COLLEGE OF SCIENCE

C207 Materials Science Building
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Email: scigrad@uah.edu
Web Site: http://www.uah.edu/HTML/Academics/Science

Degrees:

Master of Arts
Master of Science
Master of Science in Software Engineering
Doctor of Philosophy

Dean: John D. Fix, B.S., M.A., Ph.D., Professor of Physics

Associate Dean: Debra M. Moriarity, B.S., Ph.D., Professor of Biological Sciences

Mission

The College of Science at UAH is dedicated to providing high-quality undergraduate and graduate education in science and mathematics, maintaining an environment that promotes internationally recognized faculty research programs, and providing service to the university, state, and regional communities as a source of scientific and mathematical expertise.

Facilities/Services

The College of Science includes the Departments of Atmospheric Science, Biological Sciences, Chemistry, Computer Science, Mathematical Sciences, and Physics. In addition, faculty in the College are associated with numerous UAH research centers including the Center for Applied Optics, Center for Automation and Robotics, Earth System Science Center, Global Hydrology and Climate Center, Information Technology and Systems Center, Center for Microgravity and Materials Research, Center for Space Plasma and Aeronomic Research, Laboratory for Materials and Surface Science, Laboratory for Structural Biology, Consortium for Materials Development in Space and the National Space Science and Technology Center. The College takes advantage of its strategic location in the midst of the heavy concentration of high technology-oriented companies and agencies of North Alabama. Because of this, unique opportunities are offered for original research at the forefront of science and technology, including problems that are of direct interest to industry as well as to basic academic research. Dissertation and thesis work may be undertaken in areas where numerous opportunities exist for testing theoretical models under experimental conditions. In several graduate program areas there is a close working relationship with the College of Engineering.

Degrees and Programs

The College of Science offers the following graduate degree programs:

Applied Mathematics	Ph.D.
Atmospheric Science	M.S., Ph.D.
Biological Sciences	M.S.
Chemistry	M.S.
Computer Science	M.S., M.S.S.E., Ph.D.
Mathematics	M.A., M.S.
Physics	M.S., Ph.D.

Interdisciplinary programs offered in cooperation with the College of Engineering include:

Biotechnology Science and Engineering	Ph.D.
Materials Science	M.S., Ph.D.
Optical Science and Engineering	Ph.D.

These programs are described in the "Interdisciplinary Programs" section of the catalog.

In addition, certificate programs are available in Environmental Science, Software Engineering and Information Assurance.

The College of Science also offers courses for public school teachers who wish to concentrate in the sciences while pursuing graduate professional degrees in education. In addition to the usual Class A (master's level) certification, a Non-Traditional Fifth Year Program (NTFYP) is available for individuals who already have a B.A. or B.S. degree with a major in biological sciences, chemistry, mathematics, or physics, but who do not already have the Class B (bachelor's level) certification. Individuals interested in obtaining Class A (master's level) certification through the NTFYP should contact the Education Department.

ATMOSPHERIC SCIENCE

National Space Science and Technology Center
Room 4080
Telephone: (256) 961-7877
Email: atmos@uah.edu
Web Site: http://www.atmos.uah.edu

Degrees:

Master of Science
Doctor of Philosophy

Chair: Ronald M. Welch, Professor

Professors:

Christy, J.R.; climate dynamics, global change
Essenwanger, O.M. (Research); statistical climatology
Perkey, D.J.; global change, mesoscale modeling
Vaughan, W.W. (Research); satellite meteorology, reference atmospheres
Welch, R.M.; remote sensing, radiative transfer, disease and climate

Associate Professors:

Christopher, S.A.; satellite remote sensing
Han, Q.; satellite cloud climatology, remote sensing, radiative transfer
Knupp, K.R.; severe storms, radar meteorology
Newchurch, M.J.; atmospheric chemistry and air pollution

Atmospheric science is an increasingly important part of the earth system: the atmosphere. Research opportunities abound at UAH due largely to the nation's concern about the environment. The National Aeronautics and Space Administration, the National Science Foundation, the National Oceanic and Atmospheric Administration, the Army Research Office, the Environmental Protection Agency, and the Tennessee Valley Authority all fund atmospheric science research at UAH. The Department is housed in the National Space Science and Technology Center (NSSTC) a unique

institute in which scientists from the NASA Marshall Space Flight Center, the National Weather Service, the Space Science and Technology Alliance, other government agencies and industry all work together on research programs of national interest.

Atmospheric science students come from a variety of backgrounds including mathematics, physics, chemistry, computer science, and engineering, as well as traditional meteorology. Atmospheric science is an excellent field for students with a technical background who would like to apply their knowledge to important environmental problems. Global warming, ozone depletion, climate change, acid rain, air pollution, severe storms and weather forecasting are only some of the problems studied by atmospheric scientists. Because much of the information about the atmosphere must come from satellite-based instruments, and because the atmosphere is coupled with the other components of the atmosphere-ocean-land-biosphere system, the program emphasizes remote sensing and earth system science.

Admission Requirements

Applicants will be ***unconditionally admitted*** only if they have

a) a minimum grade point average (GPA) of 3.0 overall on undergraduate and graduate credit;
b) a combined score of at least 1550 on the verbal, quantitative, and analytical sections of the Graduate Record Examination (GRE) (for GRE tests taken after Oct. 1, 2002 the score on the analytical portion is obtained by multiplying the (raw score plus 2) by 100);
c) a bachelor's degree in science or engineering from a recognized and accredited college or university; and
d) in the case of international students, a Test of English as a Foreign Language (TOEFL) score of at least 550 (213 computer-based test).

Applicants will be conditionally admitted only if they have

a) a minimum GPA of 2.75 overall or 3.0 over the last 60 semester hours of undergraduate and graduate credit;
b) a combined score of at least 1500 on the verbal, quantitative, and analytical sections of the Graduate Record Examination (GRE)) (for GRE tests taken after Oct. 1, 2002 the score on the analytical portion is obtained by multiplying the (raw score plus 2) by 100);
c) a bachelor's degree in science or engineering from a recognized and accredited college or university; and
d) in the case of international students, a TOEFL score of at least 550 (213 computer-based test).

To avoid remedial work in mathematics or science, the applicant must have training through a calculus sequence (including the calculus of vector-valued functions), a course in linear algebra, and courses in ordinary and partial differential equations. He or she must also have completed at least two semesters of chemistry, two semesters of calculus-based physics, and have demonstrable computer proficiency in at least one high-level programming language.

Master of Science

To earn a master's degree in atmospheric science, each student must satisfy all requirements of the School of Graduate Studies and of the Atmospheric Science Department. Students are encouraged to formulate an appropriate Program of Study, in consultation with a faculty advisor, at the earliest opportunity, and certainly by the completion of nine semester hours of credit. Two options are available.

Plan I (Thesis)

Degree requirements under this plan include completion of at least 24 semester hours of graduate course work including the three core courses:

ATS 541 Atmospheric Thermodynamics and Cloud Physics
ATS 551 Atmospheric Fluid Dynamics I
ATS 561 Atmospheric Radiation I

The student must also earn at least two semester hours of credit in ATS 780 and 781 (Seminar series), one semester hour credit in ATS 502 (Computational Tools), and six semester hours of credit in ATS 699 (Master's Thesis). The thesis must show evidence of the student's capability for research, independent thought, and analysis in atmospheric science and must be written in fluent, acceptable English.

Plan II (Non-Thesis)

Degree requirements for the master's degree under this plan include the completion of a minimum of 33 semester hours of graduate course work including the three core courses (above), at least two semester hours of credit in ATS 780 and 781 (Seminar series), ATS 502 (Computational Tools), and the passing of a written or oral comprehensive examination. A thesis is not required.

Final Examination

A final comprehensive examination is required of all candidates for a master's degree; this examination may be written or oral, or both. The candidate will be examined on the course work and thesis in Plan I and on course work in Plan II. The examination is conducted by a committee of at least three faculty members appointed by the department chair and approved by the Graduate Dean. The majority of the committee must be full-time UAH faculty members who have Full Membership in the graduate faculty and in the major department. For thesis students a written notice of the time and place of examination is sent to the Graduate Dean. After approval by the Graduate Dean, the Department Chair sends a copy of the written notice to the candidate and each member of the committee. The examination must be given at least one month before the date of graduation, and the results reported within two working days to the Graduate Dean. A student may take the final oral or written examination only twice.

Doctor of Philosophy

To obtain the Ph.D. degree in atmospheric science, each student must satisfy all requirements of the School of Graduate Studies as well as those of the Atmospheric Science Program. In summary, the five major requirements are the following.

1. Take the core courses and pass the preliminary examination

Each student must complete the three common core courses (ATS 541, 551 and 561) and ATS 651 (Atmospheric Fluid Dynamics II). Students who have previously taken similar courses may be exempted from some of the core courses by the Department Chair.

Each student must pass a preliminary examination covering material in the three core courses plus three other ATS courses chosen from the catalog with numbers of 520 or higher, excluding ATS 761 and 770. This examination will be designed and graded by a committee appointed by the Department Chair. It is anticipated that a student will take the preliminary examination during the second year of graduate study, but students with a strong background in atmospheric science may take the examination within the first year. The preliminary examination may be taken at most twice.

After a student has passed the preliminary examination, a Supervisory Committee will be formed. The committee will consist of the student's academic advisor plus at least four other members, (three of the committee members must be full-time ATS faculty who are Full Members of the UAH graduate faculty) with the committee to be approved by the College and Graduate Deans. The committee will administer the qualifying examination and, with the consent of the Graduate Dean, give approval to all aspects of requirements 2-5.

2. Satisfy the residence requirement

According to graduate school policy, residence may be established through either (i) being enrolled as a full-time student (at least 9 graduate semester hours) either for one continuous academic year,

or for Spring and Fall semesters in the same calendar year, or (ii) being enrolled in at least 6 hours of graduate course work in at least three of four consecutive semesters.

3. Complete an acceptable Program of Study

Each Program of Study will stress breadth, depth, and research competence as well as understanding of the relationship of the major area to its applications, and will be individualized to meet the student's needs and requirements of the program. Any prerequisites required for courses in the Program of Study must be fulfilled before attempting these courses. A Program of Study will consist of at least 48 semester hours of course work at the graduate level, including the core courses needed to prepare for the preliminary examination and courses required in a major area of concentration that will prepare the student to conduct original research in that area. In addition, the student must register for doctoral dissertation (ATS 799) each semester that he or she is enrolled and receiving direction on the dissertation. A minimum of 18 hours of dissertation registration is required. Students must also register for a total of at least three hours of ATS 780, 781, 782 (Seminar series) plus ATS 502 (Computational Tools). *These four semester hours may not be used to meet minimum degree requirements.*

4. Pass the Qualifying Examination

The Qualifying Examination will cover the major areas of study and the student's proposal for a dissertation topic. It will have both written and oral components and will be prepared and graded by the student's advisory committee. This examination may be taken at most twice.

5. Complete and defend a research dissertation

Each student must complete and successfully defend a research dissertation, the results of which are publishable in a nationally recognized journal. The dissertation, which must comply with the regulations set forth in the School of Graduate Studies' Thesis and Dissertation Manual, must be approved by the student's supervisory committee, the chair of the atmospheric science department, the dean of the College of Science, and the Dean of the School of Graduate Studies.

All requirements for the Ph.D. must be completed in no more than five years after the student has passed the qualifying examination.

The atmospheric science program does not require knowledge of a foreign language, but it does require proficiency in both spoken and written English.

Graduate Courses in Atmospheric Science (ATS)

501 Survey of Atmospheric Science **3 hrs.**

General survey of the field of atmospheric science. Quantitative examination of atmospheric physical properties including atmospheric composition, structure and dynamics. Detailed inspection of evolving atmospheric structures using real-time data systems. General topics include atmospheric thermodynamics, atmospheric dynamics, cloud physics, atmospheric radiation, and related topics in atmospheric remote sensing. Prerequisites: MA 172 and PH 112 or consent of instructor. (Same as ATS 401, ES 401, ES 501.)

502 Computational Tools for Atmospheric and Environmental Scientists **1 hr.**

Designed for incoming graduate students. Fundamentals of computation using IDL or other suitable programming language, focusing on basic skills, interpretations, creating plots, and displaying data. Prerequisite: Consent of instructor. *This course may not be used to meet minimum degree requirements.* Fall. (Same as ES 502.)

509 Applications of Computers in Meteorology **3 hrs.**

Survey of data types and languages commonly used in the meteorological community along with practical application to meteorology. Course is designed to prepare students for graduate work and research in atmospheric science. Lab fee $40. Prerequisite: Consent of instructor. Summer, alternate years. *This course may not be used to meet minimum degree requirements.*

511 Introduction to Geographical Information Systems **3 hrs.**

Introduces vector, raster and tabular concepts, emphasizing the vector approach. Topics include: spatial relationships, map features, attributes, relational database, layers of data, data ingesting, digitizing from maps, projections, output, applications and availability of public data sets. (Same as CE 411, CE 511, ES 411, ES 511, ATS 411.) Fall.

513 Geographical Information Systems and Remote Sensing **3 hrs.**

Hands-on approach to GIS and satellite remote sensing. Popular satellite data sets such as LANDSAT and AVHRR are coupled with GIS data sets to increase understanding of the earth system. Topics include satellite sensors, basic radiative transfer, orbits, raster formats, atmospheric correction, distortion, image corrections, rotations and mapping, spatial resolution, image interpretation, radiometric and geometric enhancement, multispectral transformations, and classifications. (Same as ATS 413, ES 413, ES 513.) Spring.

514 Scale and Landscape in GIS **3 hrs.**

Relationship of scale processes in the interpretation of remote sensing and GIS applications. Topics include those associated with multiple representations of remote sensing data, analysis techniques for integrating multiple sets of remote sensing and auxiliary data at different scales, and geostatistics. Prerequisite: ATS 513. (Same as ATS 414, ES 414, ES 514.) Fall.

515 Advanced Topics in GIS **3 hrs.**

Advanced special topics: visualization of GIS and remote sensing data, landscape characterization (pattern vs. process), multitemporal analysis, aggregation of data types, developing an integrated GIS environment for performing complex space-time modeling analyses, and land-atmosphere interactions. Prerequisite: ATS 513. (Same as ATS 415, ES 415, ES 515.) Spring.

520 Introduction to Atmospheric Chemistry and Air Pollution **3 hrs.**

This self-contained introductory course in atmospheric chemistry and air pollution is designed to provide seniors and graduate students the basics of atmospheric chemistry and air pollution concepts. Topics include air pollutants, air-pollution meteorology, atmospheric gases and aerosols, and atmospheric processes. This course will also develop the necessary fundamentals for those wishing to take the advanced (600 level) courses in the atmospheric chemistry/air pollution study area. ES 520 and ATS 520 require a research project; ES/ATS 420 do not. Prerequisites: PH 112 and CH 121 or consent of instructor. (Same as ATS 420, ES 420, ES 520.)

541 Atmospheric Thermodynamics and Cloud Physics **3 hrs.**

General aspects of thermodynamic and cloud physical processes occurring within the atmosphere; atmospheric statics and stability, saturation point analysis, aerosols, nucleation, and the behavior/growth of cloud particles and hydrometers. Prerequisites: MA 324, PH 112. (Same as ATS 441, ES 441, ES 541.) Fall.

551 Atmospheric Fluid Dynamics I **3 hrs.**

Fluid dynamics in the atmosphere. Coriolis acceleration, scale analysis and appropriate approximations of the complete governing equations. Numerical analysis and interpretation of weather phenomena. Prerequisites: MA 324 and PH 112. (Same as ATS 451, ES 451, ES 551.) Fall.

552 Synoptic Meteorology **3 hrs.**

Analysis, interpretation and forecasting synoptic-scale and mesoscale phenomena, including air masses, frontal systems, cyclones, anti-cyclones, tropical cyclones and associated mesoscale phenomena. Emphasis on the use of remotely-sensed data from satellites, radars and profilers using state-of-the-art workstations. Prerequisites: ATS 541, 551. (Same as ATS 452, ES 452, ES 552.) Spring, even years.

554 Forecasting Mesoscale Processes **3 hrs.**

Detection and forecasting of atmospheric mesoscale phenomena, including the structure and evolution of clouds, precipitation (including floods), thunderstorms and severe weather. Includes basics on instruments used to detect mesoscale phenomena, most notably satellite and radar. Based mainly on computerized modules and related exercises. Prerequisite: ATS 551. (Same as ATS 454, ES 454, ES 554.)

561 Atmospheric Radiation I **3 hrs.**

Fundamentals of terrestrial atmospheric radiation. Topics include: solar radiation at the top of the atmosphere, radiative transfer equation, gaseous absorption, scattering by molecules and particles, band models, transmittance along an inhomogeneous path, and microwave radiative transfer. Prerequisites: MA 324, PH 112. (Same as ATS 461, ES 461, ES 561.) Spring.

603 Climate Dynamics **3 hrs.**

Origin and evolution of the climate system including underlying causes for past climates such as occurred during the ice ages. Statistical processing of various time series to extract climactic signals in the data. Determination of global-scale forcing mechanisms which impact climate. Prerequisites: ATS 541, 551. Fall, odd years.

620 Atmospheric Chemistry and Aerosis **3 hrs.**

Atmospheric chemistry and aerosols; primary processes, thermodynamics, photochemistry, kinetics, models, and measurements applied to the troposphere and stratosphere; natural and anthropogenic processes affecting the chemistry of Earth's troposphere and stratosphere; effects of chlorine, nitrogen, hydrogen, and oxygen catalytic cycles. Ground-based and satellite-borne observations of traces species are described. Requires an understanding of atmospheric structure and elementary atmospheric chemistry. Prerequisite: ATS 520 or consent of instructor. (Same as ES 620.)

622 Air Pollution Modeling **3 hrs.**

Advanced air pollution modeling, covers in considerable depth air pollution modeling concepts and methods. Lagrangian and Eulerian modeling approaches ranging from microscale (PBL) to synoptic (regional) scale. Lagrangian modeling will be focused on detailed modeling of large point- and areas-source plumes; Eulerian modeling will range from Large Eddy Simulations (LES) to regional-scale modeling with nested domains and plume-in-grid treatments; covers atmospheric transport/dispersion/chemistry, cloud and aerosol processes, and wet and dry deposition processes; students get experience in implementing specific plume, LES, and urban-regional modeling codes used in research and regulatory applications. Prerequisites: ATS 520, 551 or consent of instructor. (Same as ES 622.)

630 Physical Climatology **3 hrs.**

This course is designed to provide a hands-on perspective to the study of the climate system using satellite data sets. The emphasis will be on understanding the physical aspects of the global climate system. Topics include global energy balance, energy balance of the surface, hydrologic cycle, climate classification, ocean circulation, natural and anthropogenic climate change and other selected topics such as urban climate and mountain weather and climate. Prerequisite: ATS 501 or consent of instructor. (Same as ES 630.) Fall, even years.

635 General Circulation **3 hrs.**

Detailed examination of the observed dynamic, thermodynamic and chemical structure of the atmosphere, including mid-latitude baroclinic systems, tropical systems, global-scale energy, mass and momentum budgets and the fundamental climatology of the atmosphere. Prerequisites: MA 324, ATS 541, 551. Spring, odd years.

651 Atmospheric Fluid Dynamics II **3 hrs.**

Wave motions in the atmosphere with emphasis on Rossby, Kelvin and gravity waves. Systematic scaling of primitive equations to develop quasi-geostrophic and Ekman-layer theory. Shallow water theory, stratified flows, and barotropic and baroclinic instability. Prerequisite: ATS 551. Spring.

655 Mesoscale and Microscale Atmospheric Processes **3 hrs.**

Theory and observations of classical mesoscale circulations, atmospheric boundary layers, atmospheric fluid instabilities and turbulence, atmospheric convection, conditional instability of the second kind, turbulent dispersion. Prerequisites: ATS 541, 551. Spring, odd years.

670 Satellite Remote Sensing I **3 hrs.**

Covers a broad range of topics concerning digital image processing applied to the remote sensing of atmospheric, cloud and surface properties. Topics include image interpretation, radiometric and geometric enhancement of satellite imagery, supervised and unsupervised classification techniques, image transformations, textures, atmospheric correction, calibration and navigation of satellite imagery. Prerequisites: MA 324, PH 112. Fall, odd years.

671 Radar Meteorology **3 hrs.**

Basic principles of incoherent, Doppler, and multiparameter radar, profiler, lidar, and sodar devices. Propagation characteristics in the atmosphere. Application of radar sensing techniques to atmospheric structure and processes including measurement of wind, temperature, humidity, characteristics of hydrometers, rainfall estimation, utility in detection of internal cloud flows and turbulence, detection of severe storms. Applications to aviation and weather forecasting. Prerequisite: ATS 541. Spring, even years.

681 Numerical Atmospheric Modeling **3 hrs.**

Introduction to numerical methods applied to simulation of the atmosphere. Basic numerical solution techniques, along with filtering, radiative parameterizations, thermodynamics, turbulent parameterization, initialization and coordinate transformation. Prerequisites: MA 415, ES/ATS 551. (Same as ES 68.1)

690 Selected Topics in Atmospheric Science **1-3 hrs.**

Selected topics of interest not included under other courses. Prerequisite: Approval of instructor. All semesters.

699 Master's Thesis **3 or 6 hrs.**

Required each semester a student is enrolled and receiving direction on a master's thesis. Minimum of two semesters required.

740 Cloud Processes **3 hrs.**

Theory and observation of the bulk microphysical composition and kinematic structure of various cloud types, including fog. Topics include: precipitation formation processes in warm and cold clouds, interactions among dynamical, microphysical and radiative processes within cloud systems, the dynamics of thunderstorm systems and hurricanes, and remote sensing applications of clouds and precipitation. Prerequisites: ATS 541, 551. Spring, even years.

761 Atmospheric Radiation II **3 hrs.**

Advanced topics in atmospheric radiative transfer. Specific topics include Maxwell equations, Mie theory, polarization and radiative transfer in a scattering atmosphere. Prerequisite: ATS 561. Spring, even years.

770 Satellite Remote Sensing II **3 hrs.**

Analysis and interpretation of satellite data: AVHRR, GOES, SSM/I, ERBE and LANDSAT. Topics include retrieval and analysis of earth radiation budget, cloud liquid water, land and ocean temperatures, vegetation characteristics, cloud optical properties, biomass burning fire patterns, smoke and dust aerosols, and advanced cloud classification techniques and applications to NASA's Mission to Planet Earth. Prerequisite: ATS 570. Spring, even years.

780 Seminar **1 hr.**

Speakers are invited to report on research relevant to the field of atmospheric science. Students are expected to attend at least twelve seminars and to write short descriptions of the presentations. Fall. *This course may not be used to meet minimum degree requirements.*

781 Student Seminar **1 hr.**

Speakers are invited to report on research relevant to the field of atmospheric science. Students are expected to attend at least six seminars and to make a 15-minute conference-type presentation on a research topic in atmospheric science selected in agreement with their advisor and write a short description of the presentation. Spring. *This course may not be used to meet minimum degree requirements.*

782 Professional Development **1 hr.**

Special topics concerning professional ethics, writing scientific journal articles, proposals and resumes, preparing budgets, publish or perish quality vs. quantity, personal relationships in the workplace, research administration, funding agencies, stress and burnout. *This course may not be used to meet minimum degree requirements.*

790 Selected Topics in Atmospheric Science **1-3 hrs.**

Selected topics of interest not included under other courses. Prerequisite: Approval of instructor. All semesters.

799 Doctoral Dissertation **3, 6, or 9 hrs.**

Required each semester student is enrolled and receiving direction on a doctoral dissertation.

BIOLOGICAL SCIENCES

142 Wilson Hall
Telephone: (256) 824-6260
Email: biology.grad@uah.edu

Degree: Master of Science

Chair: Gopi K. Podila, Professor

Professors:

Campbell, P.S. (Emeritus); reproductive physiology, sex steroid hormone action, endocrine disrupters
Eley, M.H..; chemical and biological conversions of biomass
Garstka, W.R.; reproduction and chemical communication in vertebrates, paleontology
Lawton, R.O.; structure and composition of forest communities, natural products biology
Modlin, R.F. (Emeritus); biology of crustacea, ecology of marine and freshwater ecosystems
Moriarity, D.M.; regulation of eucaryotic gene expression, natural products biology
Podila, G.K.; fungal genomics, plant molecular biology and biotechnology
Shriver, J.S.; NMR spectroscopy, structural biology

Associate Professors:

Johnson, A.D.; nutritional physiology
Leahy, J.G.; environmental microbiology, molecular physiology, evolution of biodegradative microorganisms

Assistant Professors:

Bishop, A.; neurobiology, Alzheimers disease
Boyd, D.L.; developmental biology, genetics
Davis, M.R.; plant molecular biology, genomics and biotechnology
Magnuson, R.D.; signaling and regulation of bacterial gene expression
Ng, J.; structural biology, biochemical evolution of RNA, microgravity protein crystallization

The Department of Biological Sciences provides instruction, learning, and creative scholarly activities in the life sciences. Scholarly investigations are directed by scientists and undertaken by those who as graduate students (and sometimes advanced undergraduate students) are preparing to become future scholars. The department does not offer courses in all areas of biological science; rather, it has chosen to emphasize instruction in the following general areas:

1. cell biology
2. environmental biology
3. genetics and molecular biology
4. microbiology
5. physiology

The department provides an atmosphere and research facilities that are especially suitable for students pursuing an M.S. degree or the new interdisciplinary Ph.D. program in Biotechnology Science and Engineering. Our faculty members have national and international recognition and a strong commitment to research. Our faculty members understand and work with graduate students in designing their research projects and course work for M.S. or the Ph.D. degrees. Students in the program study under the guidance of a faculty advisor and an advisory committee. The department emphasizes research and course work in the following areas: cell biology, environmental biology, genetics and molecular biology, microbiology and physiology. More detailed information can be found in individual faculty web pages. Qualified graduate students may apply for teaching assistantships that provide a stipend and tuition. Individual faculty also have research projects that fund graduate research assistantships. Students applying to our M.S. or the Biotechnology Science & Engineering Ph.D. programs are encouraged to contact individual faculty for availability of research assistantships.

For additional information on the Biotechnology Science and Engineering Ph.D. program, see the Interdisciplinary Programs section of this graduate catalog.

The graduate program is exceptional in at least two ways. First, the relatively small number of graduate students fosters an academic atmosphere stressing individuality and close interaction with the graduate faculty. Second, the M.S. graduate program is a cooperative venture with Alabama A&M University, with a combined faculty at both UAH and A&M of approximately 25. This arrangement provides a faculty resource and diversity of expertise available in large universities without sacrificing the close, personal supervision that small programs can accommodate.

Admission Requirements

In addition to fulfilling admission requirements set by the School of Graduate Studies, applicants must also:

1) show competence in an area of life science related to the proposed area of study;
2) complete one year of undergraduate chemistry, including at least one semester each of organic chemistry and biochemistry;
3) have a minimum GPA of 3.0 in the major area of concentration;
4) a course in statistics is also recommended.

Applicants demonstrating potential for graduate study in the biological sciences but having some deficiencies in their previous academic work may be admitted on a conditional basis.

Masters of Science Degree Requirements

The graduate faculty, in cooperation with the biology graduate faculty of Alabama A&M University, offers an M.S. in biological sciences with emphasis in cell biology, environmental biology, genetics and molecular biology, microbiology, or physiology. A minimum of 25 percent of biological sciences course requirements must be met at the cooperating institution. A minimum of 50 percent of the graduate program must be taken at the 600-level. The graduate program of study cannot include more than 4 credit hours each of BYS 691 or BYS 692. Three credit hours of graduate seminar can be counted toward fulfillment of the graduate program. Titled BYS 691 courses offered on an *ad hoc* basis and instructed as part of the didactic curriculum are exempt from the 4 credit hour maximum.

Students may elect one of the following three plans for the Masters degree:

Plan I – Master of Science With Thesis

a. Graduate course work of 24 semester hours of an approved program;
b. Comprehensive coursework examination;
c. Acceptable thesis describing original research; minimum of six hours BYS 699 required;
d. Final oral examination.

Plan II – Master of Science Without Thesis

a. Approved program of 33 semester hours;
b. Acceptable Master's report (library search, survey, and/or experimentation);
c. Comprehensive final examination;
d. Oral presentation of Master's report before supervisory committee.

Plan III – Master of Science With Education Option (Class A Certification)

a. Approved program of 24 semester hours in biological sciences and nine semester hours in education;
b. Acceptable Master's report;
c. Comprehensive final examination;
d. Oral presentation of Master's report before supervisory committee.

Non-Traditional Fifth-Year Program Leading to the M.S. in Biological Sciences Plus a Class A Alabama High School Teacher's Certificate

Those who have a B.A. or B.S. degree with a major or its equivalent in biological sciences, as determined by the Department of Biological Sciences, and have not taken more than 12 semester hours in teacher education (graduate or undergraduate), and who are interested in obtaining Class A (master's level) certification for secondary school teaching, should consider the Non-Traditional Fifth Year Program. Contact the Education Department for preliminary advisement on admission and general program requirements. See the description in the Education section for more details.

Graduate Courses in Biological Sciences (BYS)

501 Gravitational Biology **3 hrs.**

Basic studies of responses of plants and animals to microgravity. Emphasis on effects of low-gravity at the cellular level, including cell physiology, metabolism, structure, signal transduction mechanisms of gravity sensing, and issues of human gravitational physiology. Description of organisms and summary of biological space flight experiments. Prerequisites: BYS 120, 214 or 321, 301 or 361, and 340 or 543 recommended, or permission of instructor.

505 Psychopharmacology **3 hrs.**

Introduction to drug classification and action with emphasis on physiological and psychological interactions. Prerequisite: 9 hrs. BYS or PY.

519 Gene Structure and Function **3 hrs.**

Molecular basis for inheritance and gene expression. Advanced studies of replication, transcription, translation. Includes regulation of gene expression, gene cloning and recombinant DNA technology. Prerequisites: BYS 219 and BYS/CH 361.

521 Medical Mycology **4 hrs.**

Basic studies of fungi and applied studies of various classes of fungi pathogenic to humans; reproduction, morphology, classification of disease states, pathogenesis, laboratory diagnosis, chemotherapy. Two 2-hour labs per week. Lab Fee: $40. Prerequisite: BYS 421, 430, or approval of instructor.

525 Medical Parasitology **4 hrs.**

Basic and applied studies of various classes of parasites pathogenic to humans and their laboratory identification. Arthropods and their relationship as vectors of parasites. Immunology and chemotherapy of parasitism. Two 2-hour labs per week. Lab Fee: $30. Prerequisite: BYS 321.

532 Animal Physiology **4 hrs.**

Basic organismal function. Membrane physiology and transport phenomena, muscle, nerve, synapse, and sensory receptor physiology. Physiology of respiration, heart, circulation, kidney, and endocrine system. Emphasis on regulation. One lab per week illustrating physiological principles discussed in lecture. Lab Fee: $50. Prerequisites: Senior standing with a major or minor in biological science; BYS 317 and 16 hours completed in POS, CH 113 or 331 or graduate standing.

533 Endocrinology **3 hrs.**

Anatomy, physiology, and biochemistry of endocrine glands. Emphasis on regulation of hormone secretion, hormonal integration of physiological function, and mechanism of hormone action. Prerequisites: BYS 313 and 314 or 532, BYS/CH 361.

535 Advanced Microbiology **3 hrs.**

Aspects of microbial behavior, development, morphogenesis or physiology. Prerequisites: BYS 321 and BYS/CH 361.

536 Psychobiology of Stress and Illness **3 hrs.**

Overview of physiological stress responses and their influence on health, behavior, and illness. Prerequisite: 9 hrs. BYS or PY. (Same as PY 536.)

540 Animal Behavior **3 hrs.**

Examines the experimental and theoretical foundations of the study of animal behavior. Animal behavior will be discussed in terms of immediate mechanisms, development, survival value, and evolution. Some emphasis will be placed on the relevance of animal behavior to human behavior and on the importance of understanding behavior in context. Prerequisites: PY 101, 102 and 302 or BYS 119, 120 and 4 upper level hours in BYS. (Same as PY 540.)

543 Molecular Biology of the Cell **3 hrs.**

Cellular structure and function including mitosis, meiosis, cell cycle, and cell signaling. Discussion of biological techniques such as tissue culture, hybridoma and monoclonal antibody production, gene cloning and recombinant DNA, radiotracer methodology, and specialized microscopy. Prerequisites: BYS 340; BYS/CH 361recommended.

544 Developmental Biology **3 hrs.**

Gametogenesis and regulation of reproductive cycles, fertilization, cleavage, gastrulation and developmental mechanisms such as nuclear-cytoplasmic interactions and oocyte polarity in regulating gene expression during development, selective cell affinities, contact guidance, and embryonic inductions and fields. Selected morphogenesis of germ-layer derivatives discussed. Prerequisite: BYS 340 or 543.

545 Cellular and Developmental Biology Laboratory **2 hrs.**

Theory and practice of experimental techniques used in cellular, molecular and developmental biology. Take after BYS 543. Lab Fee: $50.

547 Biochemistry I **3 hrs.**

Structural chemistry and function of biomolecules, mechanisms of biochemical reactions, enzyme kinetics, and energy transfer. Prerequisite: CH 332 or BYS/CH 361. (Same as CH 561.)

548 Biochemistry II **3 hrs.**

Metabolism, biosynthesis of macromolecular precursors, storage, transmission, expression of genetic information, and molecular physiology. Prerequisite: CH 561 or BYS 547. (Same as CH 562.)

556 Advanced Molecular Techniques **3 hrs.**

Laboratory techniques in molecular biology, including methods of recombinant DNA technology for identification, cloning, and characterization of genes. Prerequisites: BYS 219, 340, and 519 (may be taken concurrently) or approval of instructor. One 2-hour and one 5-hour lab per week. Lab Fee: $250.

561 Physiological Ecology **4 hrs.**

Physiological and behavioral responses of organisms to natural changes in their chemical and physical environment. Prerequisite: BYS 312 or approval of instructor. BYS 361 or 532 recommended. Lab Fee: $30.

562 Community Ecology **4 hrs.**

Detailed consideration of ecological principles and concepts, as well as biotic and abiotic factors relative to development of plant communities and ecosystems. One 4-hour lab per week. Field trips required. Prerequisites: BYS 312. Lab Fee: $30

563 Population Ecology **4 hrs.**

Distribution, population dynamics and behavior of animal populations in relation to environmental factors. One 4-hour lab per week. Field trips required. Prerequisites: BYS 312. Lab Fee: $30.

564 Limnology **3 hrs.**

Fresh-water environments and organisms exemplified by lakes, ponds, and streams in North Alabama.

578 Aquatic Arthropod Biology **4 hrs.**

Systematics, physiology, ecology and importance of the crustacea, insecta and arachnida that inhabit freshwater and estuarine ecosystems. Particular attention will be given to those arthropods common to the aquatic systems in and around Alabama. Since all field trips are required, prospective students should consult with the instructor prior to registration. Prerequisite: BYS 378. Lab Fee: $40.

621 Pathogenic Bacteriology **4 hrs.**

Survey of bacterial diseases in humans. Mechanisms of pathogenicity and host-parasite interactions. Includes laboratory. Prerequisites: BYS 361, 421, 430, or approval of instructor. Lab Fee: $50.

641 Advanced Cell Biology (also at AAMU) **4 hrs.**

Integrated approach to fine structure and function of various cellular processes. Particular aspects of cellular processes each semester, e.g. motility in cells and cellular differentiation. Laboratory included. Prerequisite: BYS 543 or approval of instructor. Lab Fee: $50.

644 Topics in Cell and Developmental Biology and Biological Fine Structure **2 hrs.**

Discussion of current topics in cell biology with emphasis on student participation. Both plant and animal cells will be emphasized. Depending on the number of students, some terms may be devoted to short research problems. Prerequisite: BYS 543 or 641 or approval of instructor.

646 Molecular Genetics (also at AAMU) **3 hrs.**

Advanced study of molecular mechanisms underlying genetic principles. Current molecular biology techniques. Structure of genes and chromosomes; primary, secondary, and tertiary structure of DNA; DNA replication; genetic recombination; RNA transcription; translation and genetic code; regulation of gene function; evolution at molecular level. Prerequisites: BYS 219 and BYS/CH 361.

647 Enzymology **3 hrs.**

Detailed study of enzymes including protein synthesis; primary, secondary, tertiary and quaternary structure; nomenclature, physiological and catalytic function; enzyme kinetics, and metabolic regulations of enzyme activity. Prerequisite: BYS 547 or CH 561 or approval of instructor.

660 Ecosystem Dynamics **3 hrs.**

An analytical approach (including simulation and modeling) to the interactions of organisms in terrestrial, aquatic, and marine ecosystems. Prerequisites: BYS 562, 564.

661 Advanced Population Ecology **4 hrs.**

Interaction of population structure, genetic properties, and ecology factors in controlling dynamics and evolutionary character of natural population. One 4-hour lab per week. Prerequisites: BYS 312, BYS 564, or approval of instructor. Lab Fee: $40.

690 Seminar (also at AAMU) **1 hr.**

Student reports on current journal articles, research, or assigned readings. Graduate students should attend whether enrolled for credit or not. May be taken up to three times for credit.

691 Special Topics (also at AAMU) **1-4 hrs.**

Directed readings and/or written reports on topics of individual student interest carried out under the supervision of an instructor. Permission of instructor required before registration.

692 Research (also at AAMU) **2-4 hrs.**

Individual investigations of biological problems under supervision of graduate faculty member. Permission of instructor required before registration. A special problem may be carried out at Marine Environmental Sciences Consortium, Dauphin Island, Alabama. Available to thesis students. Lab Fee: $30 for 2 hours; $40 for 3 hours; $50 for 4 hours.

699 Master's Thesis (also at AAMU) **1-6 hrs.**

Required each semester student is working and receiving direction on master's thesis. Minimum of six hours required for M.S. students. Maximum of nine hours credit upon successful completion of master's thesis.

Graduate Courses Offered at Alabama A&M University (AAMU)

Courses offered jointly by Alabama A&M University and UAH but which are taught on the A&M campus are listed below for ready reference.

510 Radiation Biology **4 hrs.**

Characteristics of radioisotopes, detection and counting techniques and instrumentation, tracer techniques, health and safety system. Prerequisite: Consultation with instructor.

511 Biological Control **4 hrs.**

Components of resistance, use of parasites, predators and microorganisms, foreign exploration, shipment, release and establishment of imported parasites and predators.

512 Histotechniques **3 hrs.**

Microscopic study of the various tissues and organs of the animal systems.

522 Microbial Physiology **3 hrs.**

Relationship between structure and biochemical functions in microorganisms. Lab Fee: $40.00. Prerequisite: Microbiology, organic chemistry, and biochemistry.

523 Principles of Virology **4 hrs.**

Principles of viral infectivity, multiplication, and chemical constitution; laboratory techniques for their isolation, cultivation, identification, and enumeration. Prerequisite: BYS 221.

524 Mycology **4 hrs.**

Lines of phycomycetes using representative species; various series of actinomycetes; representative pathogenic (crop and vegetative pathogens) and nonpathogenic heterobasidiomycetideae organisms; order and families of homobasidiomycetidae. Ontogenetics, cellular, and structural study applied to all divisions, classes, series, orders and families. Lab Fee: $40.

526 Microbial Ecology **4 hrs.**

Relationship of soil and aquatic microorganisms and their importance in ammonification, nitrification, and other biological processes. Prerequisite: BYS 321.

533 Medical Physiology I **4 hrs.**

Nerve and muscle cell function, fluid and electrolyte environment of body tissues, blood, heart, circulatory, and nervous systems. Prerequisite: Organic chemistry, preferably biochemistry.

534 Medical Physiology II **4 hrs.**

Continuation of mammalian physiology with consideration of kidney function, respiratory, digestive, reproductive, and endocrine systems. Prerequisite: Medical Physiology I.

535 Endocrinology (also at UAH) **4 hrs.**

Current developments on anatomy, physiology, chemistry, and regulations of major endocrine glands. Laboratory sessions in biological and chemical assays of hormones. Lab fee $50. Prerequisite: ZOO 409.

540 Molecular Biology **4 hrs.**

Structure, behavior, and function of larger biological molecules including biological oxidations, metabolism of carbohydrates, lipids, amino acids, and genetic aspects of metabolism. Prerequisite: Organic Chemistry.

541 Cell Physiology **4 hrs.**

Interconversions and functions of biomolecules in cells, including the major metabolic pathways, bioenergetics, interrelations of various pathways, and various mechanisms of metabolic regulation. One 3-hour lab per week. Prerequisites: BIO/CHE 361 and 362 or consent of instructor.

542 Analytical Biochemistry Laboratory **2 hrs.**

Advanced laboratory dealing with modern techniques of molecular biology and biochemistry. Prerequisite: Organic Chemistry.

546 Cytogenetics **4 hrs.**

Analysis of composition, morphology, and behavior of genes, especially as they relate to function, development, and heredity. Prerequisite: BIO 406.

551 Insect Physiology **4 hrs.**

Metabolism and utilization of carbohydrates, lipids, and nitrogen compounds; energy production, neuromuscular mechanisms, hormones and morphogenesis; role of organs and organ systems in metabolism. Prerequisites: General entomology, advanced biochemistry.

552 Insect-Pest Management **4 hrs.**

Insect surveys, ecological basis for control, plant and animal resistance to insects, control by parasites, predators, microorganisms, management by genetics principles, chemical attractants, chemical repellents, sterilization, insecticides, and integrated systems of pest management. Prerequisite: general entomology or advanced applied entomology.

553 Insect Taxonomy and Morphology **4 hrs.**

Classification of insects, external and internal anatomy of insects, with emphasis on the comparative and functional aspects. Prerequisite: BIO 455.

560 Environmental Biology **3 hrs.**

Principles of interaction between living systems and their resources. Current problems in management of natural resources including new approaches in management of pest populations.

565/565L Phycology -Morphology of Classes; Growth Requirements **4 hrs.**

Physical and chemical stresses on growth and productivity. Succession and bioassay of pollutants. Systematic physiology and metabolism of ecology and environmental stress factors. Productivity culturing methods and economics. Man's use of biotechnology and industry. Terrestrial monitoring.

570 Plant Pathology **4 hrs.**

History, nonparasitic, and parasitic diseases incited by bacteria, fungi, plasmodiophorales, nematodes, and viruses. Disease control through exclusion, eradication, protection, and post resistance. Prerequisite: BIO 344.

571 Plant Anatomy **4 hrs.**

Ontogeny, differentiation, and maturation of tissues and organs of angiosperms. Problems in growth and development of an angiosperm, using histological techniques. Two 3-hour labs per week. Lab Fee: $40. Prerequisite: BYS 372 or approval of instructor.

572 Plant Taxonomy **4 hrs.**

Principles of classifying, naming, and identifying vascular plants with emphasis on flowering plants. Ecologic factors influencing vegetational distribution.

590 Problems in Biological Sciences **4 hrs.**

(Plan III only) Problems of elementary and secondary school teachers of science in all areas of biological sciences. Relations of biological organisms to their environment, stressing climactic and soil factors that influence their distribution and adaptations. Provision for individual investigation in biological science.

622 Applied and Industrial Microbiology **4 hrs.**

Examine by microbiological assay sewage disposal and waste water treatment plants. Microorganisms of industrial importance in biological production of antibiotics, vitamins, organic acids, and alcohols. Prerequisite: Microbiology.

623 Advanced Virology **4 hrs.**

Outline of field of virology stressing molecular biology of virus replication. Immunology, genetics, and epidemiology. Bacterial and vertebrate viruses although some discussion of plant and insect viruses. Prerequisites: Microbiology, Principles of Virology.

631 Medical Pharmacology **5 hrs.**

Drug-receptor interaction, kinetics of drug absorption, distribution and elimination, and discussion of drugs affecting different systems. Pharmacogenetics, toxicity, mutagenesis, teratogenesis, carcinogenesis, and drug interactions. Mechanism of action of drugs, in relation to their use as therapeutic agents in medicine. Laboratory included. Prerequisites: Medical Physiology I and II.

632 Cardiovascular Physiology **3 hrs.**

Mechanisms of cardiac muscle excitation and interaction. Analysis of peripheral circulation. Neural regulation of circulation. Angiograph, electrocardiography, and vectorcardiography as diagnostic tools. Prerequisites: Medical Physiology I and II.

642 Advanced Cell Physiology **4 hrs.**

Biochemical and biophysical cytology. The cell as matter, life history of the cell, molecular basis of cellular activities, enzymes and energy conversions, functional localizations in subunits of the cell, mechanisms of motility, structure and function of cell membranes, effects of radiation on cells, biochemical control mechanisms, cellular differentiation and interaction between cells, hypotheses of cellular origins. Laboratory included. Prerequisites: molecular biology, physics, cytology, biochemistry.

645 Human Cytogenetics and Its Clinical Application **3 hrs.**

Review of normal human chromosome structure and normal chromosome segregation and morphology with clinical consideration.

652 Advanced Applied Entomology **4 hrs.**

Economic thresholds, economic injury levels, population dynamics, residues in food crops, chemical control, insect transmission of plant disease, and livestock. Prerequisite: General entomology.

653 Taxonomy of the Immature Insect **4 hrs.**

Literature, comparative morphology and techniques of identification of immature stages of the insect, methods of collecting and preserving the immatures. Lab Fee: $40. Prerequisite: BYS 455 or approval of instructor.

CHEMISTRY

C203 Materials Science Building
Telephone: (256) 824-6153
Email: apply@matsci.uah.edu
Web Site: http://www.chemistry.uah.edu

Degree: Master of Science

Chair: James K. Baird, Professor

Professors:

Baird, J.K.; theoretical radiation chemistry, crystal growth and critical phenomena in solution
Gregory, J.C.; cosmic ray astronomy, interaction of fast atoms with surfaces
Meehan, E.J., Jr.; x-ray crystallography of proteins
Radonovich, L.J.; x-ray crystallography, organometallic chemistry
Riley, C. (Emeritus); electrodeposited materials, biocompatible surfaces
Setzer, W.; biomedicinal aspects of biologically active phytochemicals
Shriver, J.S.; NMR spectroscopy

Associate Professors:

Edmondson, S. (Research); NMR spectroscopy
Kaukler, W. (Research); x-ray microscopy, materials processing
Weimer, J.; surface kinetics and surface bonding studies

Assistant Professors:

Chen, L. (Research); x-ray diffraction of large molecules
DiGiammarino, E. (Research); protein biochemistry and structural biology
Gebauer, A; macrocyclic compounds
George, M. A.; sensors, thin film coatings
Scholz, C.; biosurfaces, biomaterials and polymers
Vogler, B.; biological macromolecules

Research

Research in the Department of Chemistry is pursued along all five of the main subdivisions of the subject (analytical, biochemistry, inorganic, organic, and physical). This work traditionally has been closely linked with projects underway at the nearby U.S. Army's Redstone Arsenal and NASA's Marshall Space Flight Center. Students have access not only to the University Library, with 6000 holdings in chemistry and 150 current chemical journal subscriptions, but also to the U.S. Army Redstone Scientific Information Center, which is one of the best scientific libraries in the country.

Equipment

Major equipment in the Chemistry Department includes: Varian 800 and 500 MHz nuclear magnetic resonance spectrometers equipped for both liquid and solid phase studies, Auger electron spectrometer, GC/MS, fluorescence spectrometer, x-ray photoelectron spectrometer, plasma chemistry apparatus, Jarrell-Ash 2 meter spectrometer, Varian Dris-90 ultraviolet-visible spectrometer, Beckman DB-G visible-ultraviolet spectrometers, single crystal and surface x-ray diffractometers, atomic absorption spectrometers, SEM, EDS, scanning tunneling and atomic force microscopes, surface x-ray diffractometer, FTIR with small angle and microscope attachments, molecular modeling system, Waters binary gradient liquid chromatography system, Perkin-Elmer high pressure liquid chromatograph, gas chromatographs and various CWand pulsed lasers. The University has a DEC AXP7000 computer and has access to a Cray-XMP supercomputer at the Alabama Supercomputer Center located in Huntsville. The Chemistry Department has numerous IBM compatible, Macintosh personal computers, and Silicon Graphics work stations available for student use.

Admission Requirements

General requirements of the School of Graduate Studies must be satisfied. In addition, students admitted to the graduate chemistry program are assumed to have training equivalent to the chemistry B.S. degree recommended by the American Chemical Society. The ACS-approved degree includes lecture and laboratory work in elementary chemistry, organic chemistry, physical chemistry, inorganic chemistry, analytical chemistry (including instrumental analysis), elementary physics, and mathematics through linear algebra and differential equations. Graduation from an undergraduate program not adhering to ACS standards does not preclude entrance into the UAH program. Students should realize, however, that if deficiencies exist, some additional undergraduate courses may be required. The time required to complete the M.S. degree may then be proportionately increased.

Master of Science

General requirements of the School of Graduate Studies under Plan I or Plan II must be satisfied.

Plan I (thesis option)

Graduate students selecting Plan I will be asked to take placement exams in biochemistry, inorganic chemistry, organic chemistry, and physical chemistry. In the event that a student fails one

of the placement exams, the student must make up this deficiency by passing a graduate course in the appropriate field selected from Group I, below

Group I Major Field Courses

Field	Courses
1. Biochemistry:	CH 561 Biochemistry I, CH 562 Biochemistry II, CH 647 Advanced Biophysical Chemistry I and CH 648 Advanced Biophysical Chemistry II.
2. Inorganic Chemistry:	CH 549 Spectroscopy and Molecular Structure and CH 600 Inorganic Chemistry.
3. Organic Chemistry:	CH 531 Theoretical Organic Chemistry, CH 631 Advanced Organic Chemistry I, and CH 632 Advanced Organic Chemistry II.
4. Physical Chemistry:	CH 640 Advanced Chemical Thermodynamics, CH 641 Statistical Thermodynamics, CH 642 Advanced Chemical Dynamics, CH 643 Quantum Chemistry, and CH 644 Chemical Electrodynamics.
5. Polymer Chemistry:	CH 540 Polymer Synthesis and Characterization, and CH 645 Polymer Physical Chemistry.

After having passed the placement exams and/or making up any deficiencies identified by these exams, the student must take enough courses to have at least two courses from one of the five major fields listed under Group I, for example, two courses in biochemistry or two courses in inorganic chemistry, etc. A total of at least 24 semester hours of graduate course credit is required under Plan I. The hours remaining to make up the 24 should be selected from Group II below:

Group II Special Topics and Electives

A maximum of six courses can be chosen from: CH 521, 531, 540, 549, 553, 554, 560, 561, 562, 565, 600, 601, 602, 603, 621, 631, 632, 640, 641, 642, 643, 644, 645, 646, 647, 648, 650, 661, 700, 705, 721, 735, 745, 746, 765; MTS 501, 502, 660, 661, 701; BYS 519, 543; CHE 560, 561; and BSE 601.

In satisfying the Group II requirements, however, a maximum of three courses can be chosen from the special topics selections: CH 700, 705, 721, 735, 745, 765; BSE 601.

Course selection from Group II is ordinarily done with the help of the student's advisor. The student must register for CH 780 during each semester of residence, and must register for a minimum of two semesters of CH 699. The student should select a thesis advisor from among the eligible faculty, complete a thesis, and successfully defend it before his supervisory committee.

Plan II (non-thesis option)

Graduate students entering Plan II must qualify by meeting one of the following preliminary examination requirements:

a) Passing placement exams in biochemistry, inorganic chemistry, organic chemistry and physical chemistry.
b) Having previously passed at least two sections of the Materials Science Program Exam I.
c) Having previously passed the Biotechnology Science and Engineering Preliminary Exam.

Students selecting option (a) and failing to pass one or more of the subject placement exams, must make up the deficiency by passing two courses in the appropriate field selected from Group I above.

Course requirements under Plan II include 6 semester hours chosen from one of the five fields listed under Group I above plus 27 hours of graduate coursework in chemistry or related fields. Of the total of 33 hours of course work required under Plan II, at least 18 hours must be in chemistry. Plan II requires a program of study drawn up by the student and the Chemistry M.S. degree program advisor.

Students must also register for CH 780 Chemistry Seminar during at least four semesters. Because Plan II does not require any experimental work, it is not recommended for students seeking employment as industrial laboratory chemists.

Non-Traditional Fifth-Year Program Leading to the M.S. in Chemistry Plus a Class A Alabama High School Teacher's Certificate

Those who have a B.A. or B.S. degree with a major or its equivalent in chemistry as determined by the Department of Chemistry, who have not taken more than twelve semester hours in teacher education (graduate or undergraduate), and who are interested in obtaining Class A (master's level) certification for secondary school teaching, should consider the Non-Traditional Fifth Year Program. Contact the Education Department for preliminary advisement on admission and general program requirements. See the description in the Education section for more details.

Doctor of Philosophy

The Ph.D. degree with a chemistry specialty is possible within the guidelines and requirements of the Materials Science program (See "Interdisciplinary Programs").

Graduate Courses in Chemistry (CH)

521 Chemical Instrumentation **4 hrs.**

Use of basic instrumentation in electrochemical, chromatographic, and spectrophotometric analysis. Prerequisite: CH 346. Lab Fee: $60.

525 Environmental Chemistry **3 hrs.**

Principles of quantitative analyses related to minor components of a sample. Applications selected from principal analyses necessary to maintain environmental quality of air, water, and soil. Selection of conditions for collecting reliable samples, concentration of components with techniques for increasing concentration of selected component, relationships between physical and chemical changes in sample and signal output of predominant transducers, and translation of chemical analysis into meaningful specifications. Lecture only. Prerequisites: CH 521 or 223; EE 311, 342. (Same as ES 525.)

531 Theoretical Organic Chemistry **4 hrs.**

Molecular orbital theory and bonding, molecular structure, frontier molecular orbitals, pericyclic reactions, and reactive intermediates. Extensive computational laboratory work included. Prerequisites: CH 332, and 342 or 348 or approval of instructor. Lab Fee: $50.

540 Polymer Synthesis and Characterization **3 hrs.**

Synthesis of commercially relevant and novel polymers. Polymer characterization and discussion of the structural dependence of polymer properties. Prerequisites: CH 331. Students who have successfully completed CH 540 cannot also receive credit for CH 440 or MTS 649.

549 Spectroscopy and Molecular Structure **3 hrs.**

Intermediate level treatment of principles of spectroscopy and their application to determination of molecular structure. Prerequisite: CH 343.

553 Introductory Quantum Mechanics I **3 hrs.**

Waves and particles; Bohr's model of the atom; de Broglie waves, wave-packets and the uncertainty principle; postulates of quantum mechanics; Schroedinger's equation; simple systems in one, two and three dimensions; the hydrogen atom. Prerequisites: PH 113, CH 343 or PH 351, MA 244, 324. (Same as PH 451, PH 551, OSE 555, MTS 651.) Fall.

554 Introductory Quantum Mechanics II **3 hrs.**

Angular momentum and spin; atomic structure and spectrum; time-independent pertubation theory, variational methods; time-dependent pertubation theory and interactions of light with matter; scattering theory; electronic structure of solids; relativistic quantum mechanics. Prerequisite: CH 553 or PH 551. (Same as PH 452, PH 552, MTS 652.) Spring.

560 X-Ray Structure Determination **4 hrs.**

Examines both theoretical and practical aspects of molecular structure determination by x-ray diffraction methods. Diffraction of x-rays, symmetry operations and space groups, methods of data collection, theory of structure factors and Fourier synthesis, least squares methods of structure refinement. Extensive laboratory and computer work. Prerequisites: Senior standing in chemistry or physics and approval of the instructor. Lab Fee: $60.

561 Biochemistry I **3 hrs.**

Structural chemistry and function of biomolecules, mechanisms of biochemical reactions, enzyme kinetics, and energy transfer. Prerequisite: CH 332 or CH 361. (Same as BYS 547.)

562 Biochemistry II **3 hrs.**

Metabolism, biosynthesis of macromolecular precursors, storage, transmission, and expression of genetic information, and molecular physiology. Prerequisite: CH 561 or BYS 547. (Same as BYS 548.)

565 Molecular Biochemistry Laboratory **2 hrs.**

Practical experience in isolation and characterization of biomolecules. Prerequisite: CH 562. Lab Fee: $60.

600 Advanced Inorganic Chemistry **3 hrs.**

Survey with emphasis on structure and reactivity of inorganic compounds. Prerequisite: CH 401.

601 Structural Methods in Inorganic Chemistry **3 hrs.**

Physical methods applied to determination of structure of inorganic compounds. Prerequisite: CH 600.

602 Chemistry of Coordination Compounds **3 hrs.**

Modern bonding theory and stereochemistry of coordination compounds. Prerequisite: CH 600.

603 Chemistry of Nonmetal Compounds **3 hrs.**

Chemistry of selected nonmetal compounds. Prerequisite: CH 601.

621 Methods of Chemical Analysis **3 hrs.**

Literature, seminar course. Theory and methodology of various techniques of chemical analysis. Prerequisite: CH 521 or CH 421.

631 Advanced Organic Chemistry I **3 hrs.**

Organic synthetic reactions. Survey of certain reactions that enjoy widespread application to the synthesis of organic compounds. Prerequisites: CH 332, 342, or approval of instructor.

632 Advanced Organic Chemistry II **3 hrs.**

Physical organic chemistry. Reactive intermediates, structure-activity relationships, reaction mechanisms and techniques used to determine them. Prerequisite: CH 531 or approval of instructor.

640 Advanced Chemical Thermodynamics **3 hrs.**

First, second, and third laws of thermodynamics and applications. Brief introduction to statistical thermodynamics. Prerequisite: CH 341 or CH 347 or approval of instructor.

641 Statistical Thermodynamics **3 hrs.**

Principles leading to the development of Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac statistics. Thermodynamic properties calculated from partition functions. Prerequisite: CH 343.

642 Advanced Chemical Dynamics **3 hrs.**

Velocity of chemical reactions in homogeneous and heterogeneous systems. Absolute rate theory, collision theory, scattering, and concept of reaction cross sections. Prerequisite: CH 640.

643 Quantum Chemistry **3 hrs.**

Application of quantum theory to the chemical bond. Prerequisite: CH 343.

644 Chemical Electrodynamics **3 hrs.**

Electrodynamics problems encountered in chemistry. Maxwell's equations, electrostatics. Onsager and Debye theory of dielectrics, molecular dipole moments, Beer's law, Landolt's rule, light scattering from macromolecules, quantum theory of radiation, magnetic susceptibility, introduction to NMR and ESR. Prerequisites: CH 342, MA 324.

645 Polymer Physical Chemistry **3 hrs.**

Introduction to structure, properties and processing of polymers. Structural types, structure-property relationships, thermodynamics and kinetics of polymerization and depolymerization, polymer characterization, thermodynamics of polymer solutions and blends, and mechanical evaluation of polymers. Prerequisites: CH 341, 540. (Same as MTS 747.)

646 Thermodynamics of Materials **3 hrs.**

Fundamental thermodynamic review, phase equilibrium, chemical reaction equilibrium, free energy, binary and ternary phase transformations, solution models and selected topics. Prerequisite: CH 341 or equivalent. (Same as CHE 646 and MTS 646.)

647 Advanced Biophysical Chemistry I **3 hrs.**

Advanced biophysical chemistry, including the first, second, and third laws of thermodynamics and their practical applications. Solution thermodynamics and acid-base equilibria. Prerequisites: CH 342 or 348, MA 324, or approval of instructor. Students who have completed CH 347 cannot earn credit for CH 647.

648 Advanced Biophysical Chemistry II **3 hrs.**

Advanced biophysical chemistry, including intermolecular, and intramolecular forces; binding; electrolyte solutions; water and macromolecules. Prerequisite: CH 647. Students who have completed CH 348 cannot earn credit for CH 648.

650 Principles of Liquid & Solid Interfaces **3 hrs.**

Applies basic principles in thermodynamics and kinetics to characterize surfaces and surface phenomena. Fundamental properties of gas-liquid, liquid-liquid, solid-liquid and solid-gas interfaces and phenomena occurring at these interfaces. Prerequisite: CH 341. (Same as MTS 650 and CHE 650.)

661 Biological Macromolecules **3 hrs.**

Detailed analysis of structures of proteins, nucleic acids, and complex polysaccharides. Prerequisite: CH 562.

699 Master's Thesis **3 or 6 hrs.**

Required each semester a student is enrolled and receiving direction on a master's thesis. Minimum of two terms required.

700 Current Topics in Chemistry **3 hrs**

Advanced laboratory research in one of the departmental research groups. The student works on an independent or group research project. Completion of the course requires a written and an oral report. Prerequisite: approval of the instructor.

705 Selected Topics in Inorganic Chemistry **3 hrs.**

Prerequisite: CH 600 and approval of instructor.

721 Selected Topics in Analytical Chemistry **3 hrs.**

Prerequisite: CH 621 and approval of instructor.

735 Selected Topics in Organic Chemistry **3 hrs.**

Prerequisite: CH 632 and approval of instructor.

745 Selected Topics in Physical Chemistry **3 hrs.**

Prerequisite: CH 643 and approval of instructor.

746 Solid State Chemistry **3 hrs.**

Chemical properties of solids. Includes phase equilibria, chemical bonding in ionic and covalent crystals, thermodynamics of atomic defects, ionic conductivity in solids, corrosion, and introduction to surfaces and adsorption. Prerequisites: CH 342, MA 324.

765 Selected Topics in Biochemistry **3 hrs.**

Prerequisites: CH 661 and approval of instructor.

780 Chemistry Seminar **1 hr.**

Required during each semester of residence.

COMPUTER SCIENCE

300 Technology Hall
Telephone: (256) 824-6088
Email: info.grad@cs.uah.edu
Web Site: http://www.cs.uah.edu

Degrees:

Master of Science
Master of Science in Software Engineering
Doctor of Philosophy

Certificates:

Software Engineering
Information Assurance

Chair: Heggere S. Ranganath, Professor

Professors:

Amin, A.T.; algorithms, graphs and networks, software testing
Davis, C.G. (Emeritus); software engineering, software requirements definition techniques
Graves, S.J ; distributed computing, data and information systems, software engineering
Johannes, J.D (Emeritus); artificial intelligence, distributed operating systems, software engineering
Ranganath, H.S.; image processing, pattern recognition, neural networks, data mining
Richards, P.G.; numerical analysis, modeling of ionosphere and plasmasphere
Shiva, S.G. (Emeritus); artificial intelligence, software engineering, parallel and distributed processing, VLSI design methodologies
Slater, P.J.: graph theory, combinatorics

Associate Professors:

Delugach, H.S.; software requirements development, knowledge based systems
Li, W.; object oriented software design, real time software engineering
Newman, T.S.; visualization, graphics, and computer vision
Rochowiak, D.M.; cognitive science, artificial intelligence, computer ethics

Assistant Professors:

Cox, G.; computer architecture, networks, distributed systems
Etzkorn, L.H.; software re-use, object oriented software development
Hart, D.R.; distributed computing, visualization, software engineering
Weisskopf, M.E.; modern operating systems, distributed processing
Aygun, R.; Multimedia, video and image processing, data mining, bioinformatics

The Computer Science Department offers the M.S. and Ph.D. degrees with a major in computer science, and the M.S.S.E. degree in software engineering. In addition, the department offers certificate programs in software engineering and in information assurance. Certificates can be earned in conjunction with the M.S. degree, or independently of any degree program.

The UAH campus is fully networked with a fiber optics backbone and is a member of the NSF's VBNS2 network, giving high-speed connectivity to the Internet. The department has modern networked computing facilities, containing PC's and SUN work stations, and provides excellent computing support for instruction and research.

Additional information can be obtained from the Computer Science homepage at http://www.cs.uah.edu. Requests for admissions information can be sent by email to: admissions@cs.uah.edu.

Admission Requirements

Requirements for admission to the computer science graduate degree program are in addition to those of the School of Graduate Studies. Scores from the GRE basic test are required for admission to the program. Transcripts will be reviewed and deficiencies in computer science background may result in the need to take one or more broadening courses. The MAT or GMAT is not an acceptable substitute for the GRE.

Breadth Requirements

Applicants to graduate programs in computer science must satisfy the following breadth requirements before admission to the program.

Mathematics:

MA 171 Calculus A (4 hrs.)
MA 172 Calculus B (4 hrs.)
MA 244 Introduction to Linear Algebra
MA 385 Introduction to Probability

Computer Science:

CS I, CS II, CS III An Introductory sequence covering Object-Oriented Programming and Data Structures in C/C++/Java
CS 214 Introduction to Discrete Structures
CS 317 Introduction to Design and Analysis of Algorithms
CS 490 Introduction to Operating Systems
CS 513 Introduction to Computer Architecture (or CS 309 and 413)

The breadth requirements can be satisfied in one of the following ways:

1. Completion of the course at UAH with a grade of B or better;
2. Completion of an equivalent course at another institution with a grade of B or better;
3. Testing out of the course, where permitted by departmental policy.

Consult a departmental advisor for additional information.

Transfer to Computer Science from other UAH Graduate Programs

Students enrolled in other graduate programs at UAH who wish to obtain a degree in computer science should see a computer science advisor for evaluation. Such a student must fulfill the

computer science breadth requirements. Taking CS graduate courses without first checking with a departmental advisor will not eliminate the need for completing the breadth requirements.

The Program of Study

A program of study should be completed as soon as the course content of the program has been selected. The plan must be made in consultation with an advisor from the computer science faculty. The student's faculty advisor, department chair, and the Dean of the School of Graduate Studies approve the program of study. After approval, student requested changes must be agreed to by the student's advisor and submitted for approval.

Teaching Areas

The Computer Science Department offers an exceptionally broad spectrum of courses. For convenience, they are listed below by category. The teaching areas include software engineering, computer graphics and image processing, data and information technology, computer architecture and networking, artificial intelligence, languages and systems, and theoretical computer science. There is no requirement to stay within a particular area, and students may freely select from any of the areas when preparing the program of study with an advisor.

Software Engineering

Software engineering is a study of the process of large-scale software development. It includes a study of the phases of software development with emphasis on tools and practices for good software development. A student who completes the M.S. program, which includes CS 650 and 15 semester hours selected from the following: CS 550, 551, 552, 553, 555, 651, 652, 654, 656, 658, 666, 668, 750, and 695 or 696, will receive the software engineering certificate as well as the M.S. degree.

The courses in this area include

CS 550 ADA Program Support Environments
CS 551 Object Oriented Software Modeling
CS 552 Advanced Object Oriented Design
CS 553 Client Server Computing
CS 555 Formal Program Development
CS 650 The Software Engineering Process
CS 651 Advanced Object-Oriented Development using UML
CS 652 System and Software Requirements Methods
CS 654 Software and Design Techniques and Tools
CS 656 Software Testing and Reliability
CS 658 Software Project Management and Quality Assurance
CS 666 Software Studio I
CS 668 Software Studio II
CS 750 Advanced Software Engineering Topics

Computer Graphics and Image Processing

The creation of computer-generated graphic animations and photo-realistic images has a growing number of exciting and important applications. The inverse problem - the processing and extraction of information from visual and other patterns - also has many industrial, military, and space applications. Courses in this emphasis area include a sequence in computer graphics and a sequence in the theory, computational algorithms, and architecture for the design and development of pattern recognition and vision systems.

CS 545 Introduction to Computer Graphics
CS 548 Human-Computer Interaction
CS 640 Automatic Pattern Recognition
CS 642 Computer Processing of Digital Images
CS 645 Computer Graphics
CS 646 Computer Geometry Modeling
CS 742 Image Processing Algorithms and Architectures

Data and Information Technology

As the amount of information and data used by organizations rapidly increases, the need for techniques to manage, retrieve, process, and protect this geographically distributed data becomes critical. For very large data collections, these techniques must include methods to help users discover and select relevant data from the mass of available data. The data and information technology area focuses on the technology required to utilize effectively this rapidly growing volume of data and information. The courses in this area include the following:

CS 585 Introduction to Computer Security
CS 660 Large Scale Scientific Computing
CS 685 Computer Security
CS 687 Database Systems
CS 787 Advanced Database Systems

Computer Architecture and Networking

The courses offered in the area of computer architecture cover the organization, architecture and design of digital computer systems from high level conceptual design to gate level implementation. The main concentration areas are: logic design and digital computer hardware design; parallel computer architectures; distributed processing; and networks. Courses in this area include:

CS 570 Introduction to Computer Networks
CS 586 Microprocessor Architecture
CS 613 Computer Architecture
CS 670 Computer Networks
CS 713 Distributed Processing Systems
CS 714 Parallel Processing Architectures
CS 716 Computer System Performance Analysis
CS 780 Fault Tolerant Computing

Artificial Intelligence

Artificial intelligence allows the building of computer-based systems that require minimal human interaction with operational details; are easy to use through enhanced communication and understanding abilities; can adapt to environmental variations; and can describe their own operations and justify their solutions, decisions and advice. The courses listed below cover the fundamentals of artificial intelligence.

CS 530 Expert Systems and Heuristic Programming
CS 537 Introduction to Neural Networks
CS 630 Artificial Intelligence I
CS 635 Computational Models of Cognition
CS 730 Artificial Intelligence II

Languages and Systems

The languages and systems area includes instruction in programming languages, systems programming, operating systems, and their use in problem solutions.

CS 524 Programming Languages
CS 526 Program Translation and Compiler Construction
CS 590 Programming Environments with UNIX
CS 690 Advanced Operating Systems
CS 790 Operating Systems Seminar

Theoretical Computer Science

These courses develop and explore some of the theoretical aspects of computer science and provide a basis and framework for further research either in theoretical computer science or in another research area having a theoretical basis.

CS 603 Formal Languages and Automata Theory
CS 617 Design and Analysis of Algorithms
CS 703 Theory of Programming Languages
CS 717 Advanced Algorithm Design and Analysis

Graduate Certificate Programs

Software Engineering Certificate

The Software Engineering Program is designed for those students who want to broaden their knowledge in this area, but do not necessarily desire to pursue a graduate degree in computer science. The certificate requires 18 graduate semester hours of coursework in software engineering, which must include CS 650 and five courses selected from the following courses: CS 550, 551, 552, 553, 555, 652, 654, 656, 658, 750, or 695. Students desiring to complete the certificate program should have either industrial experience in software development or have undergraduate courses in software development. Students may not work toward a Software Engineering Certificate concurrently with or after receiving the M.S.S.E

Information Assurance Certificate

The Department of Computer Science collaborates with the Department of Electrical and Computer Engineering and the College of Administrative Science to offer an interdisciplinary graduate certificate program in Information Assurance. Contact the Department for further details.

Master of Science

Students applying for the master's program are expected to have an undergraduate background in CS. Those students who do not have such a background must satisfy the breadth requirements described above.

Unconditional Admission

Students applying to the M.S. program will be given unconditional admission if they meet all the requirements of the School of Graduate Studies and of the Computer Science Department including the breadth requirements listed above.

Conditional Admission

Conditional admission will be recommended for students who, in the judgment of the department, have the potential for successfully completing graduate work but who do not meet all of the requirements for admission.

Degree Requirements and Restrictions

The Master of Science degree is conferred under Plan I or Plan II.

Plan I. A minimum of 24 semester hours of coursework and the writing of an acceptable thesis is required. At least six hours of thesis credit (CS 699) must be earned. A student must present his/her thesis and pass an oral examination based on the thesis and related coursework. Plan I students must register for CS 699 each term they receive supervision from their advisor.

Plan II. A minimum of 33 semester hours of coursework is required. A student must pass a written comprehensive examination over the four core courses given below. Plan II students must complete at least 18 hours of coursework before taking the written comprehensive examination. The examination may only be taken twice.

The following requirements and restriction apply to a student in either plan.

Course Requirements

All students must take the following four courses:

CS 613 Computer Architecture	CS 650 The Software Engineering Process
CS 617 Design and Analysis of Algorithms	CS 690 Advanced Operating Systems

If a student has not had an undergraduate course in programming languages, CS 524 must be included in the program of study. No more than 50% of the hours in the program of study may be 500-level courses. No more than three hours of selected topics or independent study courses may be included in a program of study. Exceptions must be recommended by the student's advisor and approved by the department chair.

Grade Requirements

A grade of B or better must be earned in each of the core courses. A grade of B or better must be earned in each of the 500-level courses which is counted toward the degree. No grade lower than C can be counted toward a graduate degree. A 3.0 average must be maintained in all graduate work at UAH and in all work to be counted toward the degree.

Time Limit

The degree must be completed within six years. Courses older than six years may be validated according to Graduate School policy. Courses older than ten years may not be applied to the degree.

Transfer Credit

Graduate work may be transferred from another institution according to Graduate School policy.

Master of Science in Software Engineering

Students applying for the master's program are expected to have an undergraduate background in computer science. Those students who do not have such a background must satisfy the breadth requirements described above. In particular, students who have not had an undergraduate course in programming languages must take CS 524. Plan II students can count CS 524 as their additional graduate course.

Unconditional Admission

Students applying to the M.S. program will be given unconditional admission if they meet all the requirements of the School of Graduate Studies and of the Computer Science Department including the breadth requirements listed above.

Conditional Admission

Conditional admission will be recommended for students who, in the judgment of the department, have the potential for successfully completing graduate work but who do not meet all of the requirements for admission.

Degree Requirements and Restrictions

The Master of Science in Software Engineering is conferred under Plan I or Plan II

Plan I. (thesis) A minimum of 24 semester hours of coursework and the writing of an acceptable thesis is required. At least six hours of thesis credit (CS 699) must be earned. A student must present his/her thesis and pass an oral examination based on the thesis and related coursework. Plan I students must register for CS 699 each term they receive supervision form their advisor.

Plan II. (non-thesis) A minimum of 33 semester hours of coursework is required. Plan II students must complete CS 666 and 668. A Plan II student must pass a written comprehensive examination over the four core courses given below. Plan II students must complete at least 18 hours of coursework before taking the written comprehensive examination. The examination may only be taken twice.

The following requirements and restriction apply to a student in either plan.

Course Requirements

All students completing the M.S.S.E. must take the following four courses:

(12 semester hours)

CS 613 Computer Architecture
CS 650 The Software Engineering Process
CS 617 Design and Analysis of Algorithms
CS 690 Advanced Operating Systems

Plan II students must take CS 666 and CS 668 (Software Studio I and II).

Students completing the M.S.S.E. under Plan II (non-thesis) must take 15 semester hours from the Software Engineering Courses listed above (not counting CS 650) or twelve hours from the list (not counting CS 650) and an approved additional three semester hour graduate course in computer science.

Students completing the M.S.S.E. under Plan I (thesis) must take twelve hours from the Software Engineering Courses listed above (not counting 650).

If a student has not had an undergraduate course in programming languages, CS 524 must be included in the program of study. No more than 50% of the hours in the program of study may be 500-level courses. No more than three hours of selected topics or independent study courses may be included in a program of study. Exceptions must be recommended by the student's advisor and approved by the department chair.

Grade Requirements

A grade of B or better must be earned in each of the core courses. A grade of B or better must be earned in each of the 500-level courses which is counted toward the degree. No grade lower than C can be counted toward a graduate degree. A 3.0 average must be maintained in all graduate work at UAH and in all work to be counted toward the degree.

Time Limit

The degree must be completed within six years. Courses older than six years may be validated according to Graduate School policy. Courses older than ten years may not be applied to the degree.

Transfer Credit

Graduate work may be transferred from another institution according to Graduate School Rules.

Doctor of Philosophy

Admission Requirements

The admission policies for the Ph.D. program in computer science follow the general policies of the School of Graduate Studies and Computer Science Department as described above. An applicant's admission request will be reviewed in light of preparatory coursework, GRE scores, any supporting information, and general expectation of completing the degree. Students requiring a large amount of prerequisite coursework will not normally be admitted to the program until the courses have been completed. Graduate admission requests for the Ph.D. program will be reviewed once per semester by a departmental admissions committee. Applicants are required to submit supporting recommendation letters and an indication of research interests and study plans. Specific requirements are available from the Computer Science Department office. Requests for admission will be evaluated according to the following guidelines.

Unconditional Admission

Unconditional admission will be given to applicants who meet all of the requirements of the School of Graduate Studies and Computer Science Department. Students showing exceptional promise who desire to pursue the Ph.D. full-time may be admitted to the program after completing a bachelor's degree in computer science.

Conditional Admission

Conditional admission will be recommended for applicants who do not meet all of the requirements of the School of Graduate Studies and the Computer Science Department but who show high potential for completing the degree requirements.

Degree Requirements

The general requirements for the Ph.D. degree comply with those of the School of Graduate Studies. The requirements include a preliminary examination, completion of coursework, a Qualifying Examination, completion of significant research documented in a dissertation and the dissertation defense.

Major/Minor Subjects

A minimum of 54 hours of graduate course credit plus a minimum of 18 dissertation credit hours are required for the Ph.D. in computer science. The program of study will be approved by the student's Supervisory Committee. Coursework grade requirements are the same as for the M.S. degree. Coursework taken as part of a graduate degree program at another institution may be applied to the degree with permission of the student's Supervisory Committee. The program must include CS 524, CS 603, CS 613, CS 617, CS 650 and CS 690 and must have a coherent area of emphasis, of which at least 6 semester hours must be at the 700 level. At least 9 semester hours of graduate level mathematics must also be included in the program.

Preliminary Examination

Ph.D. students will be required to take a preliminary examination, consisting of (1) a written test covering CS 613, CS 617, CS 650, and CS 690, and (2) an evaluation by the graduate faculty of the student's overall academic potential.

The examination must be taken within a year after admission to the Ph.D. program, or at the earliest opportunity upon completion of the core coursework. Successful completion of the examination will provide evidence of the student's ability to continue in pursuit of the Ph.D. degree. The examination can be taken no more than twice.

Admission to Candidacy

To be admitted to candidacy for the Ph.D. degree, students must first pass the Qualifying Examination. The qualifying examination can cover any aspect of the student's program and is taken after completion of the student's coursework and upon recommendation of the student's Supervisory Committee. It is designed to test students' fitness for pursuing research projects in their chosen areas and to test their general knowledge of computer science. As part of the Qualifying Examination, each student will present a research proposal to the Supervisory Committee.

Residency Requirements

According to graduate school policy, residence may be established through either (i) being enrolled as a full-time student (at least 9 graduate semester hours) either for one continuous academic year, or for Spring and Fall semesters in the same calendar year, or (ii) being enrolled in at least 6 hours of graduate course work in at least three of four consecutive semesters.

Other Requirements

The program must be completed within five years after admission to candidacy.

The Qualifying Examination may be taken no more than twice.

CS 799 is required each semester a student is receiving direction on the doctoral dissertation.

For additional requirements, consult the Academic Information Section of this Graduate Catalog.

Dissertation

The research described in the dissertation must be submitted for publication in an approved journal prior to defense of the dissertation. A public defense of the dissertation is required.

SPECIAL COMPUTER SCIENCE COURSES (CS)

The following courses serve as broadening courses for students entering the computer science graduate program. They are not open to computer science undergraduates and cannot be taken for credit by computer science undergraduate or graduate majors.

513 Introduction to Computer Architecture **3 hrs.**

Review of combinational and sequential logic design, register transfer concept, logic design of memory, arithmetic unit, control unit, and I/O system of simple computer. Architectural trade-offs; representative computer architectures including a micro-, mini-, and large-scale computer system. Lab Fee: $50.

517 Data Structures and Algorithm Analysis **3 hrs.**

Review of basic data structures such as stacks, queues, lists, B-Trees, and binary trees. Overview of file structures and access methods. Introduction to complexity analysis of algorithms. Basic algorithm design techniques such as divide & conquer, dynamic programming, and backtracking. Introduction to the classification of problems by class; i.e., tractable, NP, intractable, and unsolvable. Prerequisite: CS 221. Lab Fee: $40.

Graduate Courses in Computer Science (CS)

Courses numbered at the 500-level may be taken for undergraduate or graduate credit with prior approval of the student's advisor, except as otherwise noted. Courses at 600-level or above are reserved for graduate students. They may be taken by other students only by approval. Consult "Seniors Taking Graduate Courses" in the Graduate Admissions section of this catalog for specific policies and approval procedures.

520 Computer-Based Instructional Technologies **3 hrs.**

Introduces prospective teachers to current state of the art in educational technology. Extensive hands-on experiences with microcomputers and other emerging technology. Emphasis on effectively integrating technology into instructional setting for both special and regular students. (Same as ED 520.) Lab Fee: $40. May not be applied to CS major or minor.

524 Programming Languages **3 hrs.**

Principles of modern programming language features and design. Imperative vs. declarative language styles. General purpose language features, e.g., operators, expressions, recursion, object-orientation. Special purpose language features, e.g., support for graphical interfaces, concurrency, non-determinism. Relationship of language design and implementation. Formal grammars, BNF notation. Brief history of programming languages. Taught as CS 424/524. Course completion and/or grade requirements for graduate credit will differ from those for undergraduate credit. Students may not receive credit for both CS 424 and CS 524 Prerequisites: CS 317 and proficiency in a modern programming language. Lab Fee: $40.

526 Program Translation and Compiler Construction **3 hrs.**

Language representation; grammar classification; lexical analysis technique and tools; parsing technique and tools; compile-time and run-time symbol table design; code generation and optimization; error diagnostics. Compiler writing tools. Prerequisites: CS 317. CS 424/524 and CS 403 recommended. Lab Fee: $50.

530 Expert Systems and Heuristic Programming **3 hrs.**

Expert systems concepts and their architectures. Languages and tools for knowledge engineering. Heuristic versus algorithmic methods, treatment of heuristics as used in expert systems, and heuristic programming techniques. Class and individual projects to illustrate concepts. Prerequisites: CS 317 and CS 524. Lab Fee: $40.

537 Introduction to Neural Networks **3 hrs.**

Introduction to neural networks, covering the most prominent neural network models. Hands-on experience with neural networks is gained through an individual or group project. Prerequisite: CS 317. Lab Fee: $40.

545 Introduction to Computer Graphics **3 hrs.**

Introduction to the underlying theory and mechanics of computer graphics. Brief historical perspective, progressing through extended discussion on topics such as display hardware technology, 2D raster scan conversion algorithms, 2D and 3D geometric transformations, and 3D projection and viewing techniques. A significant number of programming projects are assigned. Prerequisites: CS 221 (or proficiency with the C programming language), and MA 244. Lab Fee: $40.

548 Human-Computer Interaction **3 hrs.**

Introduction to human-computer interaction and principles of graphical user interface design. Includes examination of interactive environments including windowing systems development tools, multimedia, and visual programming interfaces. Prerequisite: CS 545.

550 Ada Program Support Environments **3 hrs.**

A study of advanced development concepts and support tools centered around Ada as the implementation language. Design and implementation concepts as part of the software life cycle. Prerequisite: CS 350 or equivalent introductory course in Ada. Lab Fee: $40.

551 Object Oriented Software Modeling **3 hrs.**

Object oriented methods and design concepts, the Unified Modeling Language (UML), tools for object oriented development, multiple-viewed modeling techniques, forward and reverse engineering using software modeling. Prerequisite: CS 207 or 304 or 321. Lab Fee: $40.

552 Advanced Object Oriented Design **3 hrs.**

Advanced C++ programming and techniques, concepts, and styles to realize and make object-oriented designs more reusable, extendable, and simple. Emphasis on quantification of what makes a "good" design. Introduces "design patterns" as elements of reusable object-oriented software development. Prerequisite: CS 304 or 307 or 321. Lab Fee: $40.

553 Client/Server Computing **3 hrs.**

Conceptual and practical aspects of client/server computing, a software development paradigm that requires an understanding of object-oriented software technologies, World Wide Web technologies, networking, and standardized middleware such as CORBA. Fundamental concepts of distributed object computing, multithreading, and CORBA architectures. Students will apply the concepts in the development of practical distributed programs. Techniques for developing Web-enabled software applications. Prerequisite: CS 306 or CS 321. Lab Fee: $40.

555 Formal Program Development **3 hrs.**

Propositional and predicate calculi, reasoning about programs, weakest precondition, program development, developing invariants, efficiency consideration, and program documentation. Prerequisites: CS 317 and CS 424 or 524. Lab Fee: $40.

560 Current and Emerging Instructional Technologies **3 hrs.**

Designed to build competency in computer technologies appropriate to instructional use. Concepts of authoring and scripting will be used to unify course materials. Prerequisite: ED/CS 520. (Same as ED 560.) Lab Fee: $40. May not be applied to CS major or minor.

570 Introduction to Computer Networks **3 hrs.**

Organization and operation of computer networks. Physical, Data Link, Network, Transport, and Application-layer protocols and algorithms; LAN and WAN systems; TCP/IP; Wired and wireless organizations; security approaches. Prerequisite: CS 413 or CS 513. Lab fee: $40. Taught as CS 470/570; course completion and/or grade requirements for graduate credit will differ from those for undergraduate credit. May not be taken by students who have taken CS 470.

585 Introduction to Computer Security **3 hrs.**

This course examines the issues related to security policies, models and mechanisms applicable to providing security for computer-based systems including operating systems, database management systems, and networks.

586 Microprocessor Architecture **3 hrs.**

Evolution of microprocessors. Software aspects: registers and register organization, instruction sets, addressing modes, assembler and assembler directives. Hardware aspects: redundant bus concepts, clock circuits, memory, parallel and serial input/output interfaces, programmed I/O, interrupt mode I/O, direct memory access. Survey of current microprocessor technology. Prerequisite: CS 413 or CS 513. Lab Fee: $50.

590 Programming Environments with UNIX **3 hrs.**

Advanced strategies for the design and development of systems and programs in the UNIX environment. Emphasis on automated tool and system development using UNIX tools. Parallel and supercomputer issues as treated by UNIX and C. Advanced shell concepts and programming including control flow and interrupt handling. Process and interprocess communications. Prerequisite: CS 390 or two years experience in UNIX. Lab Fee: $40.

595 Independent Study **3 hrs.**

Individual directed study under the supervision of an instructor. Prerequisite: approval of instructor

596 - 598 Selected Topics in Computer Science **3 hrs.**

Course offered by an instructor in a specialized area of computer science. Prerequisite: Approval of instructor. Lab Fee: $40.

603 Formal Languages and Automata Theory **3 hrs.**

Formal definition of programming languages. Definition of formal grammars: regular, context-free, context sensitive, and phrase-structure. Definition of automata: finite-state, pushdown, linear-bounded automata, Turing Machines. Relationship between formal languages and automata. Prerequisites: CS 317, CS 424 or 524; CS 403 recommended. Lab Fee: $40.

613 Computer Architectures **3 hrs.**

Organization, operation, and analysis of advanced computer architectures. Topics include advanced pipelining approaches, multi-processor architectures, instruction set architectures, memory hierarchy design, hardware and software-based performance optimization, and system performance measurement. Prerequisite: CS 413 or CS 513. Lab Fee: $40.

617 Design and Analysis of Algorithms **3 hrs.**

Strategies of algorithm synthesis and analysis. Design methodologies of classical algorithm categories such as: divide-and-conquer, greedy method, dynamic programming, search and traversal, back-tracking, and branch-and-bound. Computational complexity and important theoretical results from lower- and upper-bound studies, NP-hard, and NP-complete problems. Prerequisite: CS 317 or CS 517. Lab Fee: $40.

620 Curriculum Integration Technology **3 hrs.**

Prepares teachers to plan curriculum integration by using computer technology and software in various curriculum areas for both regular and special students. Also develops competency in instructional design and production skill techniques. Implementing instructional events using long-distance technologies. Prerequisites: ED/CS 520, and CS 560. (Same as ED 620.) May not be applied to CS major or minor. Lab Fee: $40.

630 Artificial Intelligence I **3 hrs.**

AI concepts and methods for problem solving, heuristic search, planning, hypothesis formation, modeling and knowledge representation, knowledge acquisition (learning), and AI's programming methodologies and tools. Applications of AI in areas of automatic programming, theorem proving, game playing, machine vision, natural language systems, and robots. Prerequisites: CS 317, CS 424 or 524. Lab Fee: $40.

635 Computational Models of Cognition **3 hrs.**

Computational models of human information processing covering topics of current interest to both artificial intelligence and cognitive psychology. Use of computer simulations to test psychological theories. Application of psychological research to building AI systems. Prerequisite: CS 630. Lab Fee: $40.

637 Neural Networks II **3 hrs.**

Advanced topics in neural network computation. Statistical mechanics and the Hopfield Net; optimal architectures for back propagation nets; self-organizing feature extraction; theory of feature mapping. Selected readings in neural networks. Prerequisite: CS 537. Lab Fee: $40.

640 Automatic Pattern Recognition **3 hrs.**

Discriminant analysis, maximum likelihood decisions, deterministic and nondeterministic approaches for trainable classifiers, preprocessing and feature extraction, clustering, syntactic pattern recognition. Pattern recognition in image analysis. Prerequisites: MA 244, MA 385 and CS 317. Lab Fee: $40.

642 Computer Processing of Digital Images **3 hrs.**

Introduction to image processing systems; sensing, sampling and quantization; image transforms; image enhancement and restoration; image segmentation, and description; image correlation; image sequence analysis; practical applications of image processing. Prerequisites: MA 244, MA 385 and CS 317. Lab Fee: $40.

645 Computer Graphics **3 hrs.**

Hierarchical modeling paradigm and 3D solid modeling. High resolution 3D graphics including topics in curve and surface representation, solid modeling, visible surface determination, color theory, illumination and shading, texture mapping, and antialiasing. Emphasis is on 3-D techniques and algorithms. A significant number of programming projects are involved. Prerequisite: CS 545. Lab Fee: $40.

646 Computer Geometry Modeling **3 hrs.**

Numerical and computer representation of curves and surfaces, solid geometry modeling and management aspects of geometric data. Computer procedures associated with coordinate transformation, curve and surface design, orientation, cubic-tension-B-splines, Bezier curves/surfaces, and interpolation methods. Discuss graph-based and Boolean models and concepts of constructive application to robotics, animation, image processing and computer graphics, CAD/CAM/CAE. Prerequisite: CS 545. Lab Fee: $40.

650 The Software Engineering Process **3 hrs.**

The process of developing complex software products. Includes software life cycles, phases of development and disciplines such as CM, QA, V&V, and T&E. Covers issues associated with professionalism and the ethical use of computers in the information age, including software piracy and copyrighting software. Prerequisites: CS 317, CS 490 and CS 424 or 524, or approval of instructor based upon applicable industrial software development experience. Lab Fee: $40.

651 Advanced Object Oriented Development Using UML **3 hrs.**

Fundamental software engineering concepts illustrated through the unified modeling language (UML), Introduces “use cases”. System architecture as developed through an incremental iterative process. Core workflows including requirements, analysis, design, implementation and test. Includes a team project. Prerequisites: CS 551 and CS 650. Lab Fee: $40.

652 System and Software Requirements Methods **3 hrs.**

Emphasis upon the requirements phases of software development. Formal and informal methods, computer aided software engineering tools, tool and technique evaluation, requirements specification characteristics. Includes experience with CASE tools on a variety of problems. Prerequisite: CS 650 or approval of instructor based upon applicable industrial software development experience. Lab Fee: $40.

654 Software Design Techniques and Tools **3 hrs.**

Alternative approaches for the design of software products. Includes design specification, characteristics of a good design, design verification and validation. Includes a design project. Prerequisite: CS 650 or approval of instructor based upon applicable industrial software development experience. Lab Fee: $40.

656 Software Testing and Reliability **3 hrs.**

Test data adequacy, test data selection, and output oracle; functional, structural, and fault-based testing methods; integration testing and system testing; system reliability models and application; test tool; test planning and management. Prerequisite: CS 650. Lab Fee: $50.

658 Software Project Management and Quality Assurance **3 hrs.**

Software life cycle, software risk reduction, software productivity, planning, organizing, directing and controlling software projects, software tools for cost estimation, configuration and data management, software quality and its impact upon development cycle, quality metrics. Prerequisite: CS 650 or approval of instructor based upon applicable industrial software development experience. Lab Fee: $50.

660 Large Scale Scientific Computing **3 hrs.**

Advanced techniques for processing data for large scientific and engineering applications. Application of parallel processing to scientific data processing. Prerequisite: MA 515. Lab Fee: $40.

666 Software Studio I **3 hrs.**

This is the first course in a two-course sequence where students work in teams on medium-sized software projects. Activities include analyzing and documenting software system requirements, producing a project plan, designing and building a prototype, and orally presenting the project for evaluation. The practice of software design and evaluation is conducted in an iterative cycle so that the design-evaluation phases are repeated twice to generate a more mature design. Prerequisites: CS 650, a designated 600-level software engineering elective, and a designated 500 or 600-level software engineering elective. Lab Fee: $50.

668 Software Studio II **3 hrs.**

This is the second course in a two-course sequence where students work in teams to continue the software engineering cycle with emphasis on software management, evolution, maintenance, quality analysis, testing, integration, validation, and security auditing. Prerequisites: CS 666. Lab Fee: $50.

670 Computer Networks **3 hrs.**

Detailed analysis of the organization and operation of computer networks, focusing on algorithms and organizations for the Network Layer and Data Link Layer protocols of Wired and Wireless systems. Prerequisite: CS 470 or CS 570. Lab fee: $40.

685 Computer Security **3 hrs.**

Advanced topics in security policies, models, and mechanisms applicable to providing security for computer based systems, including operating systems, database management systems, and networks. Prerequisite: CS 585. Lab Fee: $40.

687 Database Systems **3 hrs.**

Basic concepts of database systems. Use of semantic models in database design. Data models with a major focus on the relational and object-oriented models. Relational query languages and normal forms. Database management system design issues. Security and integrity issues. Prerequisite: CS 490. Lab Fee: $40.

690 Advanced Operating Systems **3 hrs.**

Review of multiprogramming operating systems including process management and virtual memory. Operating systems for shared and distributed memory multiprocessors and distributed systems. Topics include distributed file systems, concurrency and distributed process coordination. Introduction to network communication issues and special purpose systems such as real time systems, transaction processing systems, and client-server technology. Prerequisites: CS 490 or equivalent, CS 413, or CS 513. Lab Fee: $40.

695 Independent Study **3 hrs.**

Individual directed study under the supervision of an instructor. Prerequisite: Approval of instructor.

696-698 Selected Topics in Computer Science **3 hrs.**

Course offered by an instructor in a specialized area of computer science. Lab Fee: $40.

699 Master's Thesis **3 hrs.**

Required each semester student is working and receiving direction on master's thesis. Maximum of 9 hours of credit upon successful completion of master's thesis.

703 Theory of Programming Languages **3 hrs.**

Syntactic analysis and semantic interpretation of programming languages based on research and results in formal languages and associated compiler techniques. Identification of research directions and potential research projects in programming languages. Prerequisite: CS 603. Lab Fee: $40.

713 Distributed Processing Systems **3 hrs.**

Computer network configurations, communication protocols, and architectural tradeoffs; distributed databases; operating systems and software issues. Reconfiguration, recovery, and reliability, specification and design of distributed systems: case studies. Prerequisites: CS 670, and CS 690. Lab Fee: $40.

714 Parallel Processing Architectures **3 hrs.**

Coarse and fine grain parallelism and its effect on architecture, vector, array and multiprocessor structures. Process creation, communication and synchronization techniques, mapping algorithms to architectures, vectorization, data dependence and optimization, case studies of contemporary parallel architectures. Prerequisites: CS 613 and CS 690. Lab Fee: $40.

716 Computer System Performance Analysis **3 hrs.**

Performance evaluation: criteria for selecting techniques, performance metrics, and the establishment of performance requirements. Measurement techniques and tools: workload selection and characterization, monitors, capacity planning and data presentation. Specialized supporting theory; techniques and tools developed from the areas of probability and statistics; experimental analysis and design; simulation and queuing models. Prerequisites: CS 613, CS 524, and CS 690. Lab Fee: $40.

717 Advanced Algorithm Design and Analysis **3 hrs.**

Parallel algorithms, combinatorial algorithms, approximation algorithms for NP-complete problems, computational complexity. Distribution of algorithms across complex architectures. Prerequisite: CS 617. Lab Fee: $40.

730 Artificial Intelligence II **3 hrs.**

Rigorous treatment of special topics in artificial intelligence. Topics may include knowledge representation, automated deduction, search control, machine learning, or meta-level architectures. Prerequisite: CS 630. Lab Fee: $40.

742 Image Processing Algorithms and Architectures **3 hrs.**

Algorithms and data structures for image enhancement, segmentation, object recognition and image sequence analysis; real-time versus non real-time image processing; computer architectures for fast image processing; cellular logic array processors, distributed array processors, systolic array processors; binary array processors, etc. Prerequisites: CS 613 and CS 642. Lab Fee: $50.

750 Advanced Software Engineering Topics **3 hrs.**

Experimental framework of software engineering. Design of experiments to evaluate different methods and techniques in software development, operation, and maintenance. Quality and productivity issues. Review of current literature. Prerequisite: CS 650 or approval of instructor based upon applicable industrial software development experience. Lab Fee: $40.

780 Fault Tolerant Computing **3 hrs.**

Hardware and software system reliability; diagnosable digital systems; fault tolerant architectures; software techniques for fault tolerance; fault tolerant algorithms and data structures; system reliability; fault tolerant systems. Prerequisites: CS 613 and CS 617. Lab Fee: $40.

787 Advanced Database Systems **3 hrs.**

Advanced topics in databases. Introduction to distributed databases and current research in coupling artificial intelligence techniques to databases. Query optimization, concurrency control, security and recovery issues in both centralized and distributed databases. Prerequisite: CS 687. Lab Fee: $40.

790 Operating Systems Seminar **3 hrs.**

Advanced research topics in operating system theory and practice. Students will read and discuss classic and current papers in the literature. Each student will present reports in class and prepare a substantial research paper. Prerequisite: CS 690. Lab Fee: $40.

795 Independent Study **3 hrs**

Individual directed study under the supervision of an instructor. Prerequisite: Approval of instructor.

796-798 Advanced Selected Topics in Computer Science **3 hrs.**

Course offered by an instructor in a specialized area of computer science.. Prerequisite: Approval of instructor. Lab fee $40.

799 Doctoral Dissertation **3-6 hrs.**

Required each semester student is enrolled and receiving direction on doctoral dissertation. Maximum of 18 hours credit toward degree.

ENVIRONMENTAL SCIENCE PROGRAM

142 Wilson Hall
Telephone: (256) 824-6388
Email: lawtonr@uah.edu

Coordinator: Robert O. Lawton, Professor, Biological Sciences

Faculty:

Faculty members for this program have academic appointments in established University departments (primarily atmospheric science and biological sciences) and in local industry. The environmental science graduate program provides a series of courses which can be used to develop a coherent minor or area of specialty under M.S. and Ph.D. degree programs in science, mathematical sciences, and engineering. The program is designed to allow students pursuing advanced degrees in the above programs to obtain the necessary background to successfully pursue research topics in environmental science.

Requirements for a Minor/Certificate in Environmental Science

Minors and certificates in environmental science may be earned by students in any field with the approval of the student's advisor and the environmental science program coordinator who will tailor programs to meet the student's educational needs.

Graduate Courses in Environmental Science (ES)

501 Survey of Atmospheric Science **3 hrs.**

General survey of the field of atmospheric science. Quantitative examination of atmospheric physical properties including atmospheric composition, structure and dynamics. Detailed inspection of evolving atmospheric structures using real-time data systems. General topics include atmospheric thermodynamics, atmospheric dynamics, cloud physics, atmospheric radiation, and related topics in atmospheric remote sensing. Prerequisites: MA 172 and PH 112 or consent of instructor. (Same as ES 401 and ATS 401/501.)

502 Computational Tools for Atmospheric and Environmental Scientists **1 hr.**

Designed for incoming graduate students. Fundamentals of computation using IDL or other suitable programming language, focusing on basic skills, interpretations, creating plots, and displaying data. Prerequisite: Consent of instructor. (Same as ATS 502.) Fall. *This course may not be used to meet minimum degree requirements.*

511 Introduction to Geographical Information Systems **3 hrs.**

Introduces vector, raster and tabular concepts, emphasizing the vector approach. Topics include: spatial relationships, map features, attributes, relational database, layers of data, data ingesting, digitizing from maps, projections, output, applications and availability of public data sets. (Same as CE 411/511, ES 411 and ATS 411/511.) Fall.

513 Geographical Information Systems and Remote Sensing **3 hrs.**

Hands-on approach to GIS and satellite remote sensing. Popular satellite data sets such as LANDSAT and AVHRR are coupled with GIS data sets to increase understanding of the earth system. Topics include satellite sensors, basic radiative transfer, orbits, raster formats, atmospheric correction, distortion, image corrections, rotations and mapping, spatial resolution, image interpretation, radiometric and geometric enhancement, multispectral transformations, and classifications. (Same as ATS 413, ATS 513, ES 413.) Spring.

514 Scale and Landscape in GIS **3 hrs.**

Relationship of scale processes in the interpretation of remote sensing and GIS applications. Topics include those associated with multiple representations of remote sensing data, analysis techniques for integrating multiple sets of remote sensing and auxiliary data at different scales, and geostatistics. Prerequisite: ES 513. (Same as ATS 414, ATS 514, ES 414.) Fall.

515 Advanced Topics in GIS **3 hrs.**

Advanced special topics: visualization of GIS and remote sensing data, landscape characterization (pattern vs. process), multitemporal analysis, aggregation of data types, developing an integrated GIS environment for performing complex space-time modeling analyses, and land-atmosphere interactions. Prerequisite: ES 513. (Same as ATS 415, ATS 515, ES 415.) Spring.

520 Introduction to Atmospheric Chemistry and Air Pollution **3 hrs.**

This self-contained introductory course in atmospheric chemistry and air pollution is designed to provide seniors and graduate students the basics of atmospheric chemistry and air pollution concepts. Topics include air pollutants, air-pollution meteorology, atmospheric gases and aerosols, and atmospheric processes. This course will also develop the necessary fundamentals for those wishing to take the advanced (600 level) courses in the atmospheric chemistry/air pollution study area. ES 520 and ATS 520 require a research project; ES/ATS 420 do not. Prerequisites: PH 112 and CH 121 or consent of instructor. (Same as ATS 420, ATS 520, ES 420).

525 Environmental Chemistry **3 hrs.**

Principles of quantitative analyses related to minor components of a sample. Applications selected from principal analyses necessary to maintain environmental quality of air, water, and soil. Selection of conditions for collecting reliable samples, concentration of components with techniques for increasing concentration of selected component, relationships between physical and chemical changes in sample and signal output of predominant transducers, and translation of chemical analysis into meaningful specifications. Lecture only. Prerequisite: CH 521 or 223; EE 311, 342. (Same as CH 525.)

532 Space Orientation for Educators: Huntsville **3 hrs.**

Introduces the teacher to a variety of space-related subjects and techniques which may be used in the classroom. Curriculum is designed to reflect current research and technological development in a hands-on experience with the space program. Includes a number of experiments which can be duplicated in the classroom. Offered in cooperation with the Alabama Space and Rocket Center. (Same as ED 532.) Lab Fee: $20. *This course may not be used to meet degree requirements for UAH graduate programs.*

533 Space Orientation for Educators: Washington **3 hrs.**

Builds on material already attained by those educators who have participated in the generic program conducted at UAH, by providing educational experiences available in Washington, D.C., at the National Air and Space Museum, Goddard Space Flight Center, Owens Science Center (Challenger Center), Maryland Science Center, U.S. Naval Observatory, Space Telescope Science Institute at Johns Hopkins, National Oceanic and Atmospheric Administration, and the Office of Technology Assessment. Prerequisite: ES 532 or ED 532. (Same as ED 533.) *This course may not be used to meet degree requirements for UAH graduate programs.*

534 Space Orientation for Educators: Russia **3 hrs.**

On-site seminar on the Russian space program. Lectures deal with rocket and shuttle design, cosmonautics, Russian science education and space policy decision-making. Locations include Space Mission Control, Star City, the Baikanur Cosmodrome, and various schools, institutes, ministries, and factories involved in aerospace education and industry in Moscow, Kiev, Leningrad, and Krasnoyarski. (Same as ED 534.) *This course may not be used to meet degree requirements for UAH graduate programs.*

541 Atmospheric Thermodynamics and Cloud Physics **3 hrs.**

General aspects of thermodynamic and cloud physical processes occurring within the atmosphere; atmospheric statics and stability, saturation point analysis, aerosols, nucleation, and the behavior/growth of cloud particles and hydrometers. Prerequisites: MA 324, PH 112. (Same as ATS 441/541 and ES 441.) Fall.

551 Atmospheric Fluid Dynamics I **3 hrs.**

Fluid dynamics in the atmosphere. Coriolis acceleration, scale analysis and appropriate approximations of the complete governing equations. Numerical analysis and interpretation of weather phenomena. Prerequisites: MA 324 and PH 112. (Same as ATS 451, ATS 551, ES 451.)

552 Synoptic Meteorology **3 hrs.**

Analysis, interpretation and forecasting synoptic-scale and mesoscale phenomena, including air masses, frontal systems, cyclones, anti-cyclones, tropical cyclones and associated mesoscale phenomena. Emphasis on the use of remotely-sensed data from satellites, radars and profilers using state-of-the-art workstations. Prerequisites: ATS 541, 551. (Same as ATS 452, ATS 552, ES 452.) Spring, even years.

554 Forecasting Mesoscale Processes **3 hrs.**

Detection and forecasting of atmospheric mesoscale phenomena, including the structure and evolution of clouds, precipitation (including floods), thunderstorms and severe weather. Includes basics on instruments used to detect mesoscale phenomena, most notably satellite and radar. Based mainly on computerized modules and related exercises. Prerequisite: ATS 551. (Same as ATS 454, ATS 554, ES 454.)

561 Atmospheric Radiation I **3 hrs.**

Fundamentals of terrestrial atmospheric radiation. Topics include: solar radiation at the top of the atmosphere, radiative transfer equation, gaseous absorption, scattering by molecules and particles, band models, transmittance along an inhomogeneous path, and microwave radiative transfer. Prerequisites: MA 324, PH 112. (Same as ATS 461, ATS 561, ES 461.) Spring.

593 Directed Studies in Atmospheric and Environmental Science **1-4 hrs.**

Supervised compilation, summarization, and discussions of special topics in environmental science.

620 Atmospheric Chemistry and Aerosis **3 hrs.**

Atmospheric chemistry and aerosols; primary processes, thermodynamics, photochemistry, kinetics, models, and measurements applied to the troposphere and stratosphere; natural and anthropogenic processes affecting the chemistry of Earth's troposphere and stratosphere; effects of chlorine, nitrogen, hydrogen, and oxygen catalytic cycles. Ground-based and satellite-borne observations of traces species are described. Requires an understanding of atmospheric structure and elementary atmospheric chemistry. Prerequisite: ES 520 or consent of instructor. (Same as ATS 620.)

622 Air Pollution Modeling **3 hrs.**

Advanced air pollution modeling, covers in considerable depth air pollution modeling concepts and methods. Lagrangian and Eulerian modeling approaches ranging from microscale (PBL) to synoptic (regional) scale. Lagrangian modeling will be focused on detailed modeling of large point- and areas-source plumes; Eulerian modeling will range from Large Eddy Simulations (LES) to regional-scale modeling with nested domains and plume-in-grid treatments; covers atmospheric transport/dispersion/chemistry, cloud and aerosol processes, and wet and dry deposition processes; students get experience in implementing specific plume, LES, and urban-regional modeling codes used in research and regulatory applications. Prerequisites: ES 520, 551 or consent of instructor. (Same as ATS 622.)

630 Physical Climatology **3 hrs.**

This course is designed to provide a hands-on perspective to the study of the climate system using satellite data sets. The emphasis will be on understanding the physical aspects of the global climate system. Topic include global energy balance, energy balance of the surface, hydrologic cycle, climate classification, ocean circulation, natural and anthropogenic climate change and other selected topics such as urban climate and mountain weather and climate. Prerequisite: ES 501 or consent of instructor. (Same as ATS 630.) Fall, even years.

652 Space Science **3 hrs.**

Provides teachers in-depth experience with the science associated with the space program. Topics include: astrophysics, materials processing, plasma physics, life sciences, orbital mechanics, propulsion, weather, and remote sensing. Prerequisite: ES 532. Lab Fee: $20.

681 Numerical Atmospheric Modeling **3 hrs.**

Introduction to numerical methods applied to simulation of the atmosphere. Basic numerical solution techniques, along with filtering, radiative parameterizations, thermodynamics, turbulent parameterization, initialization and coordinate transformation. Prerequisites: MA 415, ES 551. (Same as ATS 681.)

MATHEMATICAL SCIENCES

205 Madison Hall
Telephone: (256) 824-6470
Email: math.grad@uah.edu
Web Site: http://www.math.uah.edu

Degrees:

Master of Arts
Master of Science
Doctor of Philosophy

Chair: Kyle T. Siegrist, Professor

Professors:

Ames, K.A.; partial differential equations, singular perturbation theory
Friedman, M.J.; numerical analysis, differential equations
Gibson, P.M.; linear algebra, combinatorics
Li, J.; differential equations, mathematical modeling in epidemiology
Morales, C.H.; functional analysis, operator theory
Siegrist, K.T.; probability, stochastic processes, reliability theory
Slater, P.J.; graph theory, combinatorics

Associate Professors:

Howell, K.B.; elasticity theory, partial differential equations
Huang, W.; differential equations, dynamical systems
Kunin, B.I.; fracture mechanics, differential geometry
Zhang, G.H.; graph theory, combinatorics

Assistant Professors:

Ai, S.; differential equations, dynamical systems
Ravindran, S.S.; computational fluid dynamics

The Mathematical Sciences Department offers programs leading to the Master of Arts and Master of Science degrees in mathematics and the Doctor of Philosophy degree in applied mathematics. The programs foster advanced mathematical education through closely integrated instruction and research. The concentration areas offered lead students to examine in greater depth those concepts and techniques introduced at the undergraduate level and further expose them to more sophisticated concepts and techniques. Entering graduate students will have a variety of mathematical backgrounds and goals. Consequently, programs of study leading to the M.A., M.S., or Ph.D. degree can vary considerably. Applied mathematics is emphasized with concentrations available in ordinary and partial differential equations, combinatorics and graph theory, probability and statistics, and numerical analysis. Graduate students who wish to minor in areas such as computer science, physics, atmospheric science, optics or engineering are encouraged to do so.

New graduate students should meet with the graduate program director of the department at their earliest convenience for initial guidance. Later an advisor will be assigned to work closely with each student in designing an individualized Program of Study to meet the student's needs according to the School of Graduate Studies requirements.

Admission Requirements

In addition to fulfilling School of Graduate Studies admission requirements, all applicants for graduate study in mathematics or applied mathematics should have completed the equivalent of a complete calculus sequence, a linear algebra course, MA 442, MA 452, and six additional hours in upper-division mathematics courses. Students deficient in more than two undergraduate courses in mathematics must remove these deficiencies before admission to the mathematics program. Such students should consult the graduate program director of the department on how best to remove these deficiencies.

For unconditional admission, applicants must satisfy requirements of the School of Graduate Studies. Only the aptitude portion of the Graduate Record Examination (GRE) is required by the department. The Miller Analogies Test, administered regularly on campus, is accepted by the department in lieu of the GRE for conditional admission.

Master of Arts and Master of Science

The Master of Arts and Master of Science degrees are conferred under Plan I (thesis) or Plan II (non-thesis). Students should explore with their faculty advisor which plan is better for their particular objectives. For the M.S. degree, a Program of Study must include a minor area in the College of Engineering or the College of Science. All minors must be outside of the department and must include at least six hours of approved graduate coursework. Master's programs that include a thesis (Plan I) require at least 18 hours of graduate coursework in mathematics and at least 24 hours of total graduate coursework, and programs without a thesis (Plan II) require at least 33 hours of graduate coursework and at least 24 hours of these should be in mathematics. At least 50 percent of the coursework hours must be completed in courses numbered 609 or above. MA 538 and MA 544 should be included in every Program of Study.

Students should plan a Program of Study for the master's degree with the help of a faculty advisor prior to the completion of 12 semester hours of coursework. Courses taken without an approved Program of Study may not apply toward a degree. Various areas of mathematics may be stressed in the program of study depending on the student's needs. The coursework for a non-thesis Program of Study concentrating in probability and statistics might be MA 538, MA 544, MA 585, MA 653, MA 656, MA 685, ST 687, MA 686 or ST 787, and three approved graduate courses, including at least one numbered 609 or above; and the coursework for a non-thesis program of study concentrating in numerical analysis might be MA 515, MA 526, MA 538, MA 544, MA 614, MA 615, MA 626, MA 715, and three approved graduate courses, including at least two courses numbered 609 or above. Other possible concentration areas include differential equations and discrete mathematics.

Master of Arts with Class A Teaching Certification

Teachers who hold the Alabama Class B Middle/Junior High or High School Certificate may pursue a program of study in mathematics that leads to a Master of Arts degree with Alabama Class A certification. The coursework for such a Program of Study might be MA 538, MA 542, MA 544, MA 585, MA 614, MA 633, ST 687, nine hours of appropriate graduate education courses, and one approved MA or ST course numbered 600 or above.

Individuals who are interested in obtaining a Master of Arts degree with Alabama Class A certification in mathematics, but who have not completed more than 12 semester hours in teacher education (graduate or undergraduate) courses, should consider the Non-Traditional Fifth Year Program. The MA and ST courses given in the preceding paragraph would be appropriate for such a program. Students should contact the Education Department for preliminary advisement on admission and general program requirements. More details on the Non-Traditional Fifth Year Program are given in the Education Department section.

Master's Degree Final Examination

A final comprehensive examination is required of all candidates for a master's degree. The candidate will be examined on the coursework and thesis in Plan I and on the coursework in Plan II. In the Mathematical Sciences Department this examination is oral, except that Plan II students who have passed a joint program examination for the Ph.D. degree in applied mathematics may use that examination as their master's degree final examination.

Doctor of Philosophy

The Ph.D. degree program in applied mathematics is designed to enable students to master a significant body of mathematics, including a specialty in applied mathematics; to relate this knowledge to a coherent area of science or engineering other than mathematics; and to carry on fundamental research in applied mathematics. Students who are interested in the program should contact the graduate program director of the department.

Each Program of Study requires at least 54 semester hours of graduate coursework, and must include a major area of concentration consisting of at least six courses in addition to the four common core courses (see below), and a minor consisting of at least four related graduate courses in some area outside of the department. The major, minor, and other courses in the Program of Study must be selected so that the student will be prepared to conduct research in an area of applied mathematics.

Students must pass three examinations: the joint program examination, the comprehensive qualifying examination, and the final examination. The joint program examination is a written test of the student's ability to successfully pursue a Ph.D. in applied mathematics. It covers a four course common core in real analysis (MA 653, MA 654) and linear and numerical linear algebra (MA 544, MA 614). The joint program examination can not be taken more than twice.

The comprehensive qualifying examination covers the entire Program of Study and the student's proposal for a dissertation topic, and is administered by the student's graduate study supervisory committee on behalf of the School of Graduate Studies. The examination is part written and part oral. It can not be taken more than twice. Upon successful completion of the comprehensive qualifying examination and dissertation proposal, the student is admitted to candidacy for the Ph.D. degree.

The final examination is an oral presentation of the dissertation in the form of a seminar before the student's graduate study supervisory committee. The dissertation is evidence that the student can independently identify a problem of contemporary significance through familiarity with the current literature in some area of applied mathematics, organize and execute a program of research, recognize and analyze the results, and present them in cogent, well-written exposition. It must include mathematical results suitable for publication in a nationally recognized journal.

The Ph.D. degree program in applied mathematics is a joint program with the other two campuses (Birmingham and Tuscaloosa) of the University of Alabama System. All requirements of the program can be completed at the University of Alabama in Huntsville.

Undergraduate/Graduate Mathematics Courses (MA)

The following 500-level courses may, at the discretion of the student's advisor and department, be used to partially fulfill the mathematics requirement in a Program of Study for a graduate degree.

502 Introduction to Real Analysis **3 hrs.**

Sequences, limits, continuity, differentiation of functions of one real variable, Riemann integration, uniform convergence, sequences and series of functions, power series, and Taylor series. Prerequisite: MA 330 and MA 442, or approval of instructor. This course is taught as MA 452/502. Course completion and/or grade requirements for the MA 502 course will differ from those for the MA 452 course.

503 Introduction to Complex Analysis **3 hrs.**

Complex algebra, analytic functions, Cauchy-Riemann equations, exponential, trigonometric, and logarithmic functions, integration, Cauchy integral theorem, Morera's theorem, Liouville's theorem, maximum modulus theorem, residue theory, Taylor and Laurent series, and applications. Prerequisites: MA 201 and one MA course at the 300 level or above, or approval of instructor.

504 Intermediate Differential Equations **3 hrs.**

Elementary introduction to more advanced topics in differential equations: linear systems of differential equations, nonlinear autonomous systems, critical points, Liapunov's method, limit cycles, Poincare-Bendixson theorem and strange attractors, power series solutions, Frobenius series solutions. Prerequisites: MA 244, MA 324.

506 Methods of Partial Differential Equations **3 hrs.**

Survey of theory and methods for solving elementary partial differential equations. Topics include first-order equations and the method of characteristics, second-order equations, reduction to canonical form, the wave equation, the heat equation, Laplace's equation, separation of variables, and Fourier series. Prerequisites: MA 324 and MA 244. No credit given to students who have successfully completed MA 526.

508 Applied Linear Algebra **3 hrs.**

Fundamental concepts of linear algebra are developed with emphasis on real and complex vector spaces, linear transformations and matrices. Solving systems of equations, finding inverses of matrices, determinants, vector spaces, linear transformations, eigenvalues and eigenvectors, normal matrices, canonical forms for matrices, applications to systems of linear differential equations, use of computer software such as MATLAB. Prerequisites: MA 244, MA 324. No credit given to students who have successfully completed MA 544.

Graduate Courses in Mathematics (MA)

515 Introduction to Numerical Analysis **3 hrs.**

Analysis and derivation of numerical methods for: the approximate solution of nonlinear equations; interpolation and integration of functions; approximating solutions of ordinary differential equations. Prerequisites: MA 244, 324, CS 121 or equivalent, plus one 500-level (or higher) MA course, or graduate standing in the Department of Mathematical Sciences. Lab Fee: $40.

524 Dynamical Systems I **3 hrs.**

Scalar autonomous equations; existence, uniqueness, stability, elementary bifurcations; planar autonomous equations; general properties and geometry, conservative systems, elementary bifurcations, linear systems, reduction to canonical forms, stability and instability from linearization. Liapunov functions, center manifolds, Hopf bifurcation. Prerequisite: MA 244, MA 324, and MA 452.

526 Partial Differential Equations I **3 hrs.**

Introduction to the theory for solving partial differential equations. No graduate credit given to students who have completed MA 506 for graduate credit. Topics include second-order equations, reduction to canonical form, well-posedness, the classical equations (wave, heat, and Laplace's) in one and several dimensions, separation of variables, Fourier series, general eigenfunction expansions, Sturm-Liouville theory, first-order linear and quasilinear equations, and shocks. Prerequisites: MA 502, one other 500-level MA course. (MA 506 is NOT a prerequisite.)

538 Metric Spaces with Applications **3 hrs.**

Metric spaces, continuous functions, compactness, connectedness, completeness, Arzela-Ascoli theorem, Stone-Weierstrass theorem, Hilbert spaces, contraction mappings, applications to existence and uniqueness of solutions of differential and integral equations. Prerequisites: MA 502 and at least one other MA course at the 500-level or above.

540 Combinatorial Enumeration **3 hrs.**

Counting, pigeonhole principle, permutations and combinations, generating functions, recurrence relations, principle of inclusion and exclusion, Polya's theory of counting. Prerequisite: MA 442 or approval of instructor.

542 Algebra **3 hrs.**

Topics from group theory and ring theory: subgroups, normal subgroups, quotient groups, homomorphisms, isomorphism theorems, ideals, principal ideal domains, Euclidean domains, fields, extension fields, elements of Galois theory. Prerequisite: MA 442 or approval of instructor.

544 Linear Algebra **3 hrs.**

Vector spaces over a field, bases, linear transformations, matrices, determinants, eigenvalues, similarity, Jordan canonical forms, dual spaces, orthogonal and unitary transformations. Prerequisites: MA 244 and MA 442.

561 Introduction to Fourier Analysis **3 hrs.**

Brief development of trigonometric and exponential Fourier series, derivation of the classical Fourier transform from Fourier series, classical properties of Fourier transforms, transforms of functions, convolution, elementary development of the delta function, transforms of periodic functions, use of transforms to solve systems, introduction to the discrete transform and/or multidimensional transforms, as time permits. Prerequisites: MA 244, and MA 324. This course is taught as MA 460/561. Course completion and/or grade requirements for the MA 561 course will differ from those for the MA 460 course

562 Intermediate Fourier Analysis **3 hrs.**

(Formerly MA 560). Brief review of classical Fourier analysis, Parseval's equality, Gaussian test functions. Introduction to generalized functions, the generalized transform, the generalized derivative, sequences and series of generalized functions, regular periodic arrays of delta functions, sampling, the discrete transform, the fast Fourier transform (other topics as time and interest permit). Prerequisites: MA 244, MA 324, acquaintance with classical Fourier analysis (such as covered in MA 460.)

565 Intermediate Mathematical Modeling **3 hrs.**

Designed for beginning graduate students. No prior experience in a formal mathematical modeling course is required. In-depth discussion of some types of models from physics, the life sciences, and/or the social sciences, with formulation, analysis, and criticism of the models. Process of and factors involved in formulating a model will be of prime importance. Content will be divided into approximately one-half deterministic modeling and one-half stochastic modeling. Prerequisites: MA 244, MA 324, MA 385, one MA course at 400-level or above, and CS 121 or equivalent.

585 Probability **3 hrs.**

Probability theory and its applications. Independent trials, discrete and continuous random variables, law of large numbers, basic distributions, sums of independent random variables, sequences of random variables, central limit theorem, and convergence in distribution. Prerequisites: MA 201 and one of MA 385, ISE 390, MA/ST 487, or approval of instructor.

590 Selected Topics in Mathematics **3 hrs.**

Requested selected topics.

607 Mathematical Methods I **3 hrs.**

Review of vector calculus and coordinate systems, introduction to tensors, matrices, infinite series, complex variables with applications to calculus of residues, partial differential equations, and Sturm-Liouville theory. Orthogonal functions, gamma functions, Bessel functions, Legendre functions, special functions, Fourier series, integral transform and equations. Prerequisite: MA 324. (Same as PH 607.)

609 Mathematical Methods II **3 hrs.**

Continuation of MA 607. Prerequisite: MA 607. (Same as PH 609.)

614 Numerical Methods for Linear Algebra **3 hrs.**

Norms and vector spaces, matrix factorizations and direct solution methods, stability and conditioning, iterative methods for large linear systems, the algebraic eigenvalue problem. Prerequisites: MA 415 or 515, MA 508 or MA 544, CS 121 or equivalent. Lab Fee: $50.

615 Numerical Methods for Partial Differential Equations **3 hrs.**

Finite difference methods for parabolic, elliptic, and hyperbolic partial differential equations, error analysis, stability, and convergence of finite difference methods. Prerequisites: MA 415 or MA 515, MA 506 or MA 526, MA 508 or MA 544 or MA 614, CS 121 or equivalent. Lab Fee: $50.

624 Dynamical Systems II **3 hrs.**

Brief review of linear systems; local theory for nonlinear systems; existence, uniqueness, differentiability, asymptotic behavior, the stable manifold theorem, Hartman-Grobman theorem, Hamiltonian systems; global theory for nonlinear systems; limit sets and attractors, the Poincare map, the Poincare-Bendixson theorem; some aspects of bifurcation theory and chaos; bifurcations at nonhyperbolic fixed points and periodic orbits, homoclinic bifurcations, Melnikov's method, chaos. Prerequisites: MA 524, MA 538, MA 508 or MA 544.

626 Partial Differential Equations II **3 hrs.**

Continuation of MA 526. Qualitative results for solutions to the classical equations (energy inequalities, propagation of discontinuities, maximum principles, smoothness of solutions, existence and uniqueness, etc.), non-homogeneous equations, Poisson's equation, Green's functions, and the Cauchy-Kowalewski theorem. Prerequisite: MA 526.

633 Geometry **3 hrs.**

Axioms of incidence and order, affine and metric properties, isometries, similarities, transformation groups, projective planes. Prerequisites: MA 442, MA 544 or approval of instructor.

638 General Topology **3 hrs.**

Set theory, logic, well-ordering principle, axiom of choice, topological spaces, product spaces, quotient spaces, continuous functions, connectedness, path connectedness, local connectedness, compactness, local compactness, countability and separation, generalized products, Tychonoff theorem. Prerequisite: MA 538.

640 Graph Theory **3 hrs.**

Graphs, subgraphs, trees, connectivity, Euler tours, Hamilton cycles, matchings, edge colorings, independent sets, vertex colorings, planar graphs, Kuratowski's theorem, four color theorem, directed graphs, networks, cycle and bond spaces. Prerequisite: MA 540 or MA 542.

643 Group Theory **3 hrs.**

Isomorphism theorems, permutation groups, basis theorem and fundamental theorem for finite abelian groups, the Remak-Krull-Schmidt theorem, Sylow theorems, normal series, solvable groups, extensions, and selected topics in representation theory. Prerequisite: MA 542.

644 Matrix Theory **3 hrs.**

Functions of matrices, invariant polynomials, elementary divisors, similarity of matrices, normal forms of a matrix, matrix equations, generalized inverses, non-negative matrices, localization of eigenvalues. Prerequisite: MA 544. MA 503 or MA 656 recommended.

645 Combinatorial Design **3 hrs.**

Systems of distinct representatives, difference sets, coding theory, block designs, finite geometries, orthogonal Latin squares, and Hadamard matrices. Prerequisites: MA 540, MA 544.

653 Real Analysis I **3 hrs.**

Countable sets, characterization of open and closed sets, Heine-Borel theorem, Riemann integral, Lebesgue measure and outer measure, measurable functions, Lebesgue integral, Fatou's lemma, and Lebesgue-dominated convergence theorem. Prerequisites: MA 538 and one MA course at the 540 level or above.

654 Real Analysis II **3 hrs.**

Differentiability of monotone functions, functions of bounded variation, absolute continuity, convex functions, Minkowski and Holder inequalities, Lp spaces, Riesz-Fischer representation theorem, Fubini's theorem and selected topics. Prerequisite: MA 653.

656 Complex Analysis I **3 hrs.**

Topology of the complex plane, analytic functions of one complex variable, elementary functions and their mapping properties, power series, complex integration, Cauchy's theorem and its consequences, isolated singularities, Laurent series, residue theory. Prerequisite: MA 502 or approval of instructor.

658 Introduction to Functional Analysis **3 hrs.**

Normed and inner product spaces, finite dimensional spaces, product and quotient spaces, equivalent norms, Hahn-Banach theorem, principle of uniform boundedness, openmapping theorem, Riesz representation theorem, complete orthonormal sets, Bessel's inequality, Parseval's identity, and conjugate spaces. Prerequisite: MA 538.

661 Special Functions **3 hrs.**

Gamma and beta functions, probability integral and applications, orthogonal polynomials, Bessel functions, and their applications, spherical harmonics and their applications, hypergeometric functions. Prerequisite: MA 503 or MA 656.

662 Asymptotics and Perturbation Methods **3 hrs.**

Asymptotic series, regular and singular perturbation theory, asymptotic matching, Laplace's method, stationary phase, steepest descents, WKB theory. Prerequisites: MA 502, MA 504 or MA 624, MA 503 or MA 656 recommended.

667 The Calculus of Variations and Optimal Control **3 hrs.**

Euler necessary condition for local extremum, Euler-Lagrange equation, Weierstrass necessary condition, Jacobi's necessary condition, corner conditions, problems of optimal control, Pontryagin maximum principles, transversality conditions, applications. Prerequisites: MA 324, MA 502.

685 Stochastic Processes with Applications I **3 hrs.**

Discrete and continuous Markov chains, Poisson processes, counting and renewal processes, and applications. Prerequisites: MA 585, MA 244 or approval of instructor.

686 Stochastic Processes with Applications II **3 hrs.**

Gaussian and Wiener processes, general Markov processes, special types of processes from queueing and risk theory, and selected advanced topics. Prerequisite: MA 685 or approval of instructor.

690 Special Topics in Mathematics **3 hrs.**

Offered upon demand. Advanced selected topics of interest in areas such as discrete mathematics, numerical analysis, differential equations, and stochastic processes.

695 Graduate Seminar **1 hr.**

Selected topics in advanced mathematics, conducted as a research seminar.

699 Master's Thesis **3 hrs.**

Required each semester a student is receiving direction on a master's thesis. A minimum of two terms is required. Maximum of nine hours credit awarded upon successful completion of the master's thesis.

715 Numerical Methods for Partial Differential Equations II **3 hrs.**

Finite element methods for parabolic, elliptic, and hyperbolic partial differential equations; error analysis, stability, and convergence. Prerequisites: MA 538, MA 615. Lab Fee: $50.

726 Theory of Partial Differential Equations **3 hrs.**

Hilbert space theory of existence, uniqueness, and regularity for partial differential equations. Prerequisites: MA 526, MA 538.

740 Combinatorial Algorithms **3 hrs.**

Linear, polynomial and exponential graph theoretic algorithms, generating combinatorial objects, and NP-completeness. Prerequisite: MA 640.

756 Complex Analysis II **3 hrs.**

Applications of residue theory, harmonic functions and their applications, Mittag-Leffler theorem, infinite products, Weierstrass product theorem, conformal mapping and Riemann mapping theorem, univalent functions, analytic continuation and Riemann surfaces, Picard's theorems, and selected topics. Prerequisite: MA 656 or approval of instructor.

785 Advanced Probability Theory **3 hrs.**

Measure and integration, probability spaces, convergence concepts, law of large numbers, random series, characteristic functions, central limit theorem, random walks, conditioning, Markov properties, conditional expectations, and elements of martingale theory. Prerequisites: MA 585, MA 653.

790 Special Topics in Advanced Mathematics **3 hrs.**

Offered upon demand. Advanced selected topics of interest in areas such as discrete mathematics, numerical analysis, differential equations, and stochastic processes.

795 Graduate Seminar **1 hr.**

Selected topics in advanced mathematics, conducted as a research seminar.

799 Doctoral Dissertation **3, 6, or 9 hrs.**

Required each semester a student is receiving direction on a Ph.D. dissertation.

Graduate Courses in Statistics (ST)

687 Theory of Statistics I **3 hrs.**

Distribution of statistics based on ordered samples, asymptotic sampling distributions, maximum likelihood, least squares, and other methods of point estimation, Rao-Blackwell theorem and Cramer-Rao inequality, confidence intervals, regions, and their optimal properties. Neyman-Pearson formulation and tests of simple hypothesis against simple alternatives. Prerequisites: MA 244, MA 585.

690 Special Topics in Statistics **3 hrs.**

Courses in requested special topics. Prerequisite: Approval of instructor.

787 Theory of Statistics II **3 hrs.**

Continuation of hypothesis testing, likelihood ratio and unbiased tests, uniformly most powerful tests, power function, nonparametric tests, statistical decision theory, distribution and linear models. Prerequisite: ST 687.

PHYSICS

201-B Optics Building
Telephone: (256) 824-2483
Email: physics.grad@uah.edu
Web Site: http://www.uah.edu/physics

Degrees:

Master of Science

Doctor of Philosophy

Chair: Lloyd W. Hillman, Professor

Professors:

Axford, I. (Chan Professor of Physics); solar-terrestrial relations, plasma fluid dynamics, astrophysics
Barr, T. (Emeritus); optics
Comfort, R.H.; atmospheric and magnetospheric physics
Dimmock, J.O.; optics, solid-state physics
Duthie, J.G.M. (Emeritus); nonlinear optics, optical processing
Emslie, A.G.; astrophysics, solar physics
Fix, J.D.; astrophysics, cool stars
Franz, F.; atomic physics
Franz, J.R.; solid state physics, electronic properties of disordered materials
Gregory, D.A.; optical processing
Hillman, L.W.; optics, biomedical optics, illumination, laser dynamics
Horwitz, J.L.; ionospheric and magnetospheric physics
Miller, J.A.; solar physics, plasma physics
Paciesas, W.S. (Research); x-ray and gamma-ray astronomy
Smalley, L.L. (Emeritus); theoretical physics, general relativity
Takahashi, Y.; astrophysics, cosmic rays, particle physics

Associate Professors:

Lieu, R.; EUV astrophysics, radiation processes
Pakhomov, A.V.; optics, materials
Zhang, S.N. (Research); high-energy astrophysics

Assistant Professors:

Bonamente, M. (Research); high-energy astrophysics
Lompado, A. (Research); optics, scattering, bio-optics
Miller, R. S.; astrophysics, detector development
Oluseyi, H.: astrophysics, astrophysical instrumentation
Preece, R. (Research); gamma-ray astronomy
Sanghadasa, M.F. (Research); optics

The physics graduate program provides a smooth transition to a more comprehensive and rigorous treatment of the physical principles learned in undergraduate studies. The curriculum is broad-based through the master's degree, thereupon narrowing into sub-fields and specializations for doctoral studies.

The Department of Physics recognizes three broad areas of emphasis in basic and applied research:

1. Space sciences including studies of magnetospheric physics, atmospheric physics, solar physics, solar-terrestrial physics, high-energy astrophysics, relativity, and plasma physics.
2. Optics/quantum electronics including studies of laser physics, propagation, laser media and materials, optical properties of matter, electromagnetic scattering and optical bistability and instability.
3. Solid state/materials including studies of electromagnetic properties of matter, thermal and mechanical properties of materials, and solid state physics.

Master of Science

Refer to the appropriate section of the catalog for general admission and degree requirements. There are two M.S. plans in physics. One is for an M.S. degree with a thesis. The other does not require a thesis but does require a passing grade on the final examination. The final examination is the Physics Department Comprehensive Examination which is offered once every year, early in the spring semester, and also serves as the preliminary examination for the Ph.D. degree program. Details of the examination are available in the department office. Students writing a thesis do not need to take the comprehensive examination. Students with a Graduate Research Assistantship may be required to file a Program of Study reflecting the thesis option. A thesis is also required for students seeking a degree through the Optics and Photonics Technology Curriculum.

Course work during the first one and a half years should be taken with the Comprehensive Examination in mind. A recommended schedule of courses for students entering UAH without previous graduate studies is given in the table below. Thesis students and students in the Optical Science and Engineering Ph.D. program (that desire a non-thesis MS in physics) are required to take PH 551, 552, 601, 621, and 631.

Students pursuing a degree through the Optics and Photonics Technology Curriculum should consult the appropriate brochure for detailed requirements. A total of 24 credit hours in graduate courses plus a thesis (including at least 6 hours of PH 699) or 33 credit hours (no thesis) is required to graduate. All M.S. students are required to complete two semesters of PH 792 (Physics Seminar) with a grade of "S"; seminar hours do not, however, count toward minimum degree requirements.

Typical Program for First 1.5 Years Leading to Comprehensive Exam

	Fall	*Spring*	*Summer*
First Year	PH 607	PH 609	PH 621
	PH 551	PH 552	Special Topic*
	Special Topic*	Special Topic*	
Second Year	PH 601		
	PH 631		
	PH 711		

*In this context the term "Special Topic" refers to courses taken in preparation for the special topic section of the Physics Department's Comprehensive Examination. For example: students wishing to be examined in optics should take PH 541, PH 542, and PH 645; those wishing to be examined in solid state physics should take PH 560, PH 561; those wishing to be examined in space plasma physics should take PH 531 and PH 636; and those wishing to be examined in astrophysics should take PH 571 and PH 572 or PH 573. Students should consult with their advisor regarding the selection of special topic courses.

Non-traditional Fifth-year Program Leading to the M.S. in Physics Plus a Class A Alabama High School Teacher's Certificate.

Those who have a B.A. or B.S. degree with a major or its equivalent in physics, as determined by the Department of Physics, who have not taken more than 12 semester hours in teacher education (graduate or undergraduate), and who are interested in obtaining Class A (master's level) certification for secondary school teaching, should consider the Non-Traditional Fifth-Year Program. Contact the Education Department for preliminary advisement on admission and general program requirements. See the description in the Department of Education section for more details.

Doctor of Philosophy

Students are strongly advised to consult the appropriate section of this catalog for general degree requirements, such as residence, etc. Detailed information on many pertinent matters can be found in a publication available in the department office.

Admission to the Ph.D. program in physics is dependent upon performance on the Department's Comprehensive Examination. This examination is offered once per year (early in the spring semester) and consists of four sections: classical/statistical mechanics, electromagnetism and relativity, quantum mechanics, and a special topics section reflecting the research interests of the student (e.g., optics, solid-state physics, plasma physics, astrophysics). Students entering UAH with an M.S. degree or previous graduate training in physics must take the UAH Comprehensive Examination at their earliest opportunity. Students are permitted two attempts to pass the Comprehensive Examination. A student who fails on the first attempt must retake the examination the following year.

Once the comprehensive examination is passed, a student should proceed to form supervisory committee and prepare a Program of Study. A minimum of 48 hours of graduate course credit is required for the Ph.D. in physics. A maximum of 9 semester hours credit in thesis/research work from the master's degree may be allowed to count toward the 48 hour requirement. PH 601, 621, 622, 631, 732, 751, and a minimum of 12 additional credit hours in courses numbered 600 or above must be taken. Students in the Ph.D. program are required to complete three semesters of PH 792 (Physics Seminar) with a grade of "S"; seminar hours do not, however, count toward the 48-hour minimum degree requirements. In addition, 18 hours of PH 799 (Doctoral Dissertation) are required; no more than 9 of these hours may be taken prior to passing the qualifying examination (see below). Courses in addition to those enumerated above are selected in consultation with the student's advisory committee. Transfer of credit from other institutions requires approval of the advisory committee as well as the Dean of the College of Science and the Graduate Dean. Although a minor subject is not required, students are encouraged to develop an interdisciplinary program of study. After completing the program of study, students must then pass the Ph.D. qualifying examination. This examination is conducted under the auspices of the School of Graduate Studies. It tests students' general fitness for pursuing a research project in their chosen area and their general knowledge of physics and may be taken no more than twice.

Finally, a significant portion of the dissertation must be submitted for publication in an approved journal with international circulation.

Graduate Courses in Physics (PH)

531 Introduction to Plasma Dynamics **3 hrs.**

Plasma kinetic theory including charged-particle and neutral collisions, ionization, electronic excitation and recombination, motion of charged particles, macroscopic equations. Transport coefficients, gas discharges, instabilities, sheaths, electromagnetic waves and radiation. Prerequisites: PH 421, 432. (Same as MAE 531.) Fall.

541 Geometrical Optics **3 hrs.**

Foundations and physics of geometrical optics, Fermat's principles and Huygen wavelets, refraction and reflection. The many forms of Snell's Law. Optical path lengths, geometrical wavefronts and rays. Ray tracing, ynu-chart and matrix methods. Gaussian imagery and paraxial optics, conjugate elements, cardinal points, and image-object relations. Stops and pupils, chief and marginal rays, vignetting, and the optical or Lagrange invariant. The y-ybar diagram, design of common systems: objectives, magnifiers, microscopes, collimators and detectors. Optical glasses and chromatic aberrations, wavefront and transverse aberrations, spot diagrams and ray fan plots. (Same as OSE 541 and EE 541.) Fall.

542 Physical Optics **3 hrs.**

Scalar and electromagnetic waves, polarization, coherence, reflection and refraction; two beam and multiple beam interference, interferometers, Fabry-Perots, thin films, diffraction, and absorption and dispersion. (Same as OSE 542 and EE 542.) Fall, Spring.

544 Optoelectronics **3 hrs.**

Review of polarized light, the Jones and Mueller calculi. Propagation of light in birefringent material. Modulation of light using electro-optic effect, Kerr effect, acousto-optic effect, and Faraday effect. Elements of photodetection and detectors, signal processing, and signal-to-noise. Design and analysis of beam scanners, optical rf-spectrum analyzer, optical sensors, and optical communication systems. Prerequisite: PH 342. (Same as OPT 444 and OPE 451.) Fall.

546 Radiometry, Detectors, and Sources **3 hrs.**

Theory and practice of radiometry and photometry. Blackbody radiation and Lambertian sources. The propagation of radiant energy in free space and through optical systems. Detector classes, responsivity, bandwidth, and noise. Power spectral density, properties of sources, photon noise. Prerequisite: PH 342. (Same as OPT 446, OSE 546.) Spring.

551 Introductory Quantum Mechanics I **3 hrs.**

Waves and particles; Bohr's model of the atom; de Broglie waves, wave packets and the uncertainty principle; postulates of quantum mechanics; Schroedinger's equation; simple systems in one, two and three dimensions; the hydrogen atom. Prerequisites: PH 113, PH 351 or CH 343, MA 244, 324. (Same as PH 451, CH 553, OSE 555, MTS 651.) Fall.

552 Introductory Quantum Mechanics II **3 hrs.**

Angular momentum and spin; atomic structure and spectrum; time-independent perturbation theory, variational methods; time-dependent perturbation theory and interactions of light with matter; scattering theory; electronic structure of solids; relativistic quantum mechanics. Prerequisite: PH 551or CH 553. (Same as PH 452, CH 554, MTS 652.) Spring.

560 Introduction to Solid State Physics I **3 hrs.**

Crystal binding and crystal structure. Crystal structure determination. Phonons and lattice vibrations. Free electron gas. Electronic energy band theory. Prerequisite or parallel: PH 651. (Same as MTS 660.) Fall.

561 Introduction to Solid State Physics II **3 hrs.**

Thermal properties of solids. Electronic properties, optical properties, electronic properties in a magnetic field, semiconductor devices, magnetism, superconductivity, defects and alloys, dislocations and crystal growth, non-crystalline solids, surfaces and interfaces. Prerequisite: PH 560. (Same as MTS 661.) Spring.

570 Optical and Photonic Systems Design **3 hrs.**

Review of paraxial optics, ray tracing codes, aberration and diffraction calculations; acousto- and electro-optic modulators, spatial light modulators; fibers, fiber splicers and connectors; gratings and diffractive optical elements; laser and light emitting diodes, photodetectors and CCD arrays; correlator systems; optical communication networks; signal processing systems design. Prerequisite: EE 541. Fall.

571 Astrophysics **3 hrs.**

Advanced radiation theory: black-body radiation, radiative transfer, spectral lines, Einstein coefficients, Voigt profiles, Boltzmann-Saha theory. Fundamentals of MHD theory. Star Formation: Jeans mass, fragmentation. Stellar structure: hydrostatic equilibrium, simple models, polytropes, point-convective and numerical stellar models, neutrino problems. End-points of stellar evolution: white dwarves, neutron stars, black holes. Astrodynamics: Lagrange's equations of planetary motion, variation of orbital elements. Introduction to cosmology: Friedmann-Robertson-Walker metric and associated cosmologies, observational tests, the weak and strong anthropic principles. Prerequisite: AST 371. Spring.

572 Advanced Astrophysics & Cosmology **3 hrs.**

Galactic structure: Oort constants, density waves, vertical structure, disk versus halo populations, rotation curves. Missing mass issues. Clustering and superclustering: large scale structure of Universe, voids. General relativity: tensor calculus, the metric and geodesic equation, Riemann-Christoffel tensor and Bianchi identity, Einstein's equations. Relativistic fluid dynamics. Review of cosmological principles, FRW and other cosmologies. Particle physics and cosmology, Grand Unified Theories, symmetry breaking. Prerequisite: PH 571. Fall, even years.

573 High Energy Astrophysics **3 hrs.**

Radiative Transfer: Blackbody, scattering and diffusion, bremsstrahlung, synchrotron emission, Compton scattering. Relativistic electromagnetism. Plasma effects and introduction to magnetohydrodynamics. Observational aspects of white dwarves, neutron stars and black holes. Accretion and astrophysical jets. Active galactic nuclei and gamma-ray bursts. Prerequisite: PH 571. Fall, odd years.

601 Classical Dynamics I **3 hrs.**

Variational principles and Lagrangian mechanics, rigid body motion, Hamilton's equations, and theory of small oscillations. Aspects related to modern physics. Prerequisite: PH 301. Fall.

607 Mathematical Methods I **3 hrs.**

Review of vector calculus and coordinate systems, introduction to tensors, matrices, infinite series, complex variables with applications to calculus of residues, partial differential equations, and Sturm-Liouville theory. Orthogonal functions, gamma functions, Bessel functions, Legendre functions, special functions, Fourier series, integral transforms and equations. Prerequisite: MA 324. (Same as MA 607.) Fall.

609 Mathematical Methods II **3 hrs.**

Continuation of PH 607. Prerequisite: PH 607. (Same as MA 609.) Spring.

621 Statistical Mechanics and Kinetic Theory I **3 hrs.**

Statistical methods, systems of particles, statistical thermodynamics, applications of thermodynamics, methods of statistical mechanics, applications of statistical mechanics, equilibrium between phases of chemical species. Prerequisite: PH 552. Summer.

622 Statistical Mechanics and Kinetic Theory II **3 hrs.**

Quantum statistics of ideal gases, systems of interacting particles, magnetism and low temperatures, elementary transport theory, advanced transport theory, irreversible processes and fluctuations. Prerequisite: PH 621. Spring, even years.

631 Electromagnetic Theory I **3 hrs.**

Electrostatic and magnetostatic fields in vacuum and material matter, conservation laws, homogeneous wave equations. Prerequisites: PH 432, 607. Fall.

632 Fourier Optics **3 hrs.**

Introducing the optical system as an invariant linear system, convolution, Sommerfield's diffraction integral, Fourier Transform, angular spectrum, coherent and incoherent imaging, optical transfer function. (Same as OSE 632 and EE 632.)

636 Introduction to Space Plasma Physics **3 hrs.**

Charged particles in electric and magnetic fields, cosmic rays and trapped radiation, introduction to plasmas, including collisions and macroscopic effects. Prerequisite: PH 531. Spring, even years.

645 Lasers **3 hrs.**

Incoherent light sources; atomic and molecular energy levels; equation or motion for probability amplitudes using first-order time dependent perturbation theory; electric dipole interaction. Einstein rate equations and the Planck radiation law; induced dipole moments and frequency-dependent susceptibility. Homogeneous and inhomogeneous line broadening mechanisms; laser cavities and modes, elementary laser theory, practical lasers; frequency stabilization techniques and laser line width; Q-switching and mode locking; photon statistics and noise; physical origins of noise; light modulation and detection. Prerequisite: PH 432. (This course may be substituted for OSE 645.) Summer.

651 Computational Quantum Mechanics **3 hrs.**

Numerical methods for solving the Schrodinger equation. Numerical approximation techniques: Rayleigh-Ritz theory. Quantum scattering from a spherically-symmetric potential. Multi-electron atoms: Hartree self-consistent field theory, Hartree-Fock theory, density functional theory. Electronic structure of diatomic molecules. *Ab initio* treatment of molecular structure. Additional extensive application to problems in molecular, atomic, and nuclear physics. Prerequisites: PH 552, high-level programming (e.g., C++, Fortran, IDL) experience. Offered on demand.

652 Applied Quantum Mechanics **3 hrs.**

Application of quantum mechanics in solid state, electronics, materials science, and optics. Topics to include: Hydrogen atom and molecule, excitons, phonons, Bloch's theorem, periodic boundary conditions, electrons and holes, band structure of simple semiconductors, dipole transitions, optical constants, absorption and emission processes. Introduction to device physics. Prerequisite: PH 551 or OSE 555. (Same as OSE 655.) Spring, odd years.

654 Optical Testing **3 hrs.**

Spherometry; refractive index measurements; optical bench measurements of imaging systems via T-bar nodal slide (effective focal length, f-number, axial color, field curvature and distortion, transverse ray aberrations); illumination falloff; image resolution tests (finite object); modulation transfer function; star image testing; knife edge tests; Hartmann tests; Fizeau interferometer and testing configurations; null lens testing of aspheres; wavefront measurements (point diffraction interferometer, radial shear interferometer); Prerequisites: OSE 541, 542. (Same as OSE 654.) Spring.

661 Astrophysical Instrumentation and Data Analysis **3 hrs.**

Instrumentation: CCDs and solid-state devices, proportional counters, scintillators, calorimeters. Statistics: moments of a distribution, linear and non-parameteric correlation, central limit theorem, error estimation, least squares modeling, estimating model parameters, Monte Carlo techniques. Bayes' theorem and likelihood methods. Energy and temporal spectral analyses. Power density spectra: periodic and quasi-periodic systems. Prerequisite: PH 571.

670 Optomechanical Design and Manufacturing **3 hrs.**

Practical aspects of optomechanical design, material selection, fabrication and integration of precision optical components and systems for commercial, space, and military applications. Topics include: fixture design, tolerance analysis, machining methods, thermal stabilization, integrated computer-aided design and analysis, diamond machining, finishing and plating techniques. Prerequisite: OSE 541. (Same as OSE 670.) Spring.

671 Optical Fabrication and Testing **3 hrs.**

Fabrication and testing techniques of optical components and systems. Component measurements: refractive index, curvature, focal lengths, cardinal points and field curvature. Wavefront aberration and transverse aberration function measurements: geometric tests, interferometric tests, null tests. Basics of grinding, figuring, polishing and optical coating. Laboratory experience in manufacturing, polishing, testing, and coating reflective or transmissive optics. Prerequisite: PH 670. Fall.

680-689 Selected Topics **3 hrs.**

Offered upon demand. Topics include: optical surface characterization, superconductivity, aeronomy, properties of solids, laser propagation, collision theory, magnetohydrodynamics. Fall, Spring, Summer.

699 Master's Thesis **3 or 6 hrs.**

Minimum of 6 credit hours required for Plan I M.S. students. Maximum of nine hours credit toward Ph.D. course requirements awarded upon successful completion of master's thesis. Fall, Spring, Summer.

702 Classical Dynamics II **3 hrs.**

Continuation of PH 601. Review Lagrangian and Hamiltonian dynamics, canonical transformation, Hamilton-Jacobi theory, Lagrangian field theory, selected topics. Prerequisite: PH 601. Offered upon demand.

705 Relativity **3 hrs.**

Special and general theory. A covariant formulation of electrodynamics. Prerequisites: PH 601, 631. Offered upon demand.

706 Solar Flare Physics **3 hrs.**

Overview of the flare phenomenon; magnetic field structure and stability. Radiation mechanisms; energy transport by particles, hydrodynamic motions and radiation, empirical and theoretical atmosphere models; energy release mechanisms; solar terrestrial effects. Prerequisites: PH 531, 631. Offered upon demand.

711 Problems in Physics **3 hrs.**

Application of theoretical principles of physics to an intensive analysis and solution of representative problems. Does not count toward minimum degree requirements. Prerequisites: PH 552, 601, 621, 631. Fall.

731 Advanced Plasma Theory **3 hrs.**

Kinetic theory of plasmas. Vlasov equation of plasma waves, Landau damping and kinetic theory of stability, quasi-linear and non-linear theory, transport theory in plasmas, applications to space plasmas, plasma astrophysics and fusion research. Prerequisite: PH 531. Spring, odd years.

732 Electromagnetic Theory II **3 hrs.**

Continuation of PH 631. Inhomogeneous wave equation and sources. Special relativity, radiation from accelerated charges, and Hamiltonian formulation of electrodynamics. Prerequisite: PH 631. Spring.

733 Quantum Devices **3 hrs.**

Quantum aspects of optical, electronic, and semiconductor devices approached from a phenomenological/physical point of view. Topics will include: Quantum well devices, optical modulators, optical detectors, quantum Stark effects, electrooptic devices, high speed optical devices, frequency chirping in high speed devices and system applications. Prerequisites: PH 652 or OSE 655. (Same as OSE 755.) Fall, odd years.

745 Quantum Electronics **3 hrs.**

The propagation of optical beams in homogeneous and lens-like media, optical resonators, interaction between radiation and atomic systems, laser oscillations and specific laser systems, q-switching and mode-locking of lasers, noise in laser amplifiers and oscillators, modulation of optical radiation. Prerequisites: PH 545, 552, 631. Offered upon demand.

751 Quantum Field Theory **3 hrs.**

Formalism of quantum field theory, construction and evaluation of Feynman diagrams for quantum electrodynamics and the weak interaction, first-order processes, renormalization, particle scattering and decay, nucleon structure, introduction to quantum chromodynamics, accelerator experiments, and astrophysical applications. Prerequisites: PH 552, 609. Fall, odd years.

760 Quantum Theory of Solids **3 hrs.**

Semiclassical introduction, second quantization and the electron gas, boson systems, one-electron theory and metals, electron-phonon interactions, superconductivity, dynamic electrons in a magnetic field, semiconductor crystals, energy bands, impurity states, semiconductor crystals, optical absorption and excitations. Prerequisites: PH 552, 561, 631. Offered on demand.

780-789 Selected Topics **3 hrs.**

Topics include superconductivity, advanced plasma theory, properties of solids, laser propagation, collision theory, quantum electronics, gravitational theories. Fall, Spring, Summer.

792 Physics Seminar **1 hr.**

Students attend seminars by invited speakers. Two semesters are required for all M.S. students and three semesters for Ph.D. students. Does not count toward minimum degree requirements. Fall, Spring.

795 Advanced Physics Project Laboratory **3 or 6 hrs.**

Advanced laboratory research in one of the departmental research groups. Student works on an independent or group project. Completion of the course requires a written report that becomes part of the student's record. Prerequisite: Approval of advisor. Approval of Department Chair and an oral presentation of results is required for more than 3 credit hours. Fall, Spring, Summer.

799 Doctoral Dissertation **3, 6, 9 hrs.**

Prerequisites: Students must have passed the comprehensive examination at Ph.D. level and have Ph.D. advisor's approval. No more than 9 hours may be taken prior to passing the qualifying examination. Fall, Spring, Summer.