee, and petition the department for acceptance into candidacy for the Ph.D. degree. After acceptance into candidacy, students must pass the thesis proposal exam. This examination is oral, is conducted by the candidate's committee, and is open to the faculty and to whomever else the department may invite. Approximately six months before the anticipated dissertation defense, the candidate is required to meet with the committee. At this meeting, the candidate is expected to describe in detail the status of the research upon which the dissertation is based and plan for conducting the work that remains to be done. The purpose of this meeting is to provide the committee with an opportunity to evaluate the candidate's work and plans, and to provide feedback and advice in advance of the defense. The committee may require, at its discretion, additional meetings before a defense date can be scheduled. Candidates must submit and satisfactorily defend a dissertation to a committee of at least five members, with at least one member from outside the department. The dissertation is based on original research and should contribute to the discipline's body of knowledge. The defense is oral and is open to the faculty and to whomever else the department may invite. Each year, the faculty will review how well doctoral students have progressed toward completion of their Ph.D. degree. The department provides written guidelines to help students judge their own progress. In addition, the department provides more specific regulations than those conveyed in this catalog. Students are solely responsible for familiarizing themselves with all guidelines and regulations of the department. In Computer Science and Computer Science with a specialization in Computational Science, students receiving regular admission to the M.S./Ph.D. program have (7) seven years from the

time they enter the graduate program to complete all degree requirements. There is no provisional admission to the Ph.D. programs in Computer Science. In Computer Science with a specialization in Computational Operations Research, students receiving admission to the M.S. program in Computational Operations Research must apply to the Ph.D. program in Computer Science after completing the M.S. degree requirements. Such students would have (7) seven years from the time of this second admission to complete the Ph.D. requirements.

Description of Courses

Wherever a William & Mary course is specified as a prerequisite, it is understood that appropriate experience or an equivalent course, taken at another institution, may be substituted for the specified prerequisite. Each such substitution must be approved by the instructor of the course for which a substitution is appropriate. Generally, graduate students should also consult with their advisors to verify that they meet all course prerequisites.

Note that 500-level courses are cross-listed as 400-level courses in the undergraduate catalog and will thus be open to undergraduates. In these cross-listed courses, there will be higher expectations and additional requirements for graduate students. Students should consult with the instructor of such a course for further information.

520. Elementary Topics.

Fall and Spring (1, 2, or 3 credits, depending on material) Prerequisites: Will be published in the registration schedule.

A treatment of elementary topics of interest not routinely covered by existing courses. Material may be chosen from various areas of computer science.

521. Implementation of Database Systems.

Spring (3) Prerequisite: An introductory course in database.

Issues involved in designing efficient database systems, and the strategies, data structures, and algorithms used in the implementation of such systems. Some advanced topics covered: data warehousing, online analytical processing, data mining, spatial data management.

523. Finite Automata and Theory of Computation.

Fall and Spring (3,3) Prerequisites: Linear Algebra, Algorithms.

Theory of sequential machines and finite automata. Turing machines, recursive functions, computability of functions.

524. Computer Architecture.

Spring (3). Prerequisite: Computer Organization.

An introduction to the principles of computer design. Topics include data representation, including adders, signed integer arithmetic, floating point representation and character representation. A study of microprocessor, minicomputer and mainframe architecture including clocks, memory management, bus communication and input/output.

526. Simulation.

Fall (3) Prerequisites: Calculus, Algorithms.

Introduction to simulation. Discrete and continuous stochastic models, random number generation, elementary statistics, simulation of queuing and inventory systems, Monte Carlo simulation, point and interval parameter estimation. Selected applications.

527. Computer Graphics.

Fall (3) Prerequisites: Linear Algebra, Algorithms, Computer Organization.

Introduction to computer graphics and its applications. Topics include coordinate systems, the relationship between continuous objects and discrete displays, fill and flood algorithms, two-dimensional geometric transformations, clipping, zooming, panning, and windowing. Topics from three-dimensional graphics include representations for objects, geometric and projection transformations, geometric modeling, and hidden line/surface removal algorithms.

530. Computer Languages.

Fall and Spring (1 or 2 credits, depending on material). Prerequisites: Will be published in the preregistration schedule.

Topics include syntax, semantics, and pragmatics of one computer language as well as aspects of that language's intended areas of application which influenced its design. The language studied will vary; students may repeat the course for different languages.

534. Network Systems and Design.

Fall (3) Prerequisites: Systems Programming, or permission of instructor.

The Internet; principles and design of network applications, including web servers and multimedia; transport, network and data link layers; network security; network performance evaluation and capacity planning.

535. Software Engineering.

Spring (3) Prerequisites: Programming Languages.

The software life cycle. Software design methodologies. Testing and maintenance. Programming teams.

542. Compiler Construction.

Spring (3) Prerequisites: Algorithms, Computer Organization, Programming Languages.

Principles and tools for the construction of translators for programming languages. Topics include lexical analysis, block structure, grammars, parsing, error recovery, program representation, run-time organization and code generation.

544. Principles of Operating Systems.

Fall (3) Prerequisites: Algorithms, Computer Organization, Systems Programming.

The conceptual view of an operating system as a collection of concurrent processes; semaphores, monitors, and rendezvous. Real and virtual memory organization, resource allocation, file organization and management, processor allocation and management, and external device management.

597 Problems in Computer Science.

Fall, Spring and Summer (1 Credit). Graded P (Pass) or F (Fail).

Supervised projects selected to suit the needs of the graduate student, including those wishing to perform an internship as part of the Curricular Practical Training Program. Projects to be chosen in consultation with the student's advisor. Acceptable research outlines and project reports are required. Students may count credits received in only one offering of this course toward the number of credits required for their degree.

608 Decision Theory.

(3) *Prerequisite: equivalent of Math 351.*

Development and use of systematic procedures for assisting decision makers in evaluating alternative choices. Emphasis is on problem formulation, uncertainty and risk assessment, Bayes, minimax and other decision rules and applications. Problems will be solved using appropriate software tools.

616. Stochastic Models in Computer Science.

Fall (3) Prerequisites: Discrete Mathematics, Calculus.

An introduction to stochastic models, problem solving, and expected value analysis as applied to algorithms and systems in computer science. Topics include probability, discrete and continuous random variables, discrete-time Markov chains, and continuous-time birth-death processes.

618. Models and Applications in Operations Research.

(3) *Prerequisite: equivalent of Math 323.*

A study of realistic and diverse Operations Research problems with emphasis upon model formulation, interpretation of results and implementation of solutions. Topics include applications of linear programming, goal programming, decomposition of large-scale problems, and job scheduling algorithms. Problems will be solved using appropriate software tools.

628. Linear Programming.

Fall (3). Prerequisite: equivalent of Math 211. Co-requisite: equivalent of CSci 241.

Theory and applications of linear programming. Topics include the simplex method, duality theory, sensitivity analysis and interior point methods. Problems will be solved using appropriate software tools.

638. Nonlinear Programming.

(3) *Prerequisites: CSci 628 and the equivalent of Math 212.*

Topics include unconstrained optimization, nonlinear least-squares, feasible-point methods, and penalty and barrier methods, with an emphasis on effective computational techniques.

648. Network Optimization.

(3) *Prerequisite: CSci 628.*

Network flow theory and algorithms, including transportation, maximum flow shortest path and minimum spanning tree problems. Applications to a variety of areas are also stressed. Problems will be solved using appropriate software tools.

652. Advanced Compiler Construction.

Fall (3) Prerequisite: Finite Automata, Compiler Construction.

Construction of compilers for programming languages, involving primarily the following phases: lexical analysis, parsing, semantic analysis, and code optimization. Course involves a semester project incorporating significant global code optimization. Other topics may include: error analysis and recovery, run-time organization, and code generation.

653. Analysis of Algorithms.

Fall (3) Prerequisite: Algorithms.

Algorithm design techniques including divide-and-conquer, dynamic programming and greedy method. Analysis methods including worst case and average case. Additional topics chosen from among amortized analysis, lower bound theory and NP-completeness.

654. Advanced Computer Architecture.

Fall or Spring (3) Prerequisite: Computer Architecture.

A study of high performance computer architecture with emphasis on experiments and simulation. Topics include pipelining, memory hierarchies, I/O, multiprocessors, and new designs for performance improvements.

658. Discrete Optimization.

Spring (3) Prerequisites: CSci 628 and the equivalent of CSci 303.

Topics include relaxation techniques, constructive heuristics, improving search techniques (simplex method simulated annealing, tabu search), branch and bound schemes, and valid inequalities for branch and cut methods. Problems will be solved using appropriate software tools.

663. Theory of Computation.

Spring (3) Prerequisites: Finite Automata and a strong mathematical background.

An in depth study of Turing machines and the equivalent computational models such as recursive function theory and lambda calculus. Church's thesis and incompleteness results. Computational complexity including NP-completeness.

664. Advanced Operating Systems.

Fall (3) Prerequisite: Operating Systems.

Advanced topics in the design and implementation of modern operating systems, especially those which support a distributed computer environment. Topics include: synchronization, mutual exclusion, language support, process and thread management, scheduling, remote procedure call, fault tolerance, network and parallel file systems, security, modeling and performance.

668. Reliability.

(3) Prerequisites: equivalent of Math 401 and CSci 141.

Introduction to probabilistic models and statistical method used in analysis of reliability problems. Topics include models for the lifetime of a system of components and statistical analysis of survival times data. Problems will be solved using appropriate software tools.

670. Colloquium.

Fall and Spring (1,1).

Each full-time graduate student is required to enroll in this course. No credits earned in this course may be applied to the number of credits required for a degree.

674. Parallel Computing.

Fall (3) Prerequisites: CSci 654, CSci 653, or permission of the instructor.

This course introduces parallel computation as a means of achieving high performance in modern parallel architectures. A unified approach is followed, where the design of parallel algorithms, their implementation and performance evaluation is studied in relation to the underlying system.

678. Statistical Analysis of Simulation Models.

(3) Prerequisites: equivalent of Math 351, Math 401 and CSci 141.

This course introduces statistical techniques used in the analysis of simulation models. The first half of the course develops techniques for determining appropriate inputs to a simulation model, and the last half develops analysis techniques that are applied to the output of a simulation model.

680. Topics.

Fall and Spring (1, 2, or 3 credits, depending on the material covered). Prerequisite: Will be published in the preregistration schedule.

A treatment of Master's level topics of interest not routinely covered by existing courses. Material may be chosen from various areas of computer science.

688. Topics in Computational Operations Research.

(3) May be repeated for different topics.

A treatment of Master's level topics of interest not routinely covered by existing courses. Material may be chosen from various areas of computational operations research.

****690. Readings in Computer Science.**

Fall or Spring (1, 2, or 3 credits, depending on the material covered). Graded P (Pass) or F (Failure). Prerequisite: Permission of the instructor and the Chair.

A description of the intended contents of the readings course must be approved by the Chair before the student may register for the course. Students electing to satisfy M.S. requirements by taking 24 credits and writing a thesis may not count credits received in this course toward the required 24. Students electing to satisfy M.S. requirements by taking 32 credits may count credits received in only one offering of this course toward the required 32.

695. Research.

Fall and Spring (Hours and credits to be arranged).

Required of all full-time students who have not attained Research Graduate status. No credits earned in this course may be applied to the number of credits required for a degree.

698. Simulation and Modeling Project in Computational Operations Research.

Fall (3). Prerequisites: equivalent of Math 401 and CSci 241.

Simulation model building in a high-level simulation language (SIMAN) with C++/C interface. Topics include network, discrete-event, and continuous modeling approaches. Interfaces between the three modeling approaches are presented. Familiarity with univariate and multivariate probability distributions is required for input modeling and simulation output analysis. Course culminates in a semester project in SIMAN.

***700. M.S. Thesis.**

Fall and Spring (Hours and credits to be arranged).

708. Research Project in Computational Operations Research.

Fall and Spring (2,2). Graded P (Pass) or F (Failure). Prerequisite: Permission of Graduate Director.

Students will select a faculty advisor and committee in their area of specialization within computational operations research, prepare a research proposal abstract for approval by the department's director of graduate studies, undertake a research project, and write a paper describing their research. This course is normally taken after a student has completed 18 credit hours toward the M.S. degree with a specialization in computational operation research. Not open to students who receive credit for either CSci 700 or CSci 710.

710. Research Project.

Fall and Spring (2,2). Graded P (Pass) or F (Failure). Prerequisites: Permission of Graduate Director.

Students will select a faculty advisor and committee in their area of research interest, prepare a research proposal abstract for approval by the department's director of graduate studies, undertake a research project, and write a paper describing their research. This course is normally taken after a student has completed 18 credit hours toward the M.S. degree. Not open to students who receive credit for either CSci 700 or CSci 708.

712. Advanced Compiler Construction II.

Spring (3) Prerequisites: CSci 542, CSci 652.

A project-oriented course involving compilers or compiler generators. Possible topics include syntactic error recovery, semantic analysis, code optimization and code generation.

723. Advanced Analysis of Algorithms.

Fall (3) Prerequisites: CSci 653 or consent of the instructor.

Advanced aspects of the design and analysis of computer algorithms. The study of probabilistic algorithms and parallel algorithms for solving problems from graph theory, geometry, and number theory. Lower bound theory. Intractability theory and its application to modern cryptography.

726. Discrete Event Simulation.

Spring (3) Prerequisites: CSci 526.

Methods of discrete-event simulation. Markov chains. Simulation of open and closed networks of queues. Simulation of non-stationary Poisson processes. Transient and steady-state analysis. Event list algorithms and data structures. Theoretical and empirical tests of randomness. Selected applications.

734. Distributed Computing Systems.

Fall (3) Prerequisites: CSci 544 or equivalent.

Time and order in distributed systems. Synchronous and asynchronous systems. Models of faulty behavior in distributed systems. Paradigms of distributed computing: network mutual exclusion, deterministic agreement (Byzantine and fail-stop), elections, global state acquisition, atomic transactions. Issues in programming distributed systems. Reliable distributed systems. Distributed databases. Selected case studies.

746. Discrete-State Stochastic Models.

Spring (3) Prerequisites: CSci 616.

Logic, performance, and reliability analysis of discrete-state systems. Exploration of the state space. Queuing networks, fault trees, reliability block diagrams, task graphs, Petri nets and domain-oriented languages. Underlying stochastic processes, solutions and approximations.

749. Numerical Algorithms.

Spring (3) Prerequisites: ApSc 607. Co-requisite: ApSc 608 or consent of the instructor.

In-depth study of modern numerical algorithms central to solving many scientific and engineering problems, and of the techniques used to develop and analyze those algorithms, with an emphasis on algorithmic issues.

754. Performance Evaluation of Computer Systems.

Fall or Spring (3) Prerequisites: Computer Architecture, CSci 544, CSci 616 or consent of the instructor.

Analytical modeling techniques and their application in computer system performance modeling and prediction. Modeling of resource allocation policies in parallel systems, web server analysis, measurements and workload characterization of parallel computations and multimedia applications, hardware/software design, and bottleneck analysis.

770. Colloquium.

Fall and Spring (1,1).

Each full-time graduate student is required to enroll in this course. No credits earned in this course may be applied to the number of credits required for a degree.

780. Advanced Topics.

Fall or Spring (1, 2, or 3 credits, depending on material). Prerequisites: Will be published in the preregistration schedule.

A treatment of doctoral-level topics of interest not routinely covered by existing courses. Material may be chosen from various areas of computer science.

****790. Readings in Computer Science.**

Fall or Spring (1, 2, or 3 credits, depending on the material covered). Graded P (Pass) or F (Failure). Prerequisites: Permission of the instructor and the Graduate Director.

A description of the intended contents of the readings course must be approved by the Graduate Director before the student may register for the course. Students electing to satisfy M.S. requirements by taking 24 credits and writing a thesis may not count credits received in this course toward the required 24. Students electing to satisfy M.S. requirements by taking 32 credits may count credits received in only one offering of this course toward the required 32.

795. Research.

Fall and Spring (Hours and credits to be arranged).

Required of all full-time students who have not attained Research Graduate status. No credits earned in this course may be applied to the number of credits required for a degree.

****800. Doctoral Dissertation.**

Fall and Spring (Hours and credits to be arranged).