July 1, 2009

College of Engineering and Mineral Resources

Eugene V. Cilento, Ph.D., Dean
Warren R. Myers, Ph.D., Associate Dean for Academic Affairs
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Degrees Offered

Aerospace Engineering: Master of Science and Doctor of Philosophy
Chemical Engineering: Master of Science and Doctor of Philosophy
Civil Engineering: Master of Science and Doctor of Philosophy
Computer Engineering: Doctor of Philosophy
Computer Science: Master of Science
Computer and Information Science: Doctor of Philosophy
Electrical Engineering: Master of Science and Doctor of Philosophy
Engineering: Master of Science
Industrial Engineering: Master of Science and Doctor of Philosophy
Industrial Hygiene: Master of Science
Mechanical Engineering: Master of Science and Doctor of Philosophy
Mining Engineering: Master of Science and Doctor of Philosophy
Occupational Safety and Health: Doctor of Philosophy
Petroleum and Natural Gas Engineering: Master of Science and Doctor of Philosophy
Safety Management: Master of Science
Software Engineering: Master of Science

College of Engineering and Mineral Resources (CEMR) graduate programs are administered through the Departments of Chemical Engineering, Civil and Environmental Engineering, the Lane Department of Computer Science and Electrical Engineering, Industrial and Management Systems Engineering, Mechanical and Aerospace Engineering, Mining Engineering, and Petroleum and Natural Gas Engineering.

The facilities are housed on the Evansdale campus in three buildings: the Engineering Sciences Building, the Mineral Resources Building, and the Engineering Research Building. These buildings house state-of-the-art research facilities, well-equipped teaching laboratories, classrooms, and offices for the faculty and administration of the graduate programs and Extension and Outreach.

The college offers a doctor of philosophy in most disciplines. The Ph.D. program prepares graduates for leadership in industrial, governmental, or academic fields. The areas of specialization in engineering are aerospace, chemical, civil, computer, electrical, industrial, mechanical, mining, and petroleum and natural gas engineering. In addition, the college offers a Ph.D. in computer science and a Ph.D. in occupational safety and health.

Designated master's degrees are offered in aerospace, chemical, civil, electrical, industrial, mechanical, mining, petroleum and natural gas engineering, software engineering, and computer science. A master of science in engineering (M.S.E.) degree is offered to qualified students as determined at the departmental level. The college offers two accredited Master of Science degrees in industrial hygiene, and in safety management. These programs are accredited by the Applied Science Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Currently the college offers graduate certificate programs in Computer Forensics, Information Assurance and Biometrics and Software Engineering. For specific information about a program, students should review research and graduate studies (www.cemr.wvu.edu) information of the college web site.

Special Requirements

A student desiring to take courses for graduate credit in the college must comply with the appropriate University regulations for graduate study. To become enrolled in a CEMR graduate program, a student must

apply for admission through the Office of Admissions and Records to the department housing the student's choice of major. Acceptance will depend upon review of the student's academic background and available facilities in the major program's department.

An applicant with a baccalaureate degree, or its equivalent, from a program accredited by the Accreditation Board for Engineering and Technology (ABET), Computer Science Accreditation Board (CSAB), or an internationally recognized program in engineering or computer science will be admitted on the same basis as engineering or computer science graduates of WVU. Lacking these qualifications, an applicant must first fulfill any special requirements of the department in which the student is seeking an advanced degree.

No credits which are reported with a grade lower than C are acceptable toward an advanced degree. To qualify for an advanced degree, the graduate student must have a grade point average of at least 3.0 based on all courses acceptable for graduate credit for which the student has received a grade from WVU. Graduate students in the college must also comply with the regulations of their major department.

Individual departments may establish more stringent requirements than those adopted for CEMR as a whole. These departmental requirements are contained in the individual program sections of the graduate catalog.

Course Load

A full-time graduate student must register for at least nine, but no more than 15, credit hours during each regular semester, or at least six, but no more than 12, credit hours in the summer session. Permission to carry a heavier load must be obtained in writing from the dean.

Master's Program

For all master's degree students, an Advisory and Examining Committee consisting of at least three faculty members will be appointed. A plan of study must be jointly prepared and approved by the student and all members of the student's Advisory and Examining Committee, the department chair, and the dean or dean's designate, either at the end of the second semester of the student's attendance or at the completion of the twelfth course credit hour, whichever is later. The College is authorized to grant Master's degrees under each of the following three options:

a. Thesis Option – This option requires a minimum of 24 credit hours of course work and at least six credit hours of research leading to the thesis.
b. Problem Report Option – This option requires a minimum of 30 credit hours of course work and at least three credit hours of a research or design project leading to a formal written report.
c. Course Work Option – This option requires a minimum of 33 credit hours of course work. There are two ways this option is implemented. First, although rarely permitted, this option is open to students who have practical engineering experience and/or have demonstrated an ability to organize and develop a project and write a technical report. Approval to pursue this option must be obtained from the student's Advisory and Examining Committee (AEC), the graduate program coordinator, and the department chair. Second, a department can choose to offer students within a designated program the course work only option. Normally, for each option the coursework required is greater than that required for a student doing a thesis or problem report. In addition, the department must require successful completion of a written or oral comprehensive examination.

For complete details about admission criteria and other governance details of the Masters of Science programs please refer to the Guidelines for Masters of Science Programs which can be found on the College's home page.

Application for Transfer of Graduate Credit

A student wishing to apply graduate credit earned at another institution to a master's degree at WVU must complete an application for transfer of graduate credit to WVU and have an official transcript submitted to the WVU Office of Admissions and Records from the external institution. A maximum of 12 semester hours from other institutions may be acceptable for credit at WVU in master's degree programs in CEMR. Departmental programs may choose to accept fewer transfer credit hours.

Time to Completion

All requirements for the master's degree must be completed within eight years preceding the student's graduation.

Doctor of Philosophy

Admission as a graduate student is required of all applicants for admission to a program of study and research leading to the Ph.D. degree. To be eligible for admission into a doctorate of engineering program, a candidate is expected to hold or to receive by time of enrollment a B.S. or an M.S. degree in:

a. Some discipline of engineering from an institution which has an ABET-accredited program in that discipline or which has an internationally recognized program in engineering/mineral resources,
b. Mathematics and physical sciences (as specified by individual programs)

To be eligible for admission into the Computer Sciences and Information doctoral program, a candidate is expected to hold a B.S. or an M.S. degree in:

a. Computer science,
b. Engineering,
c. Mathematics and physical sciences (as specified by the program)

To be eligible for admission into the Occupational Safety and Health doctoral program, a candidate is expected to hold a B.S. or an M.S. degree in:

a. Industrial hygiene,
b. Safety,
c. Engineering,
d. Mathematics and physical and life sciences (as specified by the program)

Although a Bachelor's degree is the minimum requirement, applicants are normally encouraged to hold a Master's degree in a relevant discipline. Admission to graduate study does not necessarily assure entrance into a CEMR doctoral program.

For complete details about admission criteria and other governance details of the Doctor of Philosophy programs please refer to the Guidelines for Doctor of Philosophy Programs which can be found on the College's home page.

Application for Transfer of Graduate Credit

A student wishing to apply credit earned at another institution to a doctoral degree program at WVU must submit an application for transfer of graduate credit to WVU and have an official transcript from the institution forwarded to the WVU Office of Admissions and Records. The approval of transfer credit is at the discretion of the student's Advisory and Examining Committee.

Advisory Committee

The student, research advisor, academic advisor, and department chairperson appoint the student's Advisory and Examining Committee. For the Ph.D. program, each committee must consist of at least five members—at least three, including the chairperson, from the student's major department and at least one from another discipline related to the student's area of interest.

Plan of Study

At the end of the second semester of a student's attendance, at the completion of the twelfth credit hour, or when master's degree requirements are completed, whichever is later, the student, with the advice and consent of the student's academic advisor, graduate coordinator, and members of the student's Advisory and Examining Committee, will submit a plan of study, initiated in the student's department, to the dean or dean's designee. Some departments may require that a preliminary dissertation research proposal be submitted along with the plan of study.

Candidacy Examination

After admission to the program and after the residence requirements are met, the applicant will take a candidacy examination in which the student must demonstrate: (a) a grasp of the important phases and problems of the field of study and an appreciation of their relation to other fields of human knowledge and accomplishments, and (b) the ability to employ the instruments of research developed in the student's area of interest. When an applicant has passed the candidacy examination, the student will be formally admitted to candidacy for the doctoral degree. A student will have only one opportunity for reexamination. Some

programs may require a student to successfully pass a qualifying examination before taking the candidacy examination.

Credit Requirements

The doctor of philosophy degree is not awarded solely on the basis of the accumulation of course credits and completion of a definite residence requirement. The amount and nature of the coursework undertaken by a doctoral student will be established for each individual student with the objective of ensuring a reasonable and coherent progression of academic development beyond the baccalaureate and/or master's degree.

Faculty

†Indicates regular membership in the graduate faculty.
* Indicates associate membership in the graduate faculty.

Chemical Engineering

Professors

†Richard C. Bailie, Ph.D. (Iowa St. U.). *Emeritus.* Biomass pyrolysis, Fluidization, Thermal processing.
†Eung H. Cho, Ph.D. (U. of Utah). Mineral processing, Hydrometallurgy.
†Eugene V. Cilento, Ph.D. (U. Cinn.). Dean. Physiological transport phenomena, Biomedical engineering, Image analysis, Mathematical modeling.
†Dady B. Dadyburjor, Ph.D. (U. Del.). Chairperson. Catalysis, Reaction engineering, Micellization, Fuels and chemicals from synthesis gas, Synthesis gas from coal.
Alfred F. Galli, M.S. (WVU). *Emeritus.* Coal conversion, Process engineering, Biomass production.
†Rakesh K. Gupta, Ph.D. (U. Del.). Berry Professor. Polymer processing, Rheology, Non-Newtonian fluid mechanics, Composite materials.
†Hisashi O. Kono, Dr. Engr. (Kyushu U.). *Emeritus* Fluidization, Powder technology, Powder material science.
†Edwin L. Kugler, Ph.D. (Johns Hopkins U.). Catalysis, Partial oxidation, Fischer-Tropsch processing, *In-situ* reaction studies.
†Alfred H. Stiller, Ph.D. (U. Cinn.). Chemistry (physical inorganic chemistry), Solution chemistry, Coal liquefaction, Carbon science.
†Richard Turton, Ph.D. (Ore. St. U.), P.E.. Fluidization, Chemical process design, Particle processing, Powder processing.
†Ray Y.K. Yang, Ph.D. (Princeton U.). Bionanotechnology, Cellulose hydrolysis, Plant-cell technology,Neural-networks modelling.
†John W. Zondlo, Ph.D. (Carnegie Mellon U.). Coal enhancement and utilization, Carbon science, Fuel Cells.

Associate Professors

†Joseph A. Shaeiwitz, Ph.D. (Carnegie Mellon U.). Engineering education, Design education, Outcomes assessment.
†Charter D. Stinespring, Ph.D. (WVU). Wide-band-gap semiconductor growth and etching, Surface kinetics.

Assistant Professors

†Brian J. Anderson, Ph.D. (MIT). Natural-gas hydrates, Energy, Molecular modeling.
†Kwang-Jea Kim, Ph.D. (U. Akron) *Research*. Reactive Polymer Processing, Rheology, Surface chemistry, Nanocomposites.
†David J. Klinke, II, Ph.D. (Northwestern U.) Systems biology, Diabetes modeling.
†Ruifeng (Ray) Liang, Ph.D. (CAS Inst. Chem.). *Research*. Polymers, Smart materials, Composites, Processing and properties.
†Wu Zhang, Ph.D. (U. London). *Research*. Natural-gas hydrates, Polymers.

Civil and Environmental Engineering

Professors

†H. L. Chen, Ph.D. (Northwestern U.). Structural dynamics, Structural experimentation, Dynamic soil-structure interaction, Damage in reinforced concrete structures.
†Julio F. Davalos, Ph.D. (VPI & SU). Benedum Distinguished Teaching Professor. Finite element analysis and modeling of structures, Spatial stability investigation, Materials characterization of engineered timber products.
†Ronald W. Eck, Ph.D., P.E. (Clemson U.). Transportation engineering, Traffic operations and safety, Highways engineering.

†Donald D. Gray, Ph.D., P.E. (Purdue U.). Fluid flow, Computational fluid mechanics.
†Udaya B. Halabe, Ph.D., P.E. (MIT). Nondestructive evaluation and in-situ condition assessment of structures and materials, Elastic and radar wave propagation, Structural analysis and design, Structural dynamics and wind/earthquake resistant design.
W. Joseph Head, Ph.D. (Purdue U.). *Emeritus.* Waste utilization, Highway and airfield pavements, Concrete.
†Ganga Rao V. S. Hota, Ph.D., P.E. (N.C. St. U.). Director, Constructed Facilities Center. Mathematical modeling of engineering systems, Bridge engineering, Prefabricated housing.
Charles R. Jenkins, Ph.D. (Okla. St. U.). *Emeritus.*
Larry D. Luttrell, Ph.D., P.E. (Cornell U.). *Emeritus.* Analysis and design of structures: steel, composite slabs, and metal buildings, Case studies of failures.
Lyle K. Moulton, Ph.D., P.E. (WVU). *Emeritus.*
William A. Sack, Ph.D., P.E. (Mich. St. U.). *Emeritus.* Environmental engineering, Biological treatment, Bioremediation of hazardous wastes, Nutrient removal, Industrial waste treatment and reclamation.
†Hema J. Siriwardane, Ph.D., P.E. (VPI & SU). Geotechnical engineering/geomechanics, Finite element method, Computer applications.
†John P. Zaniewski, Ph.D., P.E. (U. Tex.). Asphalt Technology. Director, Harley O. Staggers National Transportation Center. Pavement materials, Design, Construction, Maintenance, Infrastructure management.

Research Professors

†Ron Fortney, Ph.D. (WVU). Research. Plant systematics, Wetlands, Vegetation mapping, Environmental assessment.
†Lloyd (James) French, Ph.D., P.E. (WVU). Research. Transportation planning, Traffic engineering, intelligent transportation systems.
*Michael McCawley, Ph.D. (NYU). Research. Environmental engineering, Air pollution, Air quality.

Associate Professors

†Karl Barth, Ph.D. (Purdue U.). Steel structures, Bridge design and rehabilitation, Connections, Stability analysis, Experimental mechanics.
†Darrell R. Dean Jr., L.L.S., Ph.D. (Purdue U.). Land surveying, Mapping, Photo grammetry.
†Robert N. Eli, Ph.D., P.E. (U. Iowa). Hydrology, Hydraulics, Computer graphics.
†David R. Martinelli, Ph.D. (U. Md.). Chair. Transportation engineering, Traffic operations, Systems analysis, Infrastructure management.
†Roger Viadero, Ph.D. (WVU). Physical chemical processes, Nuclear waste management, Industrial and hazardous waste treatment.

Assistant Professors

Research Assistant Professors

†Indrajit Ray, Ph.D. (I.I.T.—India). Research. Modern concrete materials, High performance concrete and overlays, Utilization of by-products/wastes in concrete, Microstructure of cementations materials.
†P. V. Vijay, Ph.D. (WVU). Research. Concrete structures, FRP composite structures for bridges, buildings, and pavements, Aging of structures and rehabilitation, Recycled polymers for infrastructure, Analytical modeling.

Visiting Professors and Adjuncts

Samuel G. Bonasso, M.S.C.E., P.E. (WVU). Adjunct. Cable transportation, Street engineering, Communication and creativity in engineering.
Michael Blankenship, M.S.C.E., P.E. (WVU). Adjunct. Transportation and traffic engineering, Highway safety, Highway maintenance.
Dennis C. Chambers, M.S.C.E., P.E. (WVU). Adjunct. Geotechnical engineering, Construction and materials.
James G. Collin, Ph.D., P.E. (U. of Ca., Berkley). Adjunct. Geotechnical engineering, Geosynthetics, Earth retaining structures, Slope stabilization, Waste containment.
James L. Green, M.S.C.E., P.E. (WVU). Adjunct. Environmental engineering, Water treatment, Water quality.
William J. Harman, M.S.C.E., P.E. (WVU). Adjunct. Construction methods, Construction specifications.
David A. Pask, M.S., Eviron., P.E. (Tech. U. of Nova Scotia). Adjunct. Environmental engineering, Water treatment, Public health, Wastewater treatment.
Kumanaswamy Sirakumaran, Ph.D. (U. of Colo.). Adjunct. Sediment transport and hydraulic engineering.
Robert W. Wheeler, M.S.C.E. (WVU). Adjunct. Environmental engineering, Public health, Water supply.
William D. Wyant, M.S.C.E. (WVU). Adjunct. Transportation engineering, Construction methods.

Lane Department of Computer Science and Electrical Engineering

Professors

†Hany H. Ammar, Ph.D. (U. Notre Dame). Risk assessment, Software engineering, Biometrics, Performanc and dependability analysis, Modeling and evaluation of parallel and distributed systems.

†John M. Atkins, Ph.D. (U. Pitt.). Graduate coordinator for CS. Design of Database management systems, Analysis of algorithms, Mathematics of computation.

Walton W. Cannon, Ph.D. (U. Ill.). Emeritus.

†Muhammad A. Choudhry, Ph.D. (Purdue U.). Graduate coordinator for CpE & EE. Power system control, DC transmission, Stability, Power electronics.

†Wils L. Cooley, Ph.D., P.E. (Carnegie Mellon U.). Biomedical engineering, Electronics, Design.

†Parviz Famouri, Ph.D. (U. Ky.). Analysis and control of electrical machines, Motor drives, Power electronics, electric vehicles.

†Ali Feliachi, Ph.D. (Ga. Tech.). Power systems, Large-scale systems, Control.

†Mike Henry, Ph.D. (Tex. Christian U.). CS Education, Neural networks.

Franz X. Hiergeist, Ph.D. (U. Pitt.). Retired.

†Lawrence Hornak, Ph.D. (Rutgers U.). Optics, Integrated optics, Micro/Nano structures and devices, Biosensors, Biometrics.

†Ronald L. Klein, Ph.D. (U. Iowa). Automatic control, Estimation theory, System identification, Electrical vehicles.

†Powsiri Klinkhachorn, Ph.D. (WVU). Microprocessor applications, Computer architecture, Binary and nonbinary logic.

Wayne A. Muth, Ph.D. (Iowa St. U.). *Emeritus.*

†Roy S. Nutter Jr., Ph.D., P.E. (WVU). Neural networks, Microprocessor systems, Computer architecture, Computer forensics.

†Y. V. Ramana Reddy, Ph.D. (WVU). Artificial Intelligence, Knowledge-based simulation, Computer graphics.

†George E. Trapp, Ph.D. (Carnegie Mellon U.) Network modeling, Numerical analysis, Mathematical programming.

†Brian Woerner, Ph.D. (U. of Mich.) Chair. Wireless communication

Associate Professors

†Bojan Cukic, Ph.D. (U. Houston). Software engineering, High-assurance systems, Computational Intelligence, Fault-tolerant systems, Biometrics.

William H. Dodrill, Ph.D. (WVU). *Emeritus.*

†V. Jagannathan, Ph.D. (Vanderbilt U.). Distributed Intelligent Systems, Internet and security technologies.

†Mark A. Jerabek, Ph.D., P.E. (Purdue U.). Solid state devices and sensors, Electromagnetics.

Robert L. McConnell, Ph.D. (U. Ky.). Retired.

†James D. Mooney, Ph.D. (Ohio St. U.). Associate chair. Operating systems, Computer architecture, Software portability and standards, Computer security and forensics.

†Afzel Noore, Ph.D. (WVU). VLSI design and testing, Software engineering, Information assurance and Biometrics.

†Frances L. VanScoy, Ph.D. (U. Va.). Programming languages and compilers, Multisensory computing, High performance computing.

Research Associate Professors

†Srinivas Kankanahalli, Ph.D. (N. Mex. St. U.). Artificial Intelligence, Connectionism/neural networks, Parallel processing.

†Sumitra Reddy, Ph.D. (WVU). Healthcare informatics, Componentware, Intelligent systems, Information technology evolution.

Assistant Professors

†Donald Adjeroh, Ph.D. (Chinese U. of Hong Kong). Multimedia information systems (images, video, and audio), Distributed multimedia systems.

†Elaine M. Eschen, Ph.D. (Vanderbilt U.). Graduate coordinator for CS Ph.D. CCDM program. Design and analysis of algorithms, Graph theory, Combinatorics.

†Katerina Goseva-Popstojanova, Ph.D. (U. Sv. Kiril I Metodij). Software reliability engineering, Distributed systems, Computer security, Dependability, Performance and performability assessment.

†Dimitris Korakakis, Ph.D. (Boston U.). Semiconductor growth, Nanotechnology, Photonic Devices, Biosensors.

†Xin Li, Ph.D. (Princeton U.). Image processing, Computer vision, Pattern recognition.

†Supratik Mukhopadhay, Ph.D. (U. of Saarland). Computer aided verification, Program analysis, Software engineering, Logics of knowledge, Database theory, Artificial intelligence, Set constraints.
†Daryl Reynolds, Ph.D. (Tex. A&M). Statistical signal processing for communications, Iterative (turbo) processing, Transmitter precoding, Space-time coding and processing.
†Arun Ross, Ph.D. (Mich. St. U.). Statistical pattern recognition, Biometric authentication, Image processing, Computer vision.
†Natalia Schmid, Ph.D. (Wash. U. St. Louis). Estimation and detection, Biometrics, Information theory, Statistical signal and image processing.
†K. Subramani, Ph.D. (U. Md.). Scheduling, Computational biology, Computational complexity, Polyhedral combinatorics.
†Matthew C. Valenti, Ph.D. (VPI & SU). Communication theory, Wireless systems, Error control coding.

Research Assistant Professors

Kolin Brown, Ph.D. (WVU). Research project/lab coordinator. Micro/nano fabrication.
†Gamal Fahmy, Ph.D. (U. Arizona). Image processing.
†Mark Shereshevsky, Ph.D. (U. of Warwick, U.K.). Dynamical systems, Chaos theory, Cellular automata, Information theory, Neural networks.

Lecturers

David V. Baker, M.S.C.S. (WVU). Computer graphics, Virtual reality.
Rebecca Littleton, M.S.C.S. (WVU). Design and development of multimedia, instructional, web-based systems.
Todd Montgomery, M.S.E.E. (WVU). Communication protocols, Fault-tolerant systems, Network security.
Cynthia D. Tanner, M.S.C.S. (WVU). Graduate coordinator for software engineering.

Extension and Outreach

Extension and Outreach is a unit within the College of Engineering and Mineral Resources (CEMR) that is composed of two programs: Mining extension and industrial extension.

James M. Dean, M.S.E.M. (WVU). Director. Mine management, Mine safety and health, Initial miner training.
Thomas C. Mahoney, M.A. (Johns Hopkins U.). Associate director. Manufacturing technology, Management, Product development, Industrial policy, Trade, Industrial and international economics, Industrial R & D, Networks.

Industrial Extension Service

Industrial Extension Specialists

Thomas A. Bailey, B.I.E., P.E. (Ohio St. U.). Quality assurance, Environmental planning/waste reduction, Plant layout, Continuous improvement.
Cindy Decker, B.S. (L.S.U.). Project management, Sales and marketing, Supply chain management, Quality systems.
Lawrence D. Dixon, M.S.C.S.E., P.E. (WV Graduate Coll.). B.S.E.M. (WVU). B.S.E.E. (WVU Inst. of Technology). Energy conversion, Conversion devices, Energy efficiency, Rate structures.
John Frazer, M.S.I.E. (WVU). Industrial hygiene, Environmental and OSHA compliance, Training, Risk management, Process safety.
Raymond D. Neupert, B.S.I.E., P.E. (WVU). Technology development, Quality management systems, Cellular manufacturing, Strategic planning, Cost control.

Mining Extension Service

Professor

Joseph C. Dorton, B.S. (Concord Coll.). Mine foreman training, Electrical training, Mandatory miner training courses.

Associate Professors

Robert L. Halstead, B.S. (Morris Harvey Coll.). *Emeritus.* Mine foreman training, Electrical training, Production technology.
Thomas L. Savage, B.S. (Cornell U.). *Emeritus.* Hydraulics.

Assistant Professor

Luther B. Ferguson. *Emeritus.*

Mining Extension Agents

Mark A. Adkins, B.S. (WVU Inst. of Tech.). Mine foreman training, Surface and underground apprentice training and electrical training.
Thomas W. Hall, B.S. (Fairmont St. Coll.). Mine foreman training, Mandatory miner training, Mining methods.

John D. Martin, B.S. (Bera Coll.). Fire safety training, Protective clothing and equipment
Joseph E. Spiker, M.S. (WVU). M.B.A. (Waynesburg Coll.). Director, Emergency Preparedness Center. Coal mining operations, Safety and health management, Education administration.
Ireland Sutton, B.S. (WVU Inst. of Tech.). Surface mine blasting, Underground and surface power systems, Mandatory miner training.

Industrial and Management Systems Engineering

Professors

†Rashpal S. Ahluwalia, Ph.D., P.E. (Western Ontario U.). Manufacturing systems, Quality and reliability engineering, Robotics and automation.
†Jack Byrd Jr., Ph.D., P.E. (WVU). Operations research, Workforce development, Work design, Integrated product development.
†Robert C. Creese, Ph.D., P.E. (Penn. St. U.). Manufacturing processes/systems, Foundry engineering, Cost engineering.
†Daniel E. Della-Giustina, Ph.D. (Mich. St. U.). Playground and recreation safety, Sport safety, Highway and traffic management, Safety, fire, and emergency response.
†B. Gopalakrishnan, Ph.D. (VPI). Manufacturing processes and systems engineering, Information systems, Artificial intelligence applications, Expert systems development, Mechatronics, Facilities planning and materials handling, Databases, Industrial energy/waste productivity management.
†Wafik H. Iskander, Ph.D., P.E. (Tex. Tech. U.). Chairperson. Operations research and optimization, Simulation modeling and analysis, Production planning and control, Applied statistics, and Transportation planning.
†Majid Jaraiedi, Ph.D. (U. Mich.). Statistics, Quality control, Forecasting and transportation research.
†Warren R. Myers, Ph.D., C.I.H. (WVU). Associate Dean for Academic Affairs. Industrial hygiene and safety, Worker exposure assessment and modeling, Aerosol filtration, Occupational respiratory protection design and testing.
†Ralph W. Plummer, Ph.D., P.E. (WVU). Systems safety engineering, Energy conservation, Human factors, Ergonomics. *Emeritus*
†Gary Winn, Ph.D. (Ohio St. U.). Construction safety, Transportation safety and program evaluation, Total quality management, Theory of paradigm shifts.

Associate Professors

†Steven Guffey, Ph.D., C.I.H. (N.C. St. U.). Ventilation systems theory and design.
†Alan McKendall Jr., Ph.D. (U. of Mo.—Columbia). Operations research, Project scheduling, Integrated production systems.
Andrew J. Sorine, Ed.D. (WVU). Benchmarking, Safety and health programs, Safety management information systems. *Emeritus*
†Steve Wiker, Ph.D., C.P.E. (U. of Mich.). Ergnomics, Human factors and safety engineering.

Assistant Professors

David L. Durham, M.S. (WVU). Research. Acid mine drainage abatement, Waste utilization.
†Michael J. Klishis, Ph.D. (WVU). Safe behaviors, Training and loss control, Instructional development, Mine safety and health.
David Whaley, Ph.D., C.I.H. (St. U. of NY at Buffalo). *Emeritus.*

Visiting Professors and Adjuncts

Christopher Coffey, Ph.D. (WVU). Occupational safety and health, Assessment, Evaluation of respiratory protective equipment.
Ren Dong, Ph.D., Industrial Hygiene, Exposure Assessment.
Martin Harper, Ph.D. (London School of Hygiene and Tropical Medicine), Industrial Hygiene, Exposure Assessment
Paul Hewett, Ph.D., C.I.H. (U. of Pitt.). Exposure assessment strategies with a focus on data analysis paradigms.
Hongwei Hsiao, Ph.D., Industrial Hygiene, Exposure Assessment.
Christopher Pan, Ph.D., Industrial Hygiene, Exposure Assessment
Ju-Hyeong Park, Sc.D., M.P.H., C.I.H., (Harvard), Industrial Hygiene, Exposure Assessment
Ziqing Zhuang, Ph.D. (WVU). Exposure assessment, Assessment and evaluation of respiratory protective equipment.

Mechanical and Aerospace Engineering

Professors

†Richard A. Bajura, Ph.D., P.E. (U. Notre Dame). Director of NRCCE. Fluids engineering.
†Ever Barbero, Ph.D. (VPI & SU). Chairman, Materials, Experimental and computational mechanics.
†Ismail Celik, Ph.D. (U. Iowa). Fluids engineering.
†Nigel Clark, Ph.D. (U. Natel, So. Africa). Multiphase flows, I.C. engines, and emissions.
†Russell K. Dean, Ph.D. (WVU). Associate provost for Academic Affairs Admin. Engineering mechanics.
†Mridul Gautam, Ph.D. (WVU). Fluid mechanics.
†Eric K. Johnson, Ph.D., P.E. (U. Wisc.). Heat transfer, Combustion, Thermodynamics, Gas-solid flows.
†Bruce Kang, Ph.D. (U. Wash.). Experimental mechanics, Advanced materials.
†John Kuhlman, Ph.D. (Case West. Res. U.). Fluid mechanics.
†John L. Loth, Ph.D., P.E. (U. Toronto). Aerospace systems, Combustion.
†Donald W. Lyons, Ph.D., P.E. (Ga. Tech.). Director of Alternative Fuels, Engines, and Emissions Center, Manufacturing systems engineering, Instrumentation, Engines and emissions.
†Kenneth H. Means, Ph.D., P.E. (WVU). Kinematics, Dynamics and stability, Friction and wear.
†Gary Morris, Ph.D. (WVU). Fluid mechanics, Combustion, Aerodynamics.
†Victor Mucino, D.E. (U. Wisc.-Mil.). Engineering design.
†Marcello Napolitano, Ph.D. (Okla. St. U.). Aircraft stability and control, Feedback control, Dynamics.
†Samir Shoukry, Ph.D. (Aston U. in Birmingham UK). Pavement modeling, Non-destructive evaluation, Structural dynamics, Neural nets, Instrumentation
†Nithi T. Sivaneri, Ph.D. (Stanford U.). Structural mechanics, Composite materials, Finite-element analysis, Numerical methods.
†James E. Smith, Ph.D. (WVU). Mechanical design.
†Charles Stanley, Ph.D. (WVU). Pulmonary bioengineering, Mechanical instrumentation.

Research Professors

†Steve Lewellen, Ph.D. (UCLA). Research. Fluid dynamics.
†John E. Sneckenberger, Ph.D., P.E. (WVU). Mechanical design and automation.

Associate Professors

†Larry Banta, Ph.D. (Ga. Tech.). Associate chairperson and Undergraduate program director. Automation, Controls, Energy management.
†Jacky Prucz, Ph.D. (Ga. Tech.). Associate chairperson and graduate program director. Structural design, Composite materials.
†Wallace S. Venable, Ed.D., P.E. (WVU). *Emeritus.* Engineering mechanics, Engineering education.

Research Associate Professors

David Lewellen, Ph.D. (Cornell). Research. Fluid dynamic turbulence.

Assistant Professors

Darran Cairns, Ph.D. (U of Birmingham, UK). Materials science.
†Wade W. Huebsch, Ph.D. (Iowa St. U.). Fluid mechanics, CFD, Numerical methods.
Xingbo Liu, Ph.D. (U of Science & Technology,Beijing,China). Materials science.
Osama Mukdadi, (U of Colorado). Solid mechanics and materials
†Mario Perhinschi, Ph.D. (Poly Inst. Buckarest). Aircraft stability and control, Flight simulation.
†Andrei Smirnov, Ph.D. (Chalmers U.). Computational fluid dynamics, Coupled multiphysics simulation.
†Gregory Thompson, Ph.D. (WVU). Thermodynamics, Machine design.
†W. Scott Wayne, Ph.D. (WVU). Machine design, Alternative fuels.
Nianqiang Wu, Ph.D. (Zhejiang University, China). Materials science and engineering.

Research Assistant Professors

Giampiero Campa, Ph.D. (U. of Pisa). Flight control systems.
Yu Gu, Ph.D. (WVU). Flight control systems.
Mohan Krishnamurhy, Ph.D. (WVU).
Andrew Nix, Ph.D. (Virginia Polytechnic Institute). Engines and Emissions.
Brad Seanor, Ph.D. (WVU). Flight controls, Parameter estimation, Flight testing, UAV/RPVAircraft technology.
Benjamin Shade, Ph.D. (WVU). Engines and Emissions

Visiting Professors and Adjuncts

Rodney Anderson, Ph.D. (U. Mo.-Rolla). Adjunct. Aerosol and particle science.
†Chris Atkinson, Sc.D. (MIT). Adjunct. Fluid mechanics, Instrumentation, Engine emissions.
Alberto Ayala, Ph,D. (U of California, Davis), Ajunct Asst. Prof. Engine emissions.

Keh-Minn Chang, Ph.D. (U.C.—Berkeley). Adjunct, Materials, Physical metallurgy.
Mary Ann Clarke, Ph.D. (Virginia Tech). Adjunct Asst. Prof. Applied mathmatics
John Etherton, Ph.D. (WVU). Adjunct Asst. Prof. Machine design.
Donald H. Ferguson, Ph.D. (WVU). Adjunct Asst. Prof. Thermal fluid sciences.
Luis A. Godoy, Ph.D. Adjunct Prof. Structural stability.
Nabil S. Hakim, Ph.D. Adjunct Prof. Engines and Emissions.
Paul E. King, Adjunct Prof. Materials Science.
Alejandro Lozano-Guzman, Ph.D. (U Newcastle Upon Tyne England) Adjunct Prof. Design.
Eugene A. McKenzie, Ph.D. (WVU). Adjunct Asst. Prof. Design.
Koorsch Mirfakhraie, Ph.D. Adjunct Prof. Space systems.
Nilay Mukherjee, Ph.D. (Virginia Commonwealth U). Adjunct Asst. Prof. Biomedical Eng.
Timothy L. Norman, Ph.D. (Purdue U). Adjunct Prof., Tissue mechanics.
G. Michael Palmer, Ph.D. (WVU). Visiting. Instrumentation, Microprocessor applications.
Ming Pei, Ph.D., (Peking U, China). Adjuct Asst. Prof., Tissue engineering
Constantine Spyrakos, Ph.D. (U of Minnesota). Adjunct Prof. Structural stability. Finite Elements.
W. George Wang, Ph.D. (WVU). Adjunct Prof. Kinematics and Dynamics
Lane Wilson, Ph.D. (Stanford U). Adjunct Asst. Prof. Materials Science.
Steven D. Woodruff, Ph.D. (U of Michigan). Adjunct Prof. Laser Apps, Dev. and Diagnostics

Mining Engineering
Professors
†Christopher John Bise, Ph.D. (Penn. St. U.) Charles T. Holland Distinguished Professor of Mining Engineering and Chairperson, Mine design, mine health and safety
Jay H. Kelley, Ph.D. (Penn. St. U.). Distinguished. *Emeritus.*
†Keith Heasley, Ph.D. (Colo. Sch. of Mines). Numerical modeling, Rock mechanics.
†A. Wahab Khair, Ph.D. (Penn. St. U.). Rock mechanics, Ground control, surface mining, Mine surveying.
†Syd S. Peng, Ph.D. (Stanford U.). Charles E. Lawall Chair in Mining Engineering. Mining Engineering and Longwall mining, Ground control.
Associate Professors
†Yi Luo, Ph.D. (WVU). Surface subsidence.
†Felicia F. Peng, Ph.D. (WVU). Coal preparation, Coal utilization, Process control, Plant design.

Petroleum and Natural Gas Engineering
Professors
†Samuel Ameri, M.S.Pet.E., P.E. (WVU). Chairman. Formation evaluation.
†Khashayar Aminian, Ph.D. (U. Mich.). Natural gas engineering, Reservoir engineering.
†Shahab Mohaghegh, Ph.D. (Penn. St. U.). Intelligent systems professor.
Associate Professors
†H. Ilkin Bilgesu, Ph.D., P.E. (Penn. St. U.). Drilling engineering.

Department of Chemical Engineering
Dady B. Dadyburjor, Ph.D., Chair
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Degrees Offered

Master of Science in Chemical Engineering
Master of Science in Engineering with a major in Chemical Engineering
Doctor of Philosophy with a major in Chemical Engineering

The Department of Chemical Engineering, with 11 active tenured faculty members, 66 undergraduates, and 30 graduate students, has one of the oldest doctoral-granting programs in the University. From the initial doctoral degree in 1932, the graduate course program has been based on advanced chemical engineering fundamentals, while the research program has reflected a balance of fundamental research areas and their application to relevant technological areas such as bioengineering, catalysis, coal conversion, materials, and polymer processing.

Faculty Research Areas

Chemical engineering faculty are presently involved in the following research areas: biochemical engineering, biomedical engineering, carbon science, catalysis, fluid mechanics, heat transfer, materials engineering, polymers and polymer rheology, reaction engineering, separation processes, solution chemistry, surface science, and thermodynamics. These fundamental areas are finding applications in biochemical technology, bio-transport, coal gasification and liquefaction, materials handling and processing, *in-situ* combustion, non-fuel uses of coal, carbon products, and synthetic fuels.

Faculty members possess a wide variety of industrial experience and are routinely in contact with their counterparts in industry. This contact with real engineering problems enables them to convey a practical experience to students while keeping in perspective many of the fundamental concepts involved in graduate study. During the last five years, the chemical engineering faculty have authored or coauthored three books, published over 90 refereed journal articles, have been issued five patents, made over 175 presentations at professional meetings, and supervised the completion of 50 master's and ten doctoral degrees, and over ten post-doctoral students and visiting scholars. In addition, faculty members have taught short courses throughout the United States and abroad.

Degree Programs

The department is authorized to admit students to the following degree programs: Master of Science in Chemical Engineering (M.S. Ch.E.), Master of Science in Engineering (M.S.E.), and College of Engineering and Mineral Resources interdisciplinary doctor of philosophy (Ph.D.). Students in these programs must comply with the rules and regulations as presented in the general requirements for graduate work in the College of Engineering and Mineral Resources and in the Department of Chemical Engineering. Students interested in pursuing work for a master's or doctoral degree in chemical engineering should contact the department for copies of the required guidelines and application information.

Admission

Admission to the M.S.Ch.E. program is restricted to those holding a baccalaureate degree in chemical engineering or its equivalent. The M.S.E. program is available to students holding baccalaureate degrees in other fields of engineering and the physical sciences who wish to pursue a broad interdisciplinary program relevant to the major graduate areas administered by the department. To be admitted as a regular graduate student, an applicant must have a B.S. degree and a sound record in previous college work with a minimum 3.0 (on a 4.0 scale) cumulative grade point average. Applicants who cannot meet these conditions may be considered for admission in a conditional category. Students admitted with deficiencies in their undergraduate programs are required to take some chemical engineering courses as prerequisites for graduate courses. These requirements are stated as a condition for admission.

Planned Programs

M.S.Ch.E. candidates should expect to obtain their degree in about 18 months. M.S.E. students typically require one to one and a half years beyond completion of prerequisite courses. Typically, the prerequisite courses include as a minimum: CHE 310, 311, 312, 315, 320, and 325. All M.S. degree candidates are required to perform research and will follow a planned program which conforms to either of the following outlines:

- A minimum of 30 semester credit hours, excluding seminar; not more than six of which are in research leading to an acceptable thesis.
- A minimum of 33 semester credit hours, excluding seminar; not more than three of which are in research leading to an acceptable problem report. The coursework M.S. degree option is not offered by the Department of Chemical Engineering.

Required Courses

All students are required to take CHE 615, 620, and 625, and all full-time students are required to take one credit of journal club/seminar (CHE 694) for each semester enrolled. The research advisor, in conjunction with an Advisory and Examining Committee (AEC) to be designated by each student, will be responsible for following departmental guidelines to determine the plan of study appropriate to the student's program.

A written research proposal and oral presentation of this proposal is required of all M.S. students. This oral defense is administered by the student's AEC and must be completed by the end of the second semester of the first year for M.S.Ch.E candidate, and as soon as possible but not later than the end of the second semester of the second year for M.S.E. candidates.

Final Examination

All students are required to pass a final oral examination, administered by their AEC, covering both the thesis or problem report (depending on the program selected) and related course material.

Doctor of Philosophy

A candidate for the degree of doctor of philosophy must comply with the rules and regulations as outlined in the general requirements for graduate work in engineering and the specific requirements stated in the departmental guidelines. Students who are interested in pursuing a Ph.D. degree in the Department of Chemical Engineering should contact the department for specific information. A program with a major in chemical engineering, designed to meet the needs and objectives of each student, will be developed in consultation with the student's research advisor and Advisory and Examining Committee (AEC). It should be emphasized that the Ph.D. degree is primarily a research degree, and therefore the research work for a doctoral dissertation should show a high order of originality on the part of the student and must offer an original contribution to the field of engineering science.

Admission

Admission to the Ph.D. program is open to students who qualify as regular graduate students and who have obtained a B.S. or M.S. degree in science or engineering. Students admitted must have demonstrated an excellent academic record in previously completed college coursework with a minimum cumulative grade point average of 3.0 (on a 4.0 scale). Three letters of recommendation and GRE scores are required by the department. Students in the Ph.D. program should complete the requirements in two to four years.

Required Courses

All B.S. students entering the Ph.D. program are required to take CHE 615, 620, and 625, while M.S. students entering the program must demonstrate equivalent courses taken for graduate credit. In addition, all full-time students must take one credit of seminar/journal club (CHE 694) each semester. For a student admitted directly after the B.S. degree, the Ph.D. program consists of a minimum of 36 course credit hours, excluding research (CHE 797) and seminar/journal club (CHE 694). If the student has an M.S. in chemical engineering from WVU, the program consists of a minimum of 12 course credit hours (excluding CHE 797 and CHE 694). If the student has an M.S. in chemical engineering from another institution, the program consists of a minimum of 18 course credit hours (excluding CHE 797 and CHE 694). Students must complete a minor consisting of a minimum of nine semester hours of a coherent set of courses taken outside of the department. These courses may be related to the major research area. Non-technical courses are considered only under exceptional circumstances. Courses at the 400 level may be acceptable. All courses must be approved by the AEC and the academic advisor. Students must complete graduate courses with an overall

coursework average of 3.0 or better (exclusive of research credits) and complete all CHE courses with an overall grade point average of 3.0 (exclusive of research credits). A minimum of 24 credit hours in dissertation research is required. Also, two semesters of full-time attendance at the Morgantown campus is required to complete the residency requirement.

Examinations

All students must pass the Ph.D. qualifying examination given in their first year at WVU. This examination is designed to assess the basic competency of students in the chemical engineering field to determine whether or not they have sufficient knowledge to undertake independent research.

Within twelve months of passing the qualifying examination or of entering the Ph.D. program, whichever is later, the student must successfully defend an original research proposition in an oral examination. The written proposition, developed by the student alone, remains the intellectual property of the student and must be on a topic unrelated to the student's own research work for the dissertation.

Research Proposal

A student must receive acceptance of a written dissertation research proposal and must also successfully defend this proposal to the student's AEC. This requirement must be completed within six months of passing the qualifying examination or of entering the Ph.D. program, whichever is later. The research work for the doctoral dissertation should show a high order of originality on the part of the student and must offer an original contribution to the field of engineering science.

A student who has successfully completed all coursework, passed the qualifying examination, and successfully defended the original research proposition and research proposal is defined as one who is a candidate for the Ph.D. degree.

In order to complete the Ph.D. requirements, a student must pass a final oral examination on the results embodied in the dissertation. This examination is open to the public and, in order to evaluate critically the student's competency, may include testing on material in related fields, as deemed necessary by the AEC. In addition, since the Ph.D. degree is primarily a research degree that embodies the results of an original research proposal and represents a significant contribution to scientific literature, the student must submit a manuscript on this research to the AEC.

Chemical Engineering (CHE)

531. *Mathematical Methods in Chemical Engineering.* 3 Hr. PR: MATH 261 and consent. Classification and solution of mathematical problems important in chemical engineering. Treatment and interpretation of engineering data. Analytical methods for ordinary and partial differential equations, including orthogonal functions and integral transforms. Vector calculus. (3 hr. lec.)

565. *Corrosion Engineering.* 3 Hr. PR: CHE 320 or CHEM 341 or equivalent. Basic mechanisms of various types of corrosion such as galvanic corrosion, pitting corrosion, and stress corrosion cracking; methods of corrosion prevention such as cathodic and anodic preventions, by using coatings and inhibitors, and by selecting proper alloys. (3 hr. lec.)

591 A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

610. *Fluidization Engineering.* 3 Hr. PR: Consent. Fundamentals of fluidization, two-phase flow theory and powder characteristics, structure and property of the emulsion phase and bubbles, mass and heat-transfer in fluidized beds with and without chemical reaction. (3 hr. lec.)

611. *Powder Technology.* 3 Hr. PR: Consent. Characterization of powders, structure of powders, powders in two-phase flow, measurement techniques, static and dynamic behavior of powders, grinding and agglomeration, chemistry of powders. (3 hr. lec.)

615. *Transport Phenomena.* 3 Hr. PR: Consent. Introduction to equations of change (heat, mass and momentum transfer) with a differential-balance approach. Use in Newtonian flow, turbulent flow, mass and energy transfer, radiation, convection. Estimation of transport coefficients. (3 hr. lec.)

620. *Thermodynamics.* 3 Hr. PR: Consent. Logical development of thermodynamic principles. These are applied to selected topics including development and application of the phase rule, physical and chemical equilibria in complex systems, and nonideal solutions. Introduction to nonequilibrium thermodynamics. (3 hr. lec.)

625. *Chemical Reaction Engineering.* 3 Hr. PR: Consent. Homogeneous and heterogeneous reaction systems, batch and flow ideal reactors, macro- and micro-mixing, non-ideal reactors, diffusion and reaction in porous catalysts, reactor stability analysis, special topics. (3 hr. lec.)

635. *Process Dynamics and Control.* 3 Hr. PR: Consent. Dynamic response of processes and control instruments. Use of Laplace transforms and frequency-response methods in analysis of control systems. Application of control systems in chemical reactors, distillation, and heat-transfer operations. Introduction to nonlinear systems. (3 hr. lec.)

687. *Materials Engineering.* 3 Hr. A study of materials engineering fundamentals emphasizing semiconductor, polymer, metal, and ceramic/cementitious material systems. Mechanical and physical properties, theoretical aspects, testing, design criteria, manufacturing, and economics of material systems. Laboratory testing and evaluation. (Equivalent to CE 687, EE 687, MINE 687, IMSE 687 and MAE 687.) (3 hr. lec.)

694. *Seminar.* 1-6 Hr. Seminars on current research by visitors and graduate students.

697. *Research.* 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

716. *Advanced Fluid Dynamics.* 3 Hr. PR: Consent. Analysis of flow of fluids and transport of momentum and mechanical energy. Differential equations of fluid flow; potential flow, laminar boundary-layer theory, and non-Newtonian fluids. (3 hr. lec.)

717. *Advanced Heat Transfer.* 2-5 Hr. PR: Consent. Theory of transport of thermal energy in solids and fluids as well as radiative transfer. Steady-state and transient conduction; heat transfer to flowing fluids; evaporation; boiling and condensation; packed- and fluid-bed heat transfer. (3 hr. lec.)

718. *Advanced Mass Transfer.* 2-5 Hr. PR: Consent. Theory of diffusion, interphase mass-transfer theory, turbulent transport, simultaneous mass and heat transfer, mass transfer with chemical reaction, high mass-transfer rates, multicomponent macroscopic balances. (3 hr. lec.)

720. *Applied Statistical and Molecular Thermodynamics.* 3 Hr. PR: CHE 620 and consent. The connection between macroscopic phenomena (thermodynamics) and microscopic phenomena (statistical and quantum mechanics). Thermodynamics modeling for process analysis. Equations of state, perturbation theories, mixing rules, computer simulation, group-contribution models, physical-property prediction. (3 hr. lec.)

726. C*atalysis.* 3 Hr. PR: CHE 625 or consent. Physical and chemical properties of catalytic solids, nature and theories of absorption, thermodynamics of catalysis, theories of mass and energy transport, theoretical and experimental reaction rates, reactor design, and optimization. (3 hr. lec.)

727. *Non-Catalytic Solid-Fluid Reactions.* 3 Hr. PR: CHE 625 or consent. Reaction models, pseudo-steady-state approximation, effectiveness factor, transport and chemical reaction properties, geometric, thermal and transitional instabilities, simultaneous multiple reactions, selectivities in fixed-, moving-, and fluidized-bed reactor design. (3 hr. lec.)

730. *Advanced Numerical Methods.* 3 Hr. PR: CHE 230 or consent. Methods for nonlinear algebraic equations, methods for initial- and boundary-value ordinary differential equations, methods for parabolic,

hyperbolic, and elliptical partial differential equations, numerical stability and methods for stiff equations, optimization techniques. (3 hr. lec.)

731. *Optimization of Chemical Engineering Systems.* 3 Hr. PR: Consent. Optimization in engineering design, unconstrained optimization and differential calculus, equality-constraints optimization, search technique, maximum principles, geometric and dynamic programming, linear and nonlinear programming, calculus of variations. (3 hr. lec.)

761. *Polymer Rheology.* 3 Hr. Qualitative behavior of polymeric liquids; rheometry; stress, strain, and rate of strain tensors; equations of motion; Hookean solids and Newtonian liquids, linear viscoelasticity; constitutive equations for solutions and melts. (3 hr. lec.)

790. *Teaching Practicum.* 1-3 Hr. PR: Consent. Supervised practice in college teaching of chemical engineering. Note: this course is intended to ensure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading may be S/U.)

791. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

792. *Directed Study.* 1-6 Hr. Directed study, reading, and/or research.

793. *Special Topics.* 1-6 Hr. PR: Consent. A study of contemporary topics selected from recent developments in the field.

794. *Seminar.* 1-6 Hr. Seminars arranged for advanced graduate students.

795. *Independent Study.* 1-6 Hr. Faculty-supervised study of topics not available through regular course offerings.

796. *Graduate Seminar.* 1-6 Hr. PR: Consent. It is anticipated that each graduate student will present at least one seminar to the assembled faculty and graduate student body of his/her program.

797. *Research.* 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

798. *Thesis or Dissertation.* 2-4 Hr. PR: Consent. Note: this is an optional course for programs that believe that this level of control and supervision is needed during the writing of their students' reports, thesis, or dissertations. (Grading may be S/U.)

799. *Graduate Colloquium.* 1-6 Hr. PR: Consent. For graduate students not seeking coursework but who wish to meet residence requirements, use the University's facilities, and participate in its academic and cultural programs. Note: graduate students not actively involved in coursework or research are entitled, through enrollment in his/her department's graduate colloquium, to consult with graduate faculty, participate in both formal and informal academic activities sponsored by his/her program, and retain all of the rights and privileges of duly enrolled students. (Grading is S/U; colloquium credit may not be counted against credit requirements for master's programs.)

Department of Civil and Environmental Engineering
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Degrees Offered

Master of Science in Civil Engineering
Master of Science in Engineering with a major in Civil Engineering
Doctor of Philosophy with a major in Civil Engineering

The Department of Civil and Environmental Engineering offers the Master of Science in civil engineering (M.S.C.E.). In conjunction with the College of Engineering and Mineral Resources, the Master of Science in engineering (M.S.E.), and the doctor of philosophy degrees are available with emphases in civil engineering.

Approval for the M.S.C.E. degree is restricted to those holding a baccalaureate degree in civil engineering. Students who possess a baccalaureate degree in a technical area other than civil engineering may receive an M.S.E. degree.

The Department of Civil and Environmental Engineering has a full-time faculty of 18 who are active in teaching, research, and professional commitments.

Areas of Emphasis

There are four major areas of interest of the faculty and graduate studies:

- Environmental and hydrotechnical engineering, which includes occupational health; wetland and natural stream restoration; water, wastewater, and industrial waste treatment; air pollution and site remediation, groundwater hydraulics, hydrology, and fluid mechanics.
- Geotechnical engineering, which includes soil mechanics, foundations engineering, soil-structure interaction, geomechanics, environmental geotechnology, groundwater and seepage, geosynthetics, contaminant transport, landfill design, earthwork design, waste by-product utilization, materials engineering, and construction materials.
- Transportation engineering, which includes planning, design, construction, operations, and maintenance of transportation facilities/systems (roadways, railroads, airports, and public transportation) as well as related areas of infrastructure management and expert systems.
- Structural engineering, which includes advanced structural mechanics, structural dynamics, bridge engineering, building design for static and dynamic loads, advanced materials for civil infrastructure, and nondestructive testing and evaluation.

Faculty

Many of the faculty members are licensed professional engineers registered in one or more states and are involved in state, regional, and national professional organizations, serving on numerous technical committees. They are successful researchers and have published extensively in technical journals. The civil engineering faculty produces graduates who can assume the problem solving, decision making, and technical leadership roles of a professional engineer and who have the sound educational background for the continuing professional development the field requests.

Students tailor their program of study to satisfy their own special interests, with guidance from a faculty advisor. Opportunities abound within the master's and doctoral tracks for a research experience which provides a chance for a student to tackle an engineering problem individually, with guidance from a faculty advisor. The graduate program in civil engineering was established with the aim of developing its students' abilities to use today's contemporary methods of engineering analysis and design to solve tomorrow's engineering problems.

Application

An application package can be obtained from the Graduate Program Director, Department of Civil and Environmental Engineering, West Virginia University, P.O. Box 6103, Morgantown, WV 26506-6103.

Admission

To be eligible for admission into the M.S.C.E. degree program, a candidate must hold or expect to receive a B.S.C.E. degree from either an accredited ABET curriculum or an internationally recognized program. Candidates with superior academic records and a baccalaureate degree in another engineering field, mathematics, or science may be eligible for admission into any of the master's programs offered by the department and may receive an M.S.C.E. or M.S.E. degree (upon completion) and will also normally be required to attain a baccalaureate level of proficiency in certain engineering areas of the department. *An engineering technology (non-calculus based) degree is not sufficient qualification for admission into any of the graduate programs offered by the department.*

To be eligible for admission into the Ph.D. degree program, a candidate must hold or expect to receive an M.S. degree in some discipline of engineering from an institution which has an ABET accredited undergraduate program in engineering or an internationally recognized program in engineering.

The other requirements for admission into the graduate programs of the department are summarized as follows.

- To be admitted as a regular graduate student, an applicant must have a grade point average of 3.0 or better (out of a possible 4.0) in all previous college work and must meet all other requirements below.
- The applicant must first submit to the WVU Office of Admissions and Records a completed application, application fee, and transcripts of all college work completed (directly from the institution).
- Each applicant is required to have three reference letters (using standard forms available from the department) sent directly to the department; at least two of the three references should be from the institution the applicant last attended.
- A minimum score of 550 on the paper-based TOEFL or a 213 on the computer-based TOEFL is required of all applicants from countries where the native language is not English. (Students who have completed a recent four-year bachelor's degree in the USA need not submit these scores.)
- All applicants who have not received their undergraduate degree in the United States are required to submit GRE General Test scores with the Engineering Subject Test score being optional.

Provisional Admission

An applicant, who is not qualified for regular graduate student admission status due either to insufficient grade point average, incomplete credentials, or inadequate academic background, can be admitted as a provisional student. Requirements for attaining regular student status must be stated in the letter of admission. Provisional students must sign a contract, which lists these requirements in detail, no later than their first registration.

Masters of Science Program Outlines

Students must comply with rules and regulations as outlined in the general requirements for graduate work. Each candidate will, with the approval and at the discretion of the Graduate Committee, follow a planned program which must conform to one of the following outlines.

- A minimum of 30 semester credit hours, not more than six of which are in research leading to an acceptable thesis.
- A minimum of 33 semester credit hours, not more than three of which are in research leading to an acceptable problem report.
- A minimum of 36 semester credit hours, with no thesis or problem report required.
  Although rarely permitted, this option is open to students with practical engineering and/or who have demonstrated an ability to organize and develop a project and write a technical report. Approval to pursue this option must be obtained from the student's Advisory and Examining Committee (AEC), the graduate program coordinator, and the department chairperson.

No rigid curricula are prescribed for the degrees of Master of Science in civil engineering and master of science in engineering. Graduate-level work in mathematics, mechanics, or other appropriate areas of science is customary; however, at least 15 semester hours of credit should normally be selected from graduate civil engineering courses.

Thesis

A thesis or problem report is normally required of all candidates. While required credit in research (CE 797) is devoted to the thesis or report preparation, the thesis or problem report is not automatically approved after the required number of semester hours of research work has been completed. The thesis or problem

report must conform with the general WVU requirements for graduate study and with any additional requirements established by the department.

Examinations

A candidate shall be required to pass an examination which may be written or oral or both, to be administered by the student's Advisory and Examining Committee. The examination shall cover course material and the thesis or problem report, depending upon the program followed.

Approval for the M.S.C.E. degree is restricted to those holding a baccalaureate degree in civil engineering. Students who possess a baccalaureate degree in a technical area other than civil engineering may receive an M.S.C.E. or M.S.E. degree.

Master of Science in Engineering

The Master of Science in engineering program is available to students approved for the graduate program who possess a baccalaureate degree in a technical area other than civil engineering. Students entering this graduate program must complete appropriate undergraduate work as specified by departmental regulations. This degree program is administered by the College of Engineering and Mineral Resources; the program may emphasize civil engineering.

Doctor of Philosophy

The doctor of philosophy degree is administered through the college's interdisciplinary program; civil engineering may be the major. A candidate for the degree of doctor of philosophy must comply with the rules and regulations outlined in the general requirements of the College of Engineering and Mineral Resources. The research work for the doctoral dissertation must show a high degree of originality on the part of the student and must constitute an original contribution to the art and science of civil engineering.

Civil Engineering (CE)

511. *Pavement Design.* 3 Hr. PR: CE 451 or Consent. Effects of traffic, soil, environment, and loads on the design and behavior of pavement systems. Design of pavement systems. Consideration of drainage and climate. Pavement performance and performance surveys. (3 hr. lec.)

520. *Groundwater Dynamics.* 3 Hr. PR: Consent. Introduction to groundwater, formulation of equations for saturated and unsaturated flow, analytical solutions for steady and transient cases, transport of pollutants, and numerical techniques. (3 hr. lec.)

522. *Free Surface Hydrodynamics.* 3 Hr. PR: CE 322 or Consent. The dynamics of liquid flow with a free surface under the influence of gravity; open channel hydraulics, wave motion, and buoyancy effects. (3 hr. lec.)

524. Groundwater Engineering. 3 Hr. PR: CE 322 or Consent. Introduction to the nature, hydrology, mechanics, technology, and quality of groundwater. Well solutions in confined, leaky, and unconfined aquifers. Modeling concepts and public-domain computer programs.

528. *Groundwater Contaminant Transport.* 3 Hr. PR: CE 520. Solute and particle transport; aqueous geochemistry; mathematics of mass transport; transformation; retardation, and attenuation of solutes; modeling contaminant transport and remediation. (3 hr. lec.)

531. Pedestrian/Bike Transportation. 3 Hr. Planning, design, operation and maintenance of pedestrian and bicycle facilities, including multi-use trails; in-depth examination of policies, programs and design principles to encourage non-motorized travel.

532. *Airport Planning and Design.* 3 Hr. PR: CE 332 or Consent. Financing, air travel demand modeling, aircraft trends, traffic control, site selection, ground access, noise control, geometric design, pavement design, terminal facilities. (3 hr. lec.)

533. *Geometric Design of Highways.* 3 Hr. PR: Consent. The theory and practice of geometric design of modern highways, horizontal and vertical alignment, cross-slope, design speed, sight distances, interchanges, and intersections. Critical analysis of design specifications. (2 hr. lec., 3 hr. lab.)

534. *Introduction to Traffic Engineering.* 3 Hr. PR: CE 332 or Consent. The purpose, scope, and methods of traffic engineering. Laboratory devoted to conducting simple traffic studies, solving practical problems, and designing traffic facilities. (2 hr. lec., 3 hr. lab.)

535. *Airphoto Interpretation.* 3 Hr. Study of techniques for obtaining qualitative information concerning type and engineering characteristics of surface materials. Use of airphoto interpretation for evaluation of engineering problems encountered in design and location of engineering facilities. (3 hr. lec.)

537. *Public Transportation Engineering.* 3 Hr. PR: Consent. Design of rail and highway models for urban and rural areas. Consideration of vehicle technology, facility and route design, conventional and paratransit services, and related marketing, finance, and coordination issues. (3 hr. lec.)

538. *Highway Safety Engineering.* 3 Hr. PR: CE 431 or Consent. Relationship between human, vehicular, and roadway factors which impact safety; functional requirements of highway safety features; legal aspects; accident analysis; evaluation of highway safety projects. (3 hr. lec.)

539. *Traffic Engineering Operations.* 3 Hr. PR: CE 534. Theory and practice of application of traffic engineering regulations; traffic control concepts for urban street systems and freeways; freeway surveillance and incident management; driver information systems; traffic control system technology and management. (3 hr. lec.)

540. *Environmental Chemistry and Biology.* 3 Hr. PR: CE 322 or Consent. Study of physical and chemical properties of water. Theory and methods of chemical analysis of water, sewage, and industrial wastes. Biological aspects of stream pollution problems. (2 hr. lec., 3 hr. lab.)

546. *Principles of Biological Waste Treatment.* 3 Hr. PR: CE 540 or Consent. Examination of biological treatment systems related to microbiology and function. Models used to describe system behavior and kinetics are developed. Laboratory and field experiments are performed to understand the relation between operation and design. (2 hr. lec., 3 hr. lab.)

547. Applied Wetlands Ecology and Management. 3 Hr. The management and ecology of wetland vegetation, soils, hydrology, and wildlife. (Offered in fall of odd years. Also listed as WMAN 547 and PLSC 547).

549. *Solid and Hazardous Waste Management.* 3 Hr. PR: Consent. Patterns and problems of solid waste storage, transport, and disposal. Examinations of various engineering alternatives with appropriate consideration for air and water pollution control and land reclamation. Analytical approaches to recovery and reuse of materials. (2 hr. lec., 3 hr. lab.)

550. *Soil Properties and Behavior.* 3 Hr. PR: CE 451 or Consent. Soil mineralogy and the physicochemical properties of soils and their application to an understanding of permeability, consolidation, shear strength, and compaction. Prediction of engineering behavior of soils in light of physicochemical concepts. (3 hr. lec.)

551. *Soil Testing.* 3 Hr. PR: CE 351 or Consent. Experimental evaluation of soil properties and behavior. Emphasis is placed on the proper interpretation of experimental results and application of such results to practical problems. (1 hr. lec., 6 hr. lab.)

552. *The Finite Element Method.* 3 Hr. PR: Graduate standing in CE or MAE or Consent. Introductory treatment of theoretical basis of finite element method, mathematical formulation, different types of elements, stress analysis in solids, applications, and computer implementation.

553. *Advanced Finite Element Methods.* 3 Hr. PR: Consent. Formulation procedures and applications of finite element methods to two- and three-dimensional problems, techniques for nonlinear analysis, computer implementation, applications in field problems, flow, and dynamics.

561. *Statically Indeterminate Structures.* 3 Hr. PR: CE 461 or Consent. Force and displacement methods of analysis; energy principles and their application to trusses, frames, and grids; effects of axial forces; influence lines for frames, arches, and trusses; secondary stress analysis. 3 hr. lec.

563. *Introduction to Structural Dynamics.* 3 Hr. PR: CE 561 General theory for dynamic response of systems having one or several degrees of freedom. Emphasis on the application of dynamic response theory to structural design. 3 hr. lec.

564. *Nondestructive Material and Structural Evaluations.* II. 3 Hr. PR: Consent. Nondestructive evaluation (NDE) using techniques based on mechanical and electromagnetic wave propagation; theory and applications of various NDE techniques including infrared thermography, dynamic characterization, seismic reflection and refraction, ultrasonics, acoustic emission, and radar. 3 hr. lec.

566. *Advanced Materials for Infrastructure.* 3 Hr. PR: CE 462 and CE 463. Introduction to principles of material science; material structure, characterization at coupon and component level, practical information on fiber-reinforced shapes; establishment of failure analysis and standardization. 3 hr. lec.

567. *Prestressed Concrete.* 3 Hr. PR: CE 461 and CE 462 or Consent. Behavior and design of prestressed concrete members. Materials, bending, shear, torsion, methods of prestressing, prestress losses, deflections, compression members, composite members, indeterminate structures. 3 hr. lec.

591. A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

593. A-Z. *Special Topics.* 1-6 Hr. PR: Consent. A study of contemporary topics selected from recent developments in the field.

594. A-Z. Seminar. 1-6 Hr. Consent. Seminars arranged for advanced graduate students.

687. *Materials Engineering.* 3 Hr. A study of materials engineering fundamentals emphasizing semiconductor, polymer, metal, and ceramic/cementitious material systems. Mechanical and physical properties, theoretical aspects, testing, design criteria, manufacturing, and economics of material systems. Laboratory testing and evaluation. (Equivalent to CHE 687, EE 687, MINE 687, IMSE 687, and MAE 687.)

697. *Research.* 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

721. *Environmental Fluid Mechanics.* 3 Hr. PR: Consent. Equations of motion including buoyancy and Coriolis force; mechanics of jets and plumes; diffusion, dispersion, and mixing in rivers, lakes, reservoirs, and estuaries. 3 hr. lec.

722. *Deterministic Hydrology.* 3 Hr. PR: Consent. An in-depth treatment of the dynamics of the accumulation of runoff, including the formulation of the unsteady surface flow equations and the unsteady saturated-unsaturated subsurface flow equations. Both analytical and numerical solutions are presented with applications. 3 hr. lec.

723. *Stochastic Hydrology.* 3 Hr. PR: Consent. The use of probabilistic and random processes techniques in the study of hydrologic problems, including multivariate time series and frequency-domain analyses of hydrologic data, and stochastic modeling of multidimensional hydrologic processes. 3 hr. lec.

727. *Wastewater System Conveyance.* 3 Hr. PR: Consent. Water and wastewater flows and measurement, design of water transportation systems, design of gravity-flow sanitary sewers and stormwater drainage systems, pumps and pump systems, and design of pumping stations. 3 hr. lec.

732. *Transportation Systems Analysis.* 3 Hr. PR: Consent. Systematic examination of the interaction between transport technology, activity systems, and traffic flows. Quantitative analysis of the relationship among vehicle cycles, networks, congestion, choice behavior, cost functions, and resulting travel-market equilibration. 3 hr. lec.

740. *Environmental Systems Engineering.* 3 Hr. PR: Consent. Mathematical and computer modeling of environmental systems with emphasis on decision-making; applications will be selected from some or all of the following areas: water quality, water resources planning, solid waste management, waste treatment. 3 hr. lec.

742. *Water Treatment Theory.* 3 Hr. PR: CE 540. Theory of various procedures and techniques utilized in treatment of water for municipal and industrial use. Review of water quality criteria. Design of water purification facilities. 2 hr. lec., 3 hr. lab.

744. *Industrial and Advanced Waste Treatment.* 3 Hr. PR or CONC: CE 540 or consent. Basic physical and chemical unit operations used in industrial and advanced waste treatment; applications for waste water reclamation and reuse; study of industrial wastes from standpoint of process, source, and treatment. 2 hr. lec., 3 hr. lab.

748. *Design of Sanitary Works.* 3 Hr. PR: CE 321. Water supply and waste water disposal problems. Design of treatment facilities. 2 hr. lec., 3 hr. lab.

751. *Advanced Mechanics of Soils.* 3 Hr. PR: CE 351 and CE 551 and MAE 640 or consent. Stress invariants, stress history and stress path, elastic and quasi-elastic models for soils; soil plasticity, failure theories for soils; critical state soil mechanics, and determination of construction parameters. 3 hr. lec.

752. *Advanced Foundation Analysis.* 3 Hr. PR: CE 451 or consent. Study of soil-structure interaction. Applications of principles of soil mechanics and numerical methods for analysis and design of geotechnical structures: strip footings, axially and laterally loaded piles, braced excavations, sheet pile walls, tunnel lining, and buried pipes and culverts. 3 hr. lec.

753. *Advanced Earthwork Design.* 3 Hr. PR: CE 453 or consent. Application of the principles of theoretical soil mechanics to the design of embankments of earth and rock. In-depth study of compaction theory, stability of natural and man-made slopes by limit equilibrium, and deformation considerations. 3 hr. lec.

754. *Groundwater and Seepage.* 3 Hr. PR: Consent. Flow of groundwater through soils and its application to the design of highways and dams and to construction operations. Emphasis is placed on both the analytical and classical flow net techniques for solving seepage problems. 3 hr. lec.

755. *Geotechnical Risk Assessment.* 3 Hr. PR: CE 451 and CE 453 or Consent. Application of probabalistic and statistical principles to geotechnical analysis and design. Random spatial variability of soil properties; decision under uncertainty; reliability of geotechnical structures. 3 hr. lec.

756. *Soil Dynamics.* 3 Hr. PR: CE 550 and Consent. Consideration of the simple damped oscillator, wave propagation in elastic media, dynamic field and laboratory tests, dynamic soil properties, and foundation vibrations. Introduction to geotechnical aspects of earthquake engineering. 3 hr. lec.

757. *Geotechnical Case Histories.* 3 Hr. PR: CE 451 and CE 453 or Consent. Application of the principles of geotechnical engineering to professional practice as taught through the case histories approach. Study of actual problems in geotechnical engineering and their solutions. 3 hr. lec.

760. *Finite Element Methods in Structural Analysis.* 3 Hr. PR: CE 561 or Consent. Relationships of elasticity theory; definitions and basic element operations; direct and variational methods of triangular and rectangular elements related to plane stress, plane strain, and flat plates in bending; varational principles in global analysis. 3 hr. lec.

761. *Bridge Engineering.* 3 Hr. PR: CE 561 or Consent. Statically indeterminate trusses, continuous trusses; steel and concrete arches; long-span and suspension bridges; secondary stresses. 3 hr. lec.

762. *Numerical Analysis of Engineering Systems.* 3 Hr. PR: CE 561 or Consent. Numerical methods for the solution of equilibrium, eigenvalue and propagation problems of discrete and continuous structural systems with special emphasis on weighted residual techniques. 3 hr. lec.

763. *Behavior of Steel Members.* 3 Hr. PR: CE 463 or Consent. Elastic behavior of steel members subjected to axial load, bending, and torsion. Elastic and inelastic response of beams, columns, and beam-columns to load and the resulting design implications. Comparison with standard steel codes and specifications. 3 hr. lec.

764. *Light Gage Metal Design.* 3 Hr. PR: CE 461 and CE 463 or Consent. Analysis and design of light gage material systems; flexural and compression members design; investigations into post buckling strength and optimum weight systems. 3 hr. lec.

765. *Structural Design for Dynamic Loads.* 3 Hr. PR: CE 563 or Consent. Nature of dynamic loading caused by earthquakes and nuclear weapons blasts; nature of dynamic resistance of structural elements and structural systems; criteria for design of blast-resistance and earthquake-resistant structures; simplified and approximate design methods. 3 hr. lec.

766. *Analysis and Design of Multistory Structures.* 3 Hr. (May be repeated once.) PR: CE 563 and CE 462 or CE 463. Introduction; service, structural, and construction systems; analysis and design for lateral and gravity forces; structural modeling; computer applications; approximate methods; connections; foundations; review of standard building codes; special topics. 3 hr. lec.

767. *Behavior of Reinforced Concrete Members.* 3 Hr. PR: CE 462 or Consent. Studies of actual member behavior; members in flexure, combined flexure, shear, and torison; bond and anchorage; combined axial load and flexure; slender columns; deep beams; derivation of current code provisions. 3 hr. lec.

768. Behavior/Design of FRP Members. 3Hr. Studies of Fiber Reinforced Polymer (FRP)composite member behavior including rebars and wraps for concrete, under flexure,axial, shear forces and combined effects; design, durability, and rehabilitation of FRP members and systems including field applications.

790. *Teaching Practicum.* 1-3 Hr. PR: Consent. Supervised practice in college teaching of Civil Engineering. Note: this course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.)

791 A-Z. *Advanced Study.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

792. *Directed Study.* 1-6 Hr. PR: Consent. Directed study, reading, and/or research.

793. *Special Topics.* 1-6 Hr. PR: Consent. A study of contemporary topics selected from recent developments in the field.

794. *Seminar.* 1-6 Hr. PR: Consent. Seminars arranged for advanced graduate students.

795. *Independent study.* 1-6 Hr. PR: Consent. Faculty supervised study of topics not available through regular course offerings.

796. *Graduate Seminar.* 1 Hr. PR: Consent. It is anticipated that each graduate student will present at least one seminar to the assembled faculty and graduate student body of his/her program.

797. *Research.* 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project or a dissertation. (Grading may be S/U.)

798. *Dissertation.* 2-4 Hr. PR: Consent. Note: This is an optional course for programs that believe that this level of control and supervision is needed during the writing of their student's reports, thesis, or dissertations. (Grading may be S/U.)

799. *Graduate Colloquium.* 1-6 Hr. PR: Consent. For graduate students not seeking coursework credit but who wish to meet residence requirements, use the University's facilities, and participate in its academic and cultural programs. Note: graduate students not actively involved in course work or research are entitled, through enrollment in his/her department's graduate colloquium, to consult with graduate faculty, participate in both formal and informal academic activities sponsored by his/her program, and retain all of the rights and privileges of duly enrolled students. (Grading is S/U; colloquium credit may not be counted against credit requirements for master's programs.)

900. *Professional Development.* I, II, S. 1-6 Hr. PR: Consent. Professional Development courses provide skill renewal or enhancement in a professional field or content area (e.g., education, community health, geology). The continuing education courses are graded on a satisfactory or unsatisfactory grading scale and do not apply as graded credit toward a degree program.

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Degrees Offered

Master of Science in Computer Science
Master of Science in Electrical Engineering
Master of Science in Engineering
Master of Science in Software Engineering
Doctor of Philosophy in Computer Engineering
Doctor of Philosophy in Electrical Engineering
Doctor of Philosophy in Computer and Information Sciences

Faculty

The Lane Department of Computer Science and Electrical Engineering, with 30 faculty members offers an excellent graduate program. Faculty members in the department have diverse and extensive expertise in industry, research, and graduate instruction, providing opportunities for students to pursue graduate study in either theory-oriented or application-oriented fields.

Overview of Programs

The Lane Department of Computer Science and Electrical Engineering offers master's programs leading to a master of science in computer science (M.S.C.S.), a master of science in electrical engineering (M.S.E.E.), and a master of science in software engineering (M.S.S.E.). It also participates in the College of Engineering and Mineral Resources interdisciplinary program offering the master of science in engineering (M.S.E.). Master of science students must comply with the rules for master's degrees as set forth by the college in the *Guidelines for Master's Degree Programs Offered in the College of Engineering and Mineral Resources* and by the department in the *Master of Science Program Guidelines.*

The department also offers programs leading to the doctor of philosophy (Ph.D.) in computer and information sciences, and the doctor of philosophy (Ph.D.) with specialization in electrical engineering or computer engineering. Ph.D. in electrical or computer engineering students must comply with the rules set forth by both the college in *The College of Engineering and Mineral Resources Doctor of Philosophy Program Guidelines* and by the department in the *Doctor of Philosophy Program Guidelines.* Ph.D. students in computer and information sciences must comply with the rules set forth in the *Handbook for Computer Science Graduate Students.*

How to Apply

Students can apply for WVU admission online at http://www.wvu.edu (choose *admissions*), or by an e-mail request to the proper graduate coordinator for an application. Do not send applications to the Lane department. Instead, mail to Office of Admissions and Records, P.O. Box 6009, Morgantown, WV 26506-6009.

Information on degree programs and course descriptions can be found at our CSEE web site (http://www.csee.wvu.edu). Send other inquiries to the appropriate graduate coordinator of Computer Science, Electrical and Computer Engineering, or Software Engineering (whichever applies), P.O. Box 6109, Morgantown, WV 26506-6109.

Deadlines for Applications

Application deadlines are as follows:

Fall semester	March 1
Spring semester	October 1
Summer session	January 1

Applicants failing to meet these deadlines have no guarantee of consideration for timely entrance into the program for which they apply.

Admission Requirements for All Programs

All master's and Ph.D. programs require applicants to provide the items below to be considered for admission. Specific programs may have additional requirements. Exception: These requirements do not apply to nontraditional students in the Certificate of Software Engineering program and M.S.S.E. program (see certificate program and M.S.S.E. program for more information):

- A minimum cumulative grade point average of 3.0 or equivalent, based on a 4.0 system.
- Three letters of reference.

Additional Admission Requirements for Specific Programs

M.S., Ph.D. in computer science.

- An undergraduate curriculum which includes computer science courses consistent with a bachelor's degree in computer science. The GRE general test is also required M.S.E.E.
- A bachelor's degree in electrical or computer engineering, and A GRE score on the general test of either the 80th percentile on the quantitative part or 80th percentile total (verbal + quantitative + analytical). M.S.E.
- A bachelor's degree in engineering (other than EE or CPE) or the sciences M.S.S.E. (software engineering).
- See: Certificate in Software Engineering; Master of Science in Software Engineering for requirements.
- Ph.D. with major in CPE or EE.A master's degree in engineering or the sciences and a statement of purpose. A GRE score on the general test of either the 80th percentile on the quantitative part or 80th percentile total (verbal and quantitative and analytical).

Regular, Provisional, and Non-Degree Admission

Students admitted into a program are designated as regular status or provisional. The department also admits students to non-degree status in the College of Engineering and Mineral Resources, but these students are not admitted to any specific program. *Regular status* is given to students who are qualified for unconditional admission to a specific program. *Provisional status* is given to students who have deficiencies to make up such as incomplete credentials or other reasons as identified by the graduate coordinator. In all cases, the student's letter of admission will state what must be done to attain regular status.

Provisional students must complete the requirements for transfer to regular status by the end of the semester in which they complete 18 credit hours. Usually provisional students are not considered for graduate assistantships or tuition waivers.

Non-degree status is granted upon request to students meeting the minimum admission requirements. A non-degree student is one who wishes to take courses without seeking a formal degree. Non-degree students require permission of the instructor to take courses that are restricted to specific majors. There is no guarantee of eventual acceptance into a degree program, and in no case may more than 12 hours be transferred to a degree program.

Non-degree students may not be offered graduate assistantships or tuition wavers.

Master of Science in Computer Science

General Description

The M.S.C.S. program qualifies a student to assume a professional role in industry or government, teach in a junior or senior college, or undertake advanced training toward a doctorate in computer science.

The following sections describe the general procedures to be followed in completing the M.S.C.S. degree. *Note that steps are intended to be carried out in a specific order.* Further details may be found in the *Handbook for Computer Science Graduate Students.*

Admission Requirements

Students, who satisfy the admission requirements for all programs as given above, will be considered for admission. Additional criteria may be considered in making a final decision. All applicants must submit three letters of reference and complete an Applicant Information Form.

Removing Deficiencies

The minimum background expected of any student entering the M.S.C.S. program is coursework equivalent to the following:

- One year of calculus (MATH 155 and 156).
- One course in probability and statistics (STAT 215).
- Knowledge of introductory programming in a high-level programming language (CS 110).

Students not meeting these minimum requirements will be required to take the equivalent coursework before applying to the M.S.C.S. program.

Students entering without a four-year bachelor's degree in computer science may have additional deficiencies in their coursework which must be addressed before beginning the regular M.S.C.S. program. These students will be initially admitted with provisional status, and required to remove these deficiencies during their first 18 hours of coursework.

Possible deficiency areas for students having a bachelor's degree in other disciplines represent the following core areas required of all undergraduate CS students:

- Data structures (CS 111).
- Software engineering (CS 230).
- Discrete mathematics (CS 220).
- Analysis of algorithms (CS 221).
- Computer System Concepts (CS 350).
- Theory of programming languages (CS 310).

As demand justifies and resources permit, the department will offer accelerated courses to assist graduate students in satisfying deficiencies.

Program Requirements

Students may choose the *thesis option* or the *problem report option.* The thesis option requires 30 credit hours: 24 hours of formal coursework and six hours of research. At most nine hours of 400-level undergraduate coursework may be included. This option requires writing a thesis that represents research suitable for publication in a refereed journal. All theses are submitted to the University's Electronic Thesis and Dissertation program.

The problem report option requires 33 credit hours: 30 hours of formal coursework and three hours of research. Again, at most nine hours of 400-level undergraduate coursework may be included. The problem report option requires writing an acceptable report describing a research project carried out by the student.

Regardless of the option chosen, students must take at least one graduate course in each of three areas: theory, systems, and applications. The following courses may be used to meet this requirement:

- Theory: CS 510, 520, or 525.
- Systems: CS 550 or 555.
- Applications: Any other CS graduate course.

The department or the student's Graduate Committee may designate additional courses, including doctoral-level courses that may meet these requirements.

Graduate Committee

Before the end of the second semester as a regular master's student, each student must form a Graduate Committee of at least three members. The chair of this committee must have regular graduate faculty status. For a committee overseeing a thesis, the majority of the members must also have regular graduate faculty status.

The role of this committee is to guide the student both in selection of courses and in research. At the time the committee is formed, the student submits for approval a preliminary plan of study listing the courses that have been taken or will be taken. The choice of thesis or problem report option should also be indicated on the plan of study, along with a tentative title for the thesis or problem report.

Research and Final Defense

After formation of the Graduate Committee and approval of the preliminary plan of study, the student may register for research using course number CS 697. Research may begin at the same time that the coursework is being completed. However, students should normally plan on the equivalent of one semester of full-time effort to complete a problem report, or two semesters to complete a thesis.

All master's students must defend their thesis or problem report at an oral exam, attended by all members of the committee. The exam consists of two parts. The first part is a period of oral questioning on the student's coursework. This questioning is intended to ensure that the student has learned the general concepts of the courses he or she has taken. The coursework part must be completed satisfactorily before the research defense can take place. A student who fails the coursework part may have one additional attempt during the same semester.

The second part is presentation of the research and a defense of this research by answering questions from the committee. This defense may occur directly after the coursework questions or at a later time. It cannot be held until the coursework questions are answered satisfactorily.

A student who fails the research defense may repeat the defense at most once, at a time determined by the Graduate Committee but not necessarily during the same semester.

Program Length

Normally a student who has attained regular master's status should expect to spend two to three semesters plus an additional semester or summer session to complete the M.S.C.S. degree.

Master of Science in Electrical Engineering (M.S.E.E.)

Program Requirements for M.S.E.E.

There are three options available for students to gain a master's degree: coursework only thesis option, or problem report option.

Students following the *coursework option* must take 33 credit hours of formal coursework plus two hours of graduate seminar. This option is open only to professionals employed full-time in local industry. At most nine hours of 400-level coursework may count.

Students following the *problem report option* must take 35 credit hours: 30 hours of formal coursework, three hours of research, and two hours of graduate seminar. At most nine hours of 400-level undergraduate coursework may count.

Students following the *thesis option* must take 32 credit hours: 24 hours of formal coursework, six hours of research, and two hours of graduate seminar. At most nine hours of 400-level undergraduate coursework may count. Students supported by research assistantships are expected to pursue this option.

Students pursuing either the thesis or problem report option leading to the M.S. degree must have the thesis or problem report approved by the student's advisory and examining committee (AEC) before it can be accepted. The student must also pass a final oral examination and defense of the thesis or problem report administered by the AEC.

Those students who lack course prerequisites may require more than three semesters of full-time study to complete the degree. Students with research assistantships may also require more than three semesters to complete the degree.

Master of Science in Engineering Program (M.S.E.)

The master of science in engineering program is available to students who are interested in graduate work in electrical or computer engineering but hold a baccalaureate degree from another field of engineering or from another discipline. Students with a baccalaureate degree from another field of engineering or from one of the sciences should contact the department for further information. In general, a student in the M.S.E. program will be expected either to complete certain undergraduate prerequisite courses or to attain equivalent competence, but may not be required to complete all of the requirements equivalent to the B.S.E.E. or B.S.CPE. degree. However, all graduate students will be required to meet the prerequisites for each course taken for credit.

Software Engineering

The department offers a Certificate in Software Engineering program and a master of science in software engineering. For some students, completion of the certificate is the first step towards earning an M.S.S.E.

Certificate in Software Engineering

The certificate in software engineering program provides further education to individuals who are currently working in the computer and information technology industry. This program is usually offered at evening times and off-campus locations convenient for the working professional.

Admission Requirements

Applicants for the certificate in software engineering must meet the following requirements:

- Hold a bachelor's degree in any field from an accredited University.
- Submit a resume documenting at least three years of software development experience.
- Provide names and addresses of three references who are familiar with the applicant's work.

Program Requirements

The certificate program consists of completing five approved courses and the certificate final exam paper. Students who achieve a B or higher in each of the first four courses of the certificate program will qualify to enter the master of science in software engineering program, described below. Courses taken for the certificate program earn credit towards the master's degree.

Master of Science in Electrical Engineering with Emphasis in Biometrics and Information Assurance

An applicant with a baccalaureate degree or its equivalent from a program accredited by the Accreditation Board for Engineering and Technology (ABET), or an internationally recognized program in engineering will be admitted on the same basis as engineering graduates of WVU. Lacking these qualifications, an applicant must first fulfill any special requirements of the department in which the student is seeking an advanced degree.

All master's programs require applicants to satisfy the three items below in consideration for admission. Specific programs may have additional requirements.

- A GRE score on the general test of either the 80th percentile on the quantative part of 80th percentile total (verbal, quantitative, and analytical).
- A minimum cumulative grade point average of 3.0 or equivalent, based on 4.0 system. Three letters of reference.
- Familiarity with the basic concepts of Information Assurance and Biometrics.

Admission as a graduate student is required of all applicants for admission to a program of student and research. Applicants for admission must hold or expect to receive a bachelor's degree in engineering or computer science from an accredited or an internationally recognized program in engineering or computer science.

Regular, Provisional, and Non-Degree Admission

Students admitted into a program are designated as regular, provisional, or non-degree status. Regular status is given to students who are granted unconditional admissions. Provisional status is given to students who have deficiencies to make up such as incomplete credentials or other reasons as identified by the graduate coordinator. In all cases, the student's letter of admission will state what must be done to attain regular status, and students must sign and date this letter no later than the first registration. Non-degree status is granted case-by-case by the graduate coordinator. Basically, a non-degree student is one who may take courses, but sometimes with no plan of study or any guarantee for attaining provisional status.

Master Options

Three options are available to EE masters students for degree completion:

Thesis Option Total hours: 32. Eight three-credit courses, at least two hours of graduate seminar, plus 6 credits of research leading to successful thesis defense.

Problem Report Total hours: 35. Ten three-credit courses, at least two hours of graduate seminar, plus three credits of research/independent study leading to successful problem report completion.

Course Work Option Total hours: 35. Eleven three-credit courses and at least two hours of graduate seminar

Master of Science in Software Engineering (M.S.S.E.)

The M.S.S.E. degree provides graduate-level software engineering expertise to individuals who are either currently working in the computer and information technology industry or have academic credentials that provide a foundation to begin graduate work in software engineering. The M.S.S.E. program aspires to serve both adult learners from the local computer and information technology industry, and traditional, resident full-time graduate students. This program is usually offered at evening times and off-campus locations convenient for the working professional. It may also be available by distance learning methods.

Admission Requirements

Students seeking admission to the M.S.S.E. program must fall into one of three categories to be considered for admission. The categories are:

CS, CPE, or software engineering students- Students who have recently completed a bachelor's degree in computer science, computer engineering, or software engineering will be considered for admission with regular status if they satisfy requirements listed previously under Admission Requirements for All Programs.

Students from other disciplines Students who have recently completed a bachelor's degree in a field other than Computer Science, Computer Engineering, or software engineering will be considered for admission with regular status if they meet the following requirements:

- A minimum GPA of 3.0 (on a 4.0 scale), or equivalent.
- A minimum GPA of 3.0 for coursework in the major.
- A GRE score on the general test of either 80th percentile on the quantitative part or a total of 1800 (verbal + quantitative + analytical).
- A GRE score on the computer science subject test of 40th percentile or higher.

Nontraditional students - Students who have at least three years of software-development work experience in the high-technology industry are waived of all GRE and GPA requirements. Instead, they will be considered for admission with non-degree status by meeting the following requirements:

- Hold a bachelor's degree in any field from an accredited University.
- Submit a resume documenting at least three years of software development experience.
- Provide names and addresses of three references who are familiar with the applicant's work.

Nontraditional students may enroll in courses in the M.S.S.E. program, and must earn a grade of at least B in each of the first four courses. Upon meeting this requirement, students will be transferred from non-degree status to regular status for the M.S.S.E. program.

M.S.S.E. Program Requirements

Students pursuing an M.S.S.E. degree may elect a coursework only option, a problem report option, or a thesis option. The coursework option and the problem report option require completion of a total of 33 graduate credit hours: 33 hours of formal coursework, or 30 hours of formal coursework and three hours of research (SENG 697). The thesis option requires a total of 30 credit hours: 24 hours of formal coursework and six hours of research.

Doctor of Philosophy in Computer Engineering
Doctor of Philosophy in Electrical Engineering
Description

The doctor of philosophy program should be considered by those with superior academic achievement and who desire to pursue a career of research or teaching. Students interested in the Ph.D. program in electrical engineering or computer engineering should see our web page at http://www.csee.wvu.edu for information. If additional information is needed, contact the graduate coordinator of Electrical and Computer Engineering.

Admission

As a first step, students must satisfy provisions under the "Admission Requirements for All Programs" and must submit a statement of purpose.

Students who hold an M.S.E.E. or M.S.E. (or equivalent) degree will be considered for admission with regular status into the Ph.D. program. Students, who hold a master's degree in the sciences or engineering, excluding M.S.E.E. or M.S.E., will be considered for admission with provisional status and will likely have coursework deficiencies to remove. All other students must apply for admission into a master's program as the first stage in attaining the Ph.D.

Removing Deficiencies for Ph.D. in CPE or EE

Prior to the first week of classes, new Ph.D. students must meet with the graduate coordinator to select classes. This interview determines if the student needs remedial work in order to pursue a graduate degree.

Students with deficiencies may be required to take courses as prerequisites for graduate courses. Deficiencies are usually noted as a condition for admission. However, they may also be specified during the interview or later.

During the second semester, students must form their Advisory and Examining Committee (AEC) and write a plan of study. The AEC may also identify additional deficiencies to be removed, but this is rare since deficiencies should have been identified earlier in the student's career.

Program Requirements

Coursework

Students must complete at least 18 hours of formal coursework at the 600 and 700 level at WVU, beyond that required of the master's degree. Students with the help of their AEC select courses that will develop expertise in the student's area of interest, and that will strengthen knowledge of other areas supportive of research endeavors.

Examinations

Ph.D. students must pass a written qualifying examination, normally within one year of their first enrollment in the Ph.D. program. The student must also pass a written and oral candidacy examination given by the AEC, and must successfully defend in oral examination a written research proposal.

When all requirements are completed, the qualifying and candidacy examinations are passed, and the research proposal is successfully defended, the student is formally admitted to candidacy for the Ph.D. degree. For full-time students, admission to candidacy must occur within three years of entering the Ph.D. program.

After the student completes the research (at least 24 credit hours) and prepares a dissertation, the final examination consists of a public defense of the dissertation. All requirements for the degree must be completed within five years after the student has been admitted to candidacy.

Research

Research work for the doctoral dissertation must represent a significant contribution to engineering. It may entail a fundamental investigation into a specialized area or a broad and comprehensive system analysis or design. A minimum of 24 credit hours of research (CPE 797 or EE 797) is required.

Program Length

A typical Ph.D. program requires four to five years beyond the baccalaureate degree, although scholarly achievements are more important than length of program.

Doctor of Philosophy in Computer and Information Sciences

General Description

The doctor of philosophy is a research degree rather than a coursework degree. Doctoral students are required to complete a number of advanced courses, but more time is spent in original research in close association with an experienced researcher. The Ph.D. program in computer and information sciences (CIS) prepares a student for a teaching and research career in computer science or related information sciences, in industry, government, or advanced educational institutions.

An area of emphasis in combinatorial computing and discrete mathematics (CCDM) is offered within the CIS Ph.D. program. The CCDM Ph.D. program offers students the opportunity to pursue multidisciplinary studies across theoretical computer science, discrete mathematics, and statistics. Applicants are expected to satisfy the "Admission Requirements for All Programs" as given previously. In addition, for regular admission, applicants must satisfy certain CCDM specific prerequisites, and hold a master's degree in computer science, statistics, mathematics, a closely related field, or have completed equivalent graduate coursework. An applicant that does not meet all of these requirements may be admitted provisionally. Note that a CCDM Ph.D. student is not required to have or obtain the equivalent of a bachelor's or master's degree in computer science. The CCDM Entrance Exam replaces the CIS Ph.D. Qualifying Exam. Coursework requirements differ from those of the CIS Ph.D. program, but are not in conflict with any CIS Ph.D. requirements. Details for

the CCDM Ph.D. program can be found in the *Handbook of CCDM Ph.D. Program for Computer Science Graduate Students.*

The following sections describe the general procedures to be followed in completing the regular CIS Ph.D. degree. *Note that the steps are intended to be carried out in a specific order.* Further details can be found in the *Handbook for Computer Science Graduate Students.*

Admission Requirements

Students who satisfy the "Admission Requirements for All Programs" as given previously, and who have at least a bachelor's degree in computer science or a science, engineering, or mathematics discipline will be considered for admission. All applicants must submit three letters of reference and a statement of purpose, which briefly explains their objectives in seeking the degree.

Removing Deficiencies

Normally, students who do not have at least the equivalent of a bachelor's degree in computer science will be admitted initially as provisional master's students. Their first requirement will be to complete all necessary preparatory work by taking the courses as described for the M.S.C.S. degree. After meeting this requirement, these students may apply for the doctoral program.

In exceptional cases a student lacking some elements of the required background may be admitted directly as a provisional doctoral student. Students in this category must complete the needed preparatory work as described above during their first two semesters.

Preliminary Coursework

Doctoral students who do not have an M.S.C.S. degree must either earn this degree, or as a minimum, complete coursework as required for the M.S.C.S. with thesis option. It is not necessary to actually write a thesis. A minimum of 24 hours of coursework is required. Up to 12 hours may be transferred from work done at another institution.

Graduate Committee

During the second semester as a regular doctoral student, students must form their Graduate Committee and prepare a plan of study. Students planning to first complete an M.S.C.S. degree must be admitted as an M.S.C.S. student an form a Master's Committee consisting of three or more members, and follow the requirements for the M.S.C.S. as discussed above. In all other cases, or when the M.S.C.S. degree has been completed, students should form a Doctoral Committee of at least five members in consultation with the graduate coordinator. This committee must conform to all University and college requirements set forth in other sections of this catalog.

Qualifying Examinations

Within three years of admission to the doctoral degree program, applicants must take and pass a set of departmental *qualifying examinations,* demonstrating a breadth of knowledge in computer science. Information on the content of these examinations is made available by the department. The content is not necessarily limited to specific courses the student has taken.

A student may receive one of two grades on each exam: pass or fail. Students are permitted three sittings to pass the exams, but need not retake exams on which they previously received a passing grade. The student must pass all three qualifying examinations in three consecutive semesters. A Ph.D. student who does not receive a pass on these examinations after three attempts may transfer all credits earned in the doctoral program toward acquiring a master's degree.

Regular Coursework

Students who have *successfully passed the qualifying examinations,* must then take, additionally, 18 hours of advanced graduate coursework at the doctoral level. Courses used to fulfill this requirement are selected in consultation with the Doctoral Committee. Up to six of these hours may be in directed study (CS 792). All other hours must be in regular courses.

Comprehensive Examinations

After completing all regular coursework, a doctoral student will be permitted to stand for the *comprehensive examinations.* These examinations are prepared for each student by the student's Doctoral

Committee. The examinations are intended to assess the student's knowledge in areas closely related to his or her intended research area. The committee will determine the content and format of these examinations and the manner in which they will be administered.

Upon successful completion of the comprehensive examinations, the student is *formally admitted as a candidate* for the Ph.D. degree in CIS.

Research Prospectus

After completion of the comprehensive examinations, the doctoral student will present a research prospectus to his or her Graduate Committee, outlining the original research that the student proposes to perform. The prospectus will consist of a statement of the research problem, a review of the pertinent scientific literature in the area, and a description of the methods that will be employed in an attempt to solve the research problem. After the committee has questioned the student on the prospectus and approved it (with any required modifications) as the doctoral research topic, the student will be permitted to register for doctoral research.

Research and Dissertation

After approval of the research prospectus, the student carries out the dissertation research under the supervision of the Doctoral Committee. Each doctoral student must register for a total of 18 hours of dissertation research using course number CS 797. Preliminary research may be carried out before the research prospectus is approved, but not before the Doctoral Committee is formed. Normally the research requirement is fulfilled by registration for nine hours or more in two consecutive semesters of residence, which also meets University residency requirements.

Research for the CIS Ph.D. degree must represent an interesting and original contribution to the field of computer science. The results of the research must be of a quality suitable for publication in an archival journal. The student must demonstrate a good knowledge of the literature related to the research topic and the relation of his or her own work to other work that has been reported. The dissertation must provide satisfactory theoretical or experimental evidence to demonstrate the soundness of the results presented.

The results of the research are reported in a dissertation, which is presented to the Doctoral Committee and formally defended in a public meeting. When the committee determines that the candidate has successfully completed and presented the research as outlined in the prospectus, the student will be certified for graduation.

Program Length

Scholarly achievements are more important than length of program, but a typical Ph.D. program requires at least two years after all master's-level requirements have been completed. In many cases substantially more time is required.

After admission to candidacy, students must register for at least one credit hour during each semester. All requirements must be completed within five years of admission to candidacy.

Facilities and Centers for All Programs

The Lane Department of CSEE has its main office, instructional lab, and research lab space on the Evansdale campus occupying four floors of the Engineering Sciences Building and one floor of the Engineering Research Building. The department has facilities also located in Eiesland and Armstrong Halls on the downtown campus.

The department has research activities and facilities at the NASA IV&V Center and the Alan B. Mollohan Innovation Center of the West Virginia High-Tech Consortium Foundation in Fairmont, WV. Our research facilities constitute a rich and diverse resource which spans the needs of research and graduate education in computer science, computer engineering, and electrical engineering. Laboratories and centers include the Software Research Laboratory (SRL), the Reusable Software Research Group, the Institute of Combinatorial Computing and Discrete Mathematics (jointly with the Department of Mathematics), the Lab for Advanced Information and Computation Systems (LAICS), the ElectroMechanical Systems Lab (EMSL), the Power Control Systems Lab, and the Virtual Environments Lab. The Microelectronic Systems Research Center (MSRC) is part of the department and is affiliated with the LAICS. MSRC facilities include a micro system fabrication lab, photonic systems lab, systems prototyping lab with CAE/CAD tool suites and workstation cluster, electronic systems test (device through systems), surface-mount multilayer PCB fab, and a system

test bed development facility. Department faculty serve as the primary leadership and technical staff for the Concurrent Engineering Research Center (CERC).

Computing Facilities

All graduate students have access to a broad variety of computing platforms for both classwork and research. The department operates and maintains a variety of dedicated computer systems, clusters, and networks supporting both the instructional and research activities of the department. These systems include numerous Windows workstations and a clusters of Linux Servers. An additional laboratory by Hewlett-Packard supports large databases and medical informatics. Students have access to a rich set of software packages and tool suites available either on department systems or the College of Engineering and Mineral Resources Systems. All department, college, and University computing resources are fully networked via ethernet and FDDI with a campus-wide ATM backbone enabling interface to the statewide ATM network. All computing systems have Internet access enabling worldwide connectivity and access to several additional computing services via the Pittsburgh Supercomputing Center. The University is also a member of Internet2, vBNS, and SURANET, of which faculty in the department are active participants.

Areas of Research: Overview

The department is enthusiastically and vigorously involved in research, technical publication, and graduate instruction at the forefront of the field. The areas of emphasis are:

- Theory of computation, including foundations, complexity, algorithm analysis, parallelism, and graph theory.
- Computer systems, including microprocessor applications, advanced computer architecture, neural networks, fuzzy logic, parallel processing, VLSI testing techniques, fault tolerant design, software metrics, and software engineering.
- Control systems, including classical and modern control theory and applications.
- Communications and signal processing, including computer networks and image processing systems.
- Bioengineering and biometric systems including biosignal processing, bioinstrumentation, telemedicine, biometric devices, and algorithms.
- Electric power systems and power electronics, including stability and control, transients, and steady state analysis, real time control, protection, electric machines, drives, advanced motion controllers, and electric and hybrid electric vehicles.
- Electronic and photonic systems, including integrated electronic, optoelectronic, and optical devices and circuits, microelectromechanical systems (MEMS), and micro/nanofabrication.
- Software engineering, including reuse and portability, verification and validation, language issues, and user interface issues.

Areas of Research: Specifics

Theory of Computation

Research in the theory of computation covers a variety of areas ranging from foundations of computer science to algorithm design and analysis. A core of faculty performs research in areas such as discrete mathematics (including graph theory and combinatorics) and combinatorial optimization, partly in connection with the Combinatorial Computing and Discrete Mathematics Institute. Another key area of interest are analysis for parallel and distributed systems and problems in bioinformatics. The department offers core graduate courses in design and analysis of algorithms and computational complexity theory. Upper-division graduate courses cover topics such as graph algorithms, information dissemination, approximation and randomized algorithms, linear programming, and combitionatorial optimization.

Computer Systems Engineering

Computer engineering is a very broad area, covering hardware, firmware, and software engineering of complex digital systems and system components. Software and hardware systems design is the most technically intensive components of the electrical and computer engineering curriculum. A broad spectrum of research topics of both applied and theoretical nature are undertaken in the department. Some examples are: software verification and validation, software process improvement, software development environments for signal processing applications, parallel processing of fingerprint image comparison systems, fast adaptive routing algorithms for processor arrays, communication switching systems, information systems, computational accelerator using digital signal processing arrays, an automated lumber processing system,

neural network medical and industrial applications, autonomous robots, computer-controlled electric and hybrid vehicle instrumentation, a distributed microprocessor monitoring system, knowledge-based decision support system, and microprocessor-based instrumentation. A large selection of hardware and software graduate courses is offered in the department. These cover topics such as switching theory, digital communication systems, VLSI design and testing, fault-tolerant computing, computer architecture, neural networks, applied fuzzy logic, real-time software design and development, and C++ object-oriented programming. In addition, the electrical engineering and computer engineering faculty collaborate very closely with the computer science faculty. Graduate students in the computer engineering area are encouraged to include courses from computer science in their program. The department offers dedicated laboratories equipped with personal computers and workstations to support classroom instruction and research. A number of computer engineering faculty have close cooperation with several interdisciplinary research centers at WVU such as the Concurrent Engineering Research Center, the Alternate Fuels Research Center, and the Constructed Facilities Research Center.

Control Systems

The control systems area is an important part of the research program in electrical engineering. The topic has great breadth in applications ranging from electrical power systems and electrical machines to electrically energized transportation systems. (Applications of control theory in power are described in the electric power systems program description as well as in this control program description). As a research area, control systems may be characterized as both modeling and control of complex systems of both deterministic and stochastic type. The department offers courses that provide the required background to prepare students for the design and analysis of control systems. Control theory, particularly as applied to large-scale systems, is a topic emphasized in the department's research program. Current research is focused on the application of control to large dynamic systems, especially power systems, electrical machines, and maglev transportation systems. The work is primarily on algorithm development. In recent years, external funding for control systems research has come from the National Science Foundation, the Departments of Energy and Defense, and electric utilities. Four faculty members in the Department of Computer Science and Electrical Engineering have significant research activities in control systems. Other faculty members in mathematics and mechanical engineering also collaborate in the exciting on-going work at West Virginia University in the control area.

Communications and Signal Processing

Communications and signal processing are two closely interrelated fields that play an important role in today's information driven economy. Both fields involve the application of mathematics to the analysis and design of systems that convey and process analog and/or digital signals.

Communications research in the Lane Department of Computer Science and Electrical Engineering focuses on techniques to improve the performance of a wide variety of communication systems. The Wireless Communications Research Laboratory (WCRL) develops and analyzes protocols, error control mechanisms, and signal processing algorithms that enable low energy and/or high data rate transmissions in a cellular or wireless networking environment. Such technologies play a prominent role in third- and fourth- generation cellular networks and in wireless local area and personal area networking standards. A wireless testbed, consisting of low-power wireless transceivers and digital signal processing boards, allows researchers to test prospective protocols and algorithms in an actual wireless environment. The YAS Broadband Center of Excellence supports the broadband industry by performing research related to cable modem, digital subscriber loop (DSL), and fiber optic technologies. The focus of the department's broadband initiative is the development of signaling technology and network infrastructures capable of seamlessly conveying voice, video, and data with Quality of Service guarantees. In addition to the department's broadband and wireless activities, it conducts research involving the compression, storage, and retrieval of multimedia information, and the design and fabrication of RF transceivers.

Bioengineering and Biometric Systems

A majority of the signal and image processing research in the department is centered in the bioengineering and biometrics areas. Bioengineering is the multidisciplinary application of engineering to medicine and biology. Biometrics uses biological signatures (fingerprint, voice, face, DNA) for identification or authentication in criminal justice, e-commerce, and medical applications. Specific departmental projects in these areas include multimedial biometric system design and performance measures, analysis of temporal fingerprint images for determination of vitality, neural network, and genetic algorithms for matching of

fingerprint and dental images, multimedia information systems (images, video, and audio), distributed multimedia systems, and multimedia data storage and compression. Sponsors for this work include the Department of Defense, the National Science Foundation, and the Department of Homeland Security. Research entities in the department include the Center for Identification Technology. A NSF Industry/University Cooperative Research Center, the Biomedical Signal Analysis Laboratory, and the Software Architectures and High Performance Computer Research Lab.

Electric Power Systems

Electrical power systems historically have been an area of emphasis in the electrical engineering curriculum, and the graduate program in power systems at WVU is quite mature. Four faculty members have interest in electric power, and the department has an endowed position for electric power systems. Graduate courses are offered regularly in power system stability and control, real-time control of power systems, computer applications in power system analysis, advanced electric machines, and HVDC systems. In addition, there are three senior elective/graduate courses on the subjects of distribution, power electronics, and power systems analysis. The power group works closely with the control area that offers graduate courses in linear and nonlinear control systems, optimal control, and digital control. Recent and current research activities include control of power systems in a deregulated environment, energy balancing in a restructured market environment, modeling, controlling, and dispatching distributed resources, electric transportation, modeling, stability analysis, optimal design, design of modulation controllers for multiterminal ac/dc power systems, electric drives, electric machines, advanced motion control systems, and power electronics. Externally funded projects include robust design of modulation controllers for flexible ac/dc transmission lines, optimal design of permanent magnet brushless machines, spacecraft power storage controllers, investigation of voltage/current characteristics of MOS-controlled thyristors with static and dynamic loads, and identification and decentralized control of critical modes. These projects provide excellent support for both graduate student and faculty research. Extensive interaction with industry provides ample opportunity for direct contact with practitioners in the field. The department has enjoyed continuous support from local utilities.

Electronics and Photonics

The field of electronics and photonics—initially microelectronics and now pushing well into nano-electronics—is at a crossroads where further developments are forcing researchers to take a closer look at quantum mechanical processes to design and fabricate small dimensional devices. Students who chose to take the electronics area at WVU should obtain a deeper understanding of the physical basis for the design and fabrication of micro- and nano-electronic and photonic devices.

The suggested coursework draws upon the expertise of the WVU faculty in electrical engineering, physics, and chemical engineering—demonstrating the interdisciplinary characteristic of this field. These faculty have joined to form the Photonics and Microelectronics Working Group (http://msrc.wvu.edu/pmt/). The research areas that these faculty are involved in cover aspects of materials science, physics, and semi-conductor electronics to design, grow, fabricate, and characterize novel electronic and photonic devices and small subsystems. Thus, the strength of the faculty is in experimental semiconductor physics and electronics. Present areas of research include wide bandgap semiconductor growth and fabrication techniques, device design, and materials and device characterization; integration of photonics in microelectromechanical devices (MEMs) for active control and feedback; near-infrared and mid-infrared photonic materials and devices; nano-electronic materials growth and device design; and the small-scale integration of photonic and electronic devices for sensing applications.

The Center for Identification Technology Research (CITeR), (www.citer.wvu.edu) was recently established to coordinate the research in this area at WVU and three other universities and several industrial and governmental partners. Thus, students are encouraged to take courses outside of the more standard electrical engineering coursework, in information technology and biotechnology, so that they can effectively participate in these multidisciplinary research programs.

Much of the research in photonics and micro/nano-electronics is supported by the laboratory facilities of the Photonics and Microelectronics Working group in the Lane Department. The facilities include a micro/nanofabrication laboratory, a photonics laboratory, a CAD/CAE facility with workstations/PCs and commercial/academic software tools, and an electronic and photonics test facility (device through small scale systems testing). Students also have access to a number of other facilities across the University to support

specific research projects—in physics, chemistry, chemical engineering, and the Health Sciences Center as examples.

Software Engineering

Software engineering covers a well-defined and integrated set of activities to produce correct, consistent software products effectively and efficiently. Faculty perform research in many areas some of which include component-based development, validation and verification, software reuse, software portability, user interfaces, and graphic visualization. Research associations exist with the NASA Independent Verification and Validation Facility, the Institute for Software Research at the West Virginia High-Tech Consortium, and the Concurrent Engineering Research Center.

Computer Engineering (CPE)

520. *Application of Neural Networks.* 3 Hr. PR: Consent. Theories, principles, techniques, and procedures used in design implementation of supervised and unsupervised Neural Networks. Algorithms and computer programming for software realization with engineering applications.

521. *Applied Fuzzy Logic.* 3 Hr. PR: Consent. Theory and applications of Fuzzy Logic, Fuzzy Fundamentals, Fuzzy Rules, decision-making systems, control systems, pattern recognition systems, and advanced topics. Algorithms and computer programming for software realization with engineering applications.

536 Computer Data Forensics. 3 Hr. PR: CPE 435 CPE 310 or Consent. Provides students with a comprehensive overview of collecting, investigating, preserving, and presenting evidence of cybercrime; introduces topics of forensic data examination of computers and other digital storage devices.

538. Intro Computer Security Management. 3 Hr. Develops management tools to build and maintain a secure enterprise. Includes policies, procedures and the various management and auditing processes that are needed in a networked enterprise.

560. *Introduction to Information Systems.* 3 Hr. PR: CPE 310. This course will provide the student with background in the principles and practice of digital communications, beginning with early digital voice systems and extending through current systems based on “information” communications, including voice, data, and video.

568. Computer Network Forensics. 3 Hr. PR: CS 450 and CS 453 or Consent. Introduction to threat assessment in modern networked computer systems. techniques, methodologies and technologies for preventing, detecting, recovering from, and collecting evidence of intrusions, with the intent of prosecuting the offending parties.

572. *Advanced Computer Architecture.* 3 Hr. PR: CPE 271 and CPE 310, CPE 311 or Consent. Formal tools for designing large digital systems are introduced; formal descriptive algebras such as ISP, PMS, AHPL, CDL, and others. An in-depth study of computer systems designs including instruction design and data path design. (3 hr. lec.)

643. *Fault Tolerant Computing.* 3 Hr. PR: CPE 310 or Consent. Introduction to reliability analysis and Markov modeling. Computer system reliability modeling. Fault-tolerant design of computer systems. Reconfiguration strategies in VLSI and WSI arrays.

651. *VLSI System Design.* 3 Hr. Introduction to hardware modeling languages. CAD tools for logic synthesis and simulation. Design methodology. Rapid prototyping using field programmable gate arrays. IC chip design.

660. *Advanced Information Systems.* 3 Hr. This course will provide students with a background in the principles practice, and research directions of the hardware/software architecture of digital communications systems and networks. Topics include basic principles and development of digital communication system; communication standards and protocols; transmission fundamentals; network access protocols; local area and wide area networks, SONET, ATM, and Gigabit networks.

670. *Switching Circuit Theory 1.* 3 Hr. PR: CPE 271 or equivalent. Course presumes an understanding of the elements of Boolean or switching algebra. Study of both combinational and sequential switching circuits with emphasis on sequential networks. Advanced manual design and computer-aided design techniques for single and multiple output combinational circuits. Analysis and design of sequential circuits. Detection and prevention of undesired transient outputs. (3 hr. lec.)

673. *Design of Computer Arithmetic Circuits.* 3 Hr. PR: CPE 271 or equivalent. Study of logic networks usable in performing binary arithmetic. Emphasis is on design of high-speed, parallel arithmetic units using binary numbers. Consideration of systems for representation of negative numbers. Available arithmetic subsystems are studied. (3 hr. lec.)

684. *Advanced Real-Time Systems.* 3 Hr. PR: CS 415 and CPE 484 or consent. Project-based course focused on analysis and design of real-time systems using the Unified Modeling language. Object-oriented development process based on design patterns and frameworks is described.

691 A-Z. *Advanced Topics.* I, II, S. 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

695. *Independent Study.* I, II, S. 1-6 Hr. PR: Consent. Faculty supervised study of topics not available through regular course offerings.

697. Research I, II. 1-5 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper, or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

699. *Graduate Colloquium.* 1-6 Hr. PR: Consent. For graduate students not seeking coursework credit but who wish to meet residence requirements, use the University's facilities, and participate in its academic and cultural programs. Note: graduate students not actively involved in course work or research are entitled, through enrollment in his/her department's graduate colloquium, to consult with graduate faculty, participate in both formal and informal academic activities sponsored by his/her program, and retain all of the rights and privileges of duly enrolled students. (Grading is S/U; colloquium credit may not be counted against credit requirements for master's programs.)

771. *Switching Circuit Theory 2.* 3 Hr. PR: CPE 670, Math 236 or equivalent. Switching circuit theory is used to model the operations of networks of logic gates and flip-flops. Networks of this type are one form of discrete parameter systems. Studies the use of linear sequential machine as a means of modeling the general class of discrete parameter information systems. Systems approach and the techniques of abstract algebra used throughout. (3 hr. lec.)

772. *Advanced Digital Systems Design.* 3 Hr. PR: CPE 572 or Consent. Students will design a specific digital system, i.e., CPU control, interrupt structure, memory, or input/output system. They will design and test a project oriented toward one specific objective.

790. *Teaching Practicum.* 1-3 Hr. PR: Consent. Supervised practice in college teaching of computer engineering. Note: this course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.)

791 A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

792. *Directed Study.* 1-6 Hr. Directed study, reading, and/or research.

793. *Special Topics.* 1-6 Hr. A study of contemporary topics selected from recent developments in the field.

794. *Seminar.* 1-6 Hr. Seminars arranged for advanced graduate students.

795. *Independent Study.* 1-6 Hr. PR: Consent. Faculty supervised study of topics not available through regular course offerings.

796. *Graduate Seminar.* 1 Hr. PR: Consent. It is anticipated that each graduate student will present at least one seminar to the assembled faculty and graduate student body of his/her program.

797. *Research.* 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

798. *Dissertation.* 2-4 Hr. PR: Consent. Note: this is an optional course for programs that believe that this level of control and supervision is needed during the writing of their student's reports, thesis, or dissertations. (Grading may be S/U.)

799. *Graduate Colloquium.* 1-6 Hr. PR: Consent. For graduate students not seeking coursework credit but who wish to meet residence requirements, use the University's facilities, and participate in its academic and cultural programs. Note: graduate students not actively involved in coursework or research are entitled, through enrollment in his/her department's graduate colloquium, to consult with graduate faculty, participate in both formal and informal academic activities sponsored by his/her program, and retain all of the rights and privileges of duly enrolled students. (Grading is S/U; colloquium credit may not be counted against credit requirements for master's programs.)

Computer Science (CSET)

510. *Formal Specification of Language.* 3 Hr. PR: CS 410 Specifications of language syntax and semantics by grammars and automata and by attribute grammars, denotational semantics, and action equations; algebraic, denotational, and operational semantics; application of formal specifications to construction of software tools.

512. *Design of Language Processors.* 3 Hr. PR: CS 410. Study of the design and construction of automatic programming language processors. Investigation of the structure of scientific and business oriented compilers, list processors, and information processing languages.

520. *Advanced Analysis of Algorithms.* II. 3 Hr. PR: CS 320 Analysis and design techniques for efficient sequential and parallel algorithm design; NP-completeness, advanced analysis techniques, advanced algorithms, and parallel algorithms.

525. *Computational Complexity.* 3 Hr. PR: CS 422, Math 375 or Consent. Introduction to the theory of computational complexity. Topics include: turning machines, computability, complexity classes P, NP, and co-NP, the theory of NP-completeness, randomized complexity classes, inapproximability, complexity classes beyond NP.

530. *Formal Methods in Software Engineering.* 3 Hr. PR: CS 430. Principles of rigorous specification, designing, implementation, and validation of sequential, concurrent, and realtime software; emphasis on reading current papers on these topics.

533. *Developing Portable Software.* 3 Hr. PR: CS 330 and CS 450 or Consent. Issues, problems, and techniques in the practical development of portable software and in the adaptation of programs to new environments; development of a simple interactive application; porting to several diverse computing platforms.

535. *Software Verification and Validation.* 3 Hr. PR: CS 310 and CS 330. Principles of formal software specification; formal verification, testing, and other validation techniques.

537. *Object-Based Software Design.* 3 Hr. PR: CS 330. Data type and structure specification, axiomatic and model-based specification, algebraic techniques, testing and verification specifications, data abstraction facilities in modern programming languages, examples, and associated algorithms.

539. Computer Forensics and the Law. 3 Hr. PR: CpE 435. Surveys the emerging field of Computer Law and how it applies to businesses and law enforcement, both to aid and to circumscribe the policies and procedures to tackle computer crime.

540. *Theory of Database Systems.* 3 Hr. PR: CS 440. Abstract and newer database models; introduction to database design techniques in the context of semantic data modeling; equivalence of different relational models; object-oriented databases.

550. *Theory of Operating Systems.* 3 Hr. PR: CS 450. Theoretical analysis of selected aspects of operating system design; topics include interaction of concurrent processes; scheduling and resource allocation; virtual memory management; access control; and distributed and realtime system issues.

552. Advanced Automata Theory II. 3 Hr. PR: CS 422. Survey of automata outside the Chomsky hierarchy with applicability to parallel processing, learning, temporal logic, and language processing.

555. *Advanced Computer Systems Architecture.* 3 Hr. PR: CS 455 or CPE 481. High performance techniques, pipelined and parallel systems, and high-level architectures; comparative evaluation of architectures for specific applications; emphasis on software implications of hardware specifications.

556. Distributed and Pervasive Computing. 3 Hr. Pervasive (or ubiquitous) availability of computers, connectivity and location technologies (GPS) and advances in sensor technologies are beginning to have a profound effect on the way we live and work. This course examines the enabling technologies, processes and infrastructures that underpin this revolution in computing. I have based this course on a similar course taught at Carnegie Mellon University (15-821/15-843) by Professsors Satyanarayanan and Siewiorek . The reading list and course outline are taken from the course website: http://www.cs.cmu.edu/~15-821/

557. *Software Engineering in Data Communications.* 3 Hr. PR: CS 450. Data communication principles, testing and debugging techniques, networks and data link control, software design in a network environment. A “hands-on” project in data communications design is included.

558. *Multimedia Systems.* 3 Hr. PR: CS 350, or EE 465, or consent. Requirements and QOS, multimedia data acquisition, object decomposition, multimedia storage servers, multimedia communications—networking, traffic characterizations, traffic scheduling, multicasting, compression for images, video and audio, multimedia information systems—indexing and retrieval of multimedia data.

563. *Numerical Interpolation and Approximation.* 3 Hr. PR: CS 460. Interpolation and approximation using Chebychev polynomials, Pade approximations, Chebychev economization of Taylor Series. Hermite interpolation, orthogonal polynomials and Gaussian Quadrature.

568. Computer Networking Forensics. 3 Hr. PR: CS 450 and CS 453, or Consent. Introduction to threat assessment in modern networked computer systems. Techniques, methodologies and technologies for preventing, detecting, recovering from, and collecting evidence of intrusions, with the intent of prosecuting the offending parties.

570. *Interactive Computer Graphics.* 3 Hr. PR: CS 320. Viewing in three dimensions, projections, rendering of surfaces and solids, illumination and shading, interaction handling, display processors and programming systems, and graphics system organization.

572. *Advanced Artificial Intelligence Techniques.* 3 Hr. PR: CS 472. Reasoning under uncertainty; nonmonotonic reasoning, statistical reasoning, fuzzy logic; planning, parallel, and distributed AI, natural language processing, learning, connectionist models, temporal logic, common sense knowledge and qualitative reasoning, AI techniques and robotics.

575. *Artificial Neural Networks.* 3 Hr. PR: MATH 243 or MATH 441 or Consent. Fluency in a high-level programming language. Theory of artificial neural networks (ANN) as mathematical models; techniques of linear algebra and calculus applied to understanding ANN-based learning and recall methods; introduction of several basic ANNs; ANN implementations via student-designed software.

591 A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

665. *Computer System Security.* 3 Hr. PR: CS 465 or Consent. Course describes modern approaches to information and system security including encryption techniques, secure communication protocols, operating system security principles, and network intrusion detection techniques.

690. *Teaching Practicum.* I, II, S. 1-3 Hr. PR: Consent. Supervised practices in college teaching of Computer science. Note: this course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.)

691 A-Z. *Advanced Topics.* I, II, S. 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

695. *Independent Study.* 1-6 Hr. Faculty supervised study of topics not available through regular course offerings.

696. *Graduate Seminar.* I, II, S. 1 Hr. PR: Consent. It is anticipated that each graduate student will present at least one seminar to the assembled faculty and graduate student body of his/her program.

697. *Research.* 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

719. *Information Modeling.* 2 Hr. PR: CS 440 or CS 537. Information modeling, data definition languages, graphical information models (NIAM and IDEF), computer-readable information models (EXPRESS); information exchange and sharing using STEP application protocols.

722. *Advanced Theory of Computing.* 3 Hr. PR: CS 520 or CS 522. Advanced structural complexity theory and its relationship to algorithmic problems. Interactive proofs, hierarchies (polynomial time, low, high) and hardness of approximation. (Alternate years.)

725. *Computability and Recursive Function Theory.* 3 Hr. PR: CS 525. Introduction to recursive function theory, approaches to computability, Church's thesis, decidability, recursive and recursively enumerable sets, numbering computable functions, Godel's incompleteness theorem, reducibility, and computational complexity.

727. *Information Dissemination.* 3 Hr. PR: CS 520. Research issues in information dissemination in graphs; emphasis on broadcasting and gossiping algorithms, including identification and solution of open research questions.

734. *Software Reuse.* 3 Hr. PR: CS 530 or CS 535. Formal and practical modular verification of functionality and performance; soundness and completeness of proof systems; module testing.

735. *Advanced Software Verification.* 3 Hr. PR: CS 535. Formal and practical modular verification of functionality and performance; soundness and completeness of proof systems; module testing.

740. *Advanced Databases Theory.* 3 Hr. PR: CS 540. Design theory for relational databases; functional dependencies; multivalued dependencies and normal forms; projection mappings, tableaux and the chase; representation theory.

750. *Secure and Survivable Systems.* 3 Hr. PR: CS 680 or consent. An in-depth study of principles, standards, practices, and architectures in the area of secure and survivable systems. Case studies, simulations, and games will be used to gain deep understanding of the issues.

757. *Distributed Systems and Algorithms.* 3 Hr. PR: CS 320 and CS 550. Distributed and networked operating systems and the algorithms necessary to achieve such goals as transparency, sharing, fault tolerance, and efficient process and task scheduling.

770. *Advanced Graphics and Multimedia.* 3 Hr. PR: CS 570 and fluency in C, Unix, and X. Computer graphics and multimedia; raster graphic architectures, advanced raster algorithms, ray tracing, radiosity, multimedia representation, multimedia communications, and similar topics.

772. *Global Knowledge Networks.* 3 Hr. PR: CS 572. Representational formalisms and effective retrieval techniques to obtain information from international knowledge repositories connected via high-speed networks.

775. *Advanced Neural Networks.* 3 Hr. PR: CS 575 or equivalent. Continuation of CS 575. Unsupervised learning: Hebbian and competitive; Hamming and Euclidean distance classifiers; discussion of Hamming, Maxnet, Kohonen, and Art 1 ANN's; presentation of papers by students from research literature.

790. *Teaching Practicum.* I, II, S. 1-3 Hr. PR: Consent. Supervised practice in college teaching of computer science. Note: this course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.)

791 A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses. Study may be independent or through specially scheduled lectures.

792 A-Z. *Directed Study.* 1-6 Hr. Directed study, reading, and/or research.

792 A. *Directed Study.* 1-6 Hr. Directed study, reading, and/or research.

793. *Special Topics.* 1-6 Hr. A study of contemporary topics selected from recent developments in the field.

794. *Seminar.* 1-6 Hr. Seminars arranged for advanced graduate students.

795. *Independent Study.* 1-6 Hr. Faculty supervised study of topics not available through regular course offerings.

796. *Graduate Seminar.* 1 Hr. PR: Consent. It is anticipated that each graduate student will present at least one seminar to the assembled faculty and graduate student body of his/her program.

797. *Research.* 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

798. *Dissertation.* 2-4 Hr. PR: Consent. Note: this is an optional course for programs that believe that this level of control and supervision is needed during the writing of their student's reports, thesis, or dissertations. (Grading may be S/U.)

799. *Graduate Colloquium.* 1-6 Hr. PR: Consent. For graduate students not seeking coursework credit but who wish to meet residence requirements, use the University's facilities, and participate in its academic and cultural programs. Note: graduate students not actively involved in coursework or research are entitled, through enrollment in his/her department's graduate colloquium, to consult with graduate faculty, participate in both formal and informal academic activities sponsored by his/her program, and retain all of the rights and

privileges of duly enrolled students. (Grading is S/U; colloquium credit may not be counted against credit requirements for master's programs.)

900. *Professional Development.* 1-6 Hr. Professional development courses provide skill renewal or enhancement in a professional field or content area (e.g., education community health, geology). The continuing education courses are graded on a satisfactory or unsatisfactory grading scale and do not apply as graduate credit toward a degree program.

Electrical Engineering (EE)

511. *Applied Nonlinear Control.* 3 Hr. PR: EE 411 or Consent. Study of the major analytical tools that are being used to analyze and control nonlinear systems such as phase plane analysis, Lyapunov theory, describing function analysis, feedback linearization, and sliding control.

513. *Stochastic Systems Theory.* 3 Hr. PR: Consent. Probability distribution and density functions. Bayes rule and conditional probability. Stochastic process and linear systems. Gauss-Markov Process. Optimal linear estimation. Introduction to Wiener and Kalman filtering. Decision theory fundamentals. (3 hr. lec.)

515. *Linear Control Systems.* 3 Hr. PR: Consent. Basic concepts in the theory of linear control systems; state variable representation, solution of state equations, controlability, observability, stability, transfer function descriptions, design of controllers and observers. (3 hr. lec.)

517. *Optimal Control.* 3 Hr. PR: Consent. Methods of direct synthesis and optimization of feedback systems; Wiener theory; Pontryagin's maximum principle; dynamic programming; adaptive feedback systems. (3 hr. lec.)

519. *Digital Control.* 3 Hr. PR: EE 411 or Consent. Sampling of continuous-time signals; transform analysis of discrete-time systems. Translation of analog design. Controllability and observability. State-space design methods; and introduction to optimal control for discrete systems. (3 hr. lec.)

525. *Biomedical Instrumentation.* 3 Hr. This course covers biomedical instrumentation used to measure signals generated by living systems. A significant portion of the course deals with the origin and characteristics of biological signals. (3 hr. lec.)

531. *Advanced Electrical Machinery.* 3 Hr. PR: EE 131 and EE 136 or Consent. Theory and modeling of synchronous, induction, and direct-current machines, and their steady-state and transient analysis. (3 hr. lec.)

533. *Computer Applications in Power System Analysis.* 3 Hr. PR: EE 436 or Consent. Steady state analysis by digital computers of large integrated electrical power systems. Bus admittance and impedance matrices, load flow studies, economic dispatch and optimal power flow, steady state security analysis, fault studies. (3 hr. lec.)

535. *Power System Control and Stability.* 3 Hr. PR: EE 515. Review of stability theory, classical transient analysis, dynamical models of synchronous machines, power system stability under small and large perturbations, dynamic simulation of power systems. (3 hr. lec.)

537. *Advanced Power Electronics and Drives.* 3 Hr. PR: EE 435. Study of solid-state power semi-conductor devices with emphasis on their applications in power conditioned electric motor drives systems. Examination of control philosophies, steady-state models, and numerical simulation. Current topics of interest from the literature.

550. *Advanced Semiconductor Electronics.* 3 Hr. PR: EE 450 or equivalent. Theory of electronic and photonic device. Semiconductors properties and their impact on devices behavior - p-n junctions, bipolar transistors, and MOS transistors. Quantum mechanical effects introduced. Development of models to simulate devices and simple circuits.

551. *Linear Integrated Circuits.* 3 Hr. PR: EE 555 and EE 556 or equivalent . This course deals with the design and analysis of analog integrated circuits. First, the course will introduce to special requirements for

analog integrated circuit design together with an overview of the different fabrication technologies, including Bioplar, MOS, and BiCMOS. (3 hr. lec.)

553. *Integrated Logic Circuits.* 3 Hr. PR: EE 156, EE 157 or equivalent, or Consent (Intended for students specializing in digital circuits.) Techniques of integrated circuit design and fabrication. Development of transistor model for nonlinear operations. Design, analysis, and comparison of emitter-coupled, direct-coupled, diode-transistor, transistor-transistor integrated logic circuits. 3 hr. lec.

561. *Communication Theory.* 3 Hr. PR: EE 461 or Consent. Detailed study of probability theory and its use in describing random variables and stochastic processes. Emphasis on applications to problems in communication system design. 3 hr. lec.

562. *Wireless Communication System.* 3 Hr. PR: EE 461 and EE 513. Architecture and design of cellular and wireless communication networks, electromagnetic effects of the wireless channel and corresponding statistical models, implementation and performance of diversity reception techniques, multiple-access.

568. *Information Theory.* 3 Hr. PR: STAT 215 or equivalent, or consent. Information measures and mutual information, noiseless coding theorem, construction of compact codes and universal codes, channel coding theorem and error correcting codes, cryptography information theory, algorithmic information theory, and rate distortion theory.

591 A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

595. *Independent Study.* 1-6 Hr. Faculty supervised study of topics not available through regular course offerings.

613. Detection and Estimation Theory. 3 Hr. PR: EE 513 or Equivalent. Study of detection, estimation, and signal representation, detection of signal in noise, estimation of signal parameters, linear estimation theory. Performance bounds on Estimation and Detection, Kalman-Bucy and Wiener filters. Modern optimal estimation and detection.

625. *Advanced Signal Processing.* 3 Hr. PR: EE 513 or Consent. Statistical aspects of signal processing. Includes advanced techniques, such as autocorrelation/ cross correlation, autoregressive models, linear prediction, power spectral density, and other topics. Course will contain significant student-driven application component using biomedical, communication, and/or other signals. 3 hr. lec.

650. *Optoeletronics.* 3 Hr. PR: EE 450 or PHYS 471 or approval. Semiconductor physics theory of light-emitting diodes, homojunction lasers, single and double heterojunction lasers, separate confinement quantum well lasers, p-i-n and photo detectors and avalanche photo detectors. Optical and electrical analysis of epitaxial and device designs.

687. *Materials Engineering.* 3 Hr. A study of materials engineering fundamentals emphasizing semiconductor, polymer, metal, and ceramic/cementitious material systems. Mechanical and physical properties, theoretical aspects, testing, design criteria, manufacturing, and economics of material systems. Laboratory testing and evaluation. (Equivalent to CHE 687, CE 687, MINE 687, IMSE 687, and MAE 687.)

691 A-Z. *Advanced Topics.* I, II, S. 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

695. *Independent Study.* I, II, S. 1-6 Hr. PR: Consent. Faculty supervised study of topics not available through regular course offerings.

697. *Research.* I, II, S. 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

711. *Nonlinear Control System Analysis.* 3 Hr. PR: Consent. Application of Liapunov's and Popov's methods to nonlinear control systems, together with classical techniques. 3 hr. lec.

713. *Large-Scale System Modeling.* 3 Hr. PR: EE 515. Characterization of large-scale systems, model simplification through aggregation and perturbation methods, optimal and chained aggregation, balanced realization and cost component procedures; optimal model reduction; simplification effects; decentralized control; feasibility and design. 3 hr. lec.

715. *Stochastic Estimation and Control.* 3 Hr. PR: EE 517 or Consent. Techniques of optimal estimation and control for linear systems. Balanced emphasis is placed on both continuous and discrete time systems. Some advanced topics of interest will be considered. 3 hr. lec.

731. *Real Time Control of Power System.* 3 Hr. PR: EE 515 and EE 517 and EE 533. Application of computers to modern control theory for reliable and economic real-time operation of integrated power systems. 3 hr. lec.

733. *Protection of Power Systems.* 3 Hr. PR: EE 436 or Consent. Principles of relay protection for faults on transmission lines and other devices. Use of overcurrent, differential distance, and pilot relaying systems. Special relay applications. Determination of short-circuit currents and voltages from system studies. 3 hr. lec.

735. *HVDC Transmission.* 3 Hr. PR: EE 435 and EE 533. Line-commutated converter analysis, operation of twoterminal and multiterminal dc systems, harmonics and filters, modeling of ac/dc system, and design of modulation controllers.

790. *Teaching Practicum.* I, II, S. 1-3 Hr. PR: Consent. Supervised practice in college teaching of electrical engineering. Note: this course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.)

791 A-Z. *Advanced Topics.* I, II, S. 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

792. *Directed Study.* I, II, S. 1-6 Hr. Directed study, reading, and/or research.

793. *Special Topics.* I, II, S. 1-6 Hr. A study of contemporary topics selected from recent developments in the field.

794. *Seminar.* 1-6 Hr. Seminars arranged for advanced graduate students.

794 A-Z. *Seminar.* 1-6 Hr. Seminars arranged for advanced graduate students.

795. *Independent Study.* I, II, S. 1-6 Hr. Faculty supervised study of topics not available through regular course offerings.

796. *Graduate Seminar.* I, II, S. 1 Hr. PR: Consent. It is anticipated that each graduate student will present at least one seminar to the assembled faculty and graduate student body of his/her program.

797. *Research.* I, II, S. 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. Grading may be S/U.

798. *Dissertation.* 2-4 Hr. PR: Consent. Note: this is an optional course for programs that believe that this level of control and supervision is needed during the writing of their student's reports, thesis, or dissertations. (Grading may be S/U.)

799. *Graduate Colloquium.* I, II, S. 1-6 Hr. PR: Consent. For graduate students not seeking coursework credit but who wish to meet residence requirements, use the University's facilities, and participate in its academic

and cultural programs. Note: Graduate students not actively involved in coursework or research are entitled, through enrollment in his/her department's Graduate Colloquium, to consult with graduate faculty, participate in both formal and informal academic activities sponsored by his/her program, and retain all of the rights and privileges of duly enrolled students. Grading is S/U; colloquium credit may not be counted against credit requirements for master's programs.

Software Engineering (SENG)

510. *Software Project Management.* 3 Hr. Techniques and tools for managing the software development process for large development projects.

520. *Software Analysis and Design.* 3 Hr. Defining software requirements and an introduction to the principles and concepts relevant to the design of large programs and software systems.

530. *Validation and Verification.* 3 Hr. Tools and techniques for applied verification and validation of computer software including requirements, design, and code relevant to several development lifecycle models.

540. *Software Evolution.* 3 Hr. Software process and the Capability Maturity Model (CMM), software maintenance and evolution, program understanding, reengineering, software configuration management, and software tools related to these issues.

591 A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

691 A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

697. *Research.* 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

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http://www.imse.cemr.wvu.edu/grad/degree-info.php?degree=phdosh
Graduate Safety Management web page: http://www.cemr.wvu.edu/~wwwsem/

Degrees Offered

Master of Science in Industrial Engineering
Master of Science in Engineering with a major in Industrial Engineering
Master of Science in Occupational Hygiene and Occupational Safety
Master of Science in Safety Management
Doctor of Philosophy with a major in Industrial Engineering
Doctor of Philosophy with a major in Occupational Safety and Health

One of the defining attributes in the success of the department is the dedication and talent of its 16 faculty and three staff members. The aggregate careers of our faculty and staff represent nearly 300 years of service to students at WVU. In these 300 years of service is embodied the wisdom and experience to successfully prepare industrial engineers and occupational health and safety professionals for the 21st century. The faculty and staff typically educate 110 to 120 undergraduate, 210 to 230 M.S., and seven to ten Ph.D. students. The department is in the unique position in the United States of having two complimentary graduate programs in occupational health and safety accredited by the Applied Science Accreditation Commission

(ASAC) of the Accreditation Board for Engineering and Technology (ABET). The combined resources and faculty talents of these two programs create synergies that provide our students with outstanding academic and research experiences in the field of occupational safety and health. Excellent academic and research opportunities are also available for students in the areas of operations research, decision sciences, and manufacturing.

Faculty Research

The department has quality research laboratories in manufacturing, robotics and vision systems, CAD/CAM, operations research, production planning and control, decision sciences, ergonomics, industrial hygiene, and safety. Graduate students are encouraged to utilize these resources to explore and develop their capabilities. Research initiatives and on-going funding opportunities are available to students in the areas of: ergonomics; operations research; manufacturing; occupational safety and health; artificial intelligence; and respirator research.

Master's Degree Programs

Industrial and Management Systems Engineering

Graduate programs in industrial and management systems engineering are designed to give students experience in developing innovative solutions to real problems by implementing creative ideas. Students can expect to develop their creative abilities in order to be effective in innovative environments while improving their abilities to communicate and implement new ideas.

Four degrees are offered at the master's level: M.S.I.E., M.S.E., M.S. in industrial hygiene, and M.S. in safety management

- The M.S. industrial engineering degree program is appropriate for students with a B.S. in industrial engineering or other engineering discipline. See our graduate IE web page at http://www.ieng.cemr.wvu.edu/grad/.
- The M.S. engineering degree program is designed for students having a baccalaureate degree in a technical field other than industrial engineering who wish to pursue a broader, more interdisciplinary program of graduate studies. An undergraduate degree in either another engineering field or the basic sciences is required for admission to the M.S.E. See our graduate IE web page at http://www.ieng.cemr.wvu.edu/grad.
- The M.S. in industrial hygiene and is accredited in industrial hygiene by the Applied Science Accreditation Committee (ASAC) of the Accreditation Board of Engineering and Technology (ABET). Suitable undergraduate degrees include engineering, chemistry, biology, medical sciences, animal sciences, and the physical sciences. The three disciplines that form the basis of occupational hygiene and occupational safety are industrial hygiene, industrial safety, and ergonomics. See our graduate IH program web page at http://www.imse.cemr.wvu.edu/grad/msih.
- The M.S. in safety management degree program is accredited in safety by the Applied Science Accreditation Committee (ASAC) of the Accreditation Board of Engineering and Technology (ABET). It is designed for students trained in the areas of business and economic sciences, animal sciences, chemical and biological sciences, engineering and technology sciences, medical sciences, and the physical sciences who have an interest in safety management. See the safety management graduate program web page at http://www.imse.cemr.wvu.edu/grad/safm.

Program Objectives and Outcomes

The program objectives of the Industrial Hygiene program are as follows:
Graduates of the Industrial Hygiene MS program will be prepared to:

- Practice Industrial Hygiene and to initiate and develop leadership roles in business, industry and/or government.
- Continue professional development and life-long learning.
- Interact in society and business in a professional, ethical manner to promote occupational and environmental health.
- Be proficient in written and oral communication and to utilize people-oriented skills in individual and team environments.
- Apply the skills from Industrial Hygiene to be proficient in his or her chosen field or doctoral studies.

The program objectives of the Safety Management program are as follows:
Graduates of the Safety Management Program will be able to:

- Communicate effectively, orally and in writing, including the transmission of safety data to management and employees.
- Demonstrate knowledge and skills in the area of safety management.
- Demonstrate knowledge of ethical and professional responsibilities and knowledge of applicable legislation and regulations.
- Demonstrate the ability to apply various research activities through the decision-making process used in safety management.

The program outcomes of the Industrial Hygiene program are as follows:
At the time of their graduation, students must have:

- The ability to use the techniques, skills, and modern scientific and technical tools necessary for professional practice such as:
  - Principles and methods of industrial hygiene
  - Principles and methods of ergonomics
  - Principles and methods of safety
  - Principles of environmental sciences (Environmental elective)
  - Principles of epidemiology and biostatistics
  - Principles and methods of control of physical and chemical hazards
- The ability to apply knowledge of math, science, and Industrial Hygiene
- The ability to design and conduct experiments, analyze and interpret data, develop implementation strategies, shape recommendations so that results will be achieved and findings will be communicated effectively
- The ability to work individually, in teams, and/or in multi-disciplinary teams to identify, formulate and solve problems using Industrial Hygiene, safety, and ergonomics knowledge, skills and tools
- The ability to formulate or design a system, process or program to meet desired needs;
- An understanding of professional and ethical responsibility and the broad education and knowledge of contemporary issues necessary to understand the impact of solutions in a global and societal context
- A recognition of the need for and an ability to engage in life-long learning
- The professional characteristics expected of a successful Industrial Hygienist.

The program outcomes of the Safety Management program are as follows:
At the time of their graduation, students must have the ability to:

- Demonstrate knowledge and skills to build a comprehensive Safety and Health Program based on loss control and regulations.
- Demonstrate knowledge and skills to use analytical techniques in the Safety and Health function.
- Demonstrate knowledge and skills with federal, state, and non-governmental Safety and Health Program standards and best practices.
- Demonstrate skills in communications, written and oral, at the level of professionals in safety and health positions.
- Demonstrate knowledge and skills in writing and evaluating safety and health research proposals.
- Demonstrate knowledge and skills in using management tools to implement and evaluate SHE Programs.

Admission

To qualify as a regular graduate student, applicants must have as a minimum, the equivalent of a 3.0 GPA. Applicants with a minimum 2.75 GPA (or the equivalent) may be admitted on a provisional basis. Foreign students must demonstrate proficiency in communicating in English (550 or more in TOEFL). Students must comply with the rules and regulations as outlined in this catalog for graduate work in the College of Engineering and Mineral Resources.

- For admission into the M.S.I.E. and M.S.E. programs, applicants must have a bachelor of science degree from an engineering department, or from physics, chemistry, computer sciences, mathematics, or similar technical or science program. In general a degree in one of the “hard” science programs is required with at least two years of calculus or equivalent mathematics.

- For admission into the M.S. industrial hygiene program, applicants must meet ABET/ASAC prerequisite course requirements which are currently a minimum of 63 credit hours of approved science, mathematics, and other technical courses. Of these, at least 15 credit hours must be junior or senior level. Specific pre/co-requisite course requirements include one semester of computer application (must include spread-sheets and databases), one semester of statistics, two semesters of general/inorganic chemistry, and two semesters of physics. On an individual basis, the faculty may identify additional pre/co-requisite coursework, often including organic chemistry and biology. Applicants will be advised about their specific requirements at the time of admission. Applicants not meeting all of the listed requirements may be considered for admission as provisional students.
- For admission into the M.S. safety management program, applicants must meet ABET/ASAC prerequisite course requirements, which are currently a minimum of 63 credit hours of approved science, mathematics, and other technical courses. Of these, at least 15 credit hours must be junior or senior level. In addition, students must have a minimum of 21 hours of social sciences, humanities, and/or communications. On an individual basis, the faculty may identify additional prerequisite coursework. Applicants will be advised about their specific requirements at the time of admission. Applicants not meeting all of the listed requirements may be considered for admission as provisional students.

Required Courses

Required courses are determined by the student's degree program and area of emphasis. Specific course information by program area is available at the following web site:www.imse.cemr.wvu.edu/grad/courses.

Thesis

When a student elects the thesis or problem report option, the thesis or problem must conform to the general requirements of the University and to written requirements of the Department of Industrial and Management Systems Engineering.

Graduation Requirements

The M.S.I.E. or M.S.E. degree requirements for the thesis option include completion of a minimum of 24 credit hours, plus a six-hour thesis; or candidates may take 33 credit hours and complete a three-hour problem report. A candidate for the M.S.I.E., M.S.E., or M.S.I.H. degrees must pass an oral examination on coursework and the thesis or problem report. M.S. in safety management degree candidates may opt to complete a minimum of 30 credit hours, plus a six-hour thesis, or they may opt to complete a minimum of 33 credit hours and a problem report or a 36-credit-hour all coursework program. Candidates who take the 33- or 36-hour options are also required to pass a final comprehensive written examination. All graduate students must have a final grade point average of at least 3.0.

Doctor of Philosophy

A candidate for the degree of doctor of philosophy (Ph.D.) must comply with the rules and regulations of the College of Engineering and Mineral Resources and the University. To be accepted in the Ph.D. program, applicants should have at a minimum (or equivalent) of a 3.40 GPA in their graduate work. They must also meet all the entrance requirements stated earlier for the master's programs. Each student will develop a program with a major in industrial engineering or occupational safety and health designed to meet his/her needs and objectives in consultation with an advisor and the Advisory and Examining Committee. Required core courses for the Ph.D. program are determined by the student's area of emphasis. In general, Ph.D. students take approximately 54 hours of coursework beyond their baccalaureate degree, with a minimum of 30 hours in industrial engineering or occupational safety and health. The research work for the doctoral dissertation may entail a fundamental investigation or a broad and comprehensive investigation into an area of specialization.

Early in the doctoral program, the student must pass an examination to demonstrate master's-level proficiency in industrial engineering or occupational safety and health subject matter. Upon completion of the coursework, the student must pass a written examination in order to be admitted to candidacy. An acceptable dissertation must be written and defended.

The department also offers a Ph.D. degree in Occupational Safety and Health. More details are available on the web site: www.imse.cemr.wvu.edu.

Industrial Engineering (IENG)

502. *Advanced Manufacturing Processes.* 3 Hr. PR: IENG 302 and IENG 303. Metal cutting economic models, solidification processes, bulk deformation, sheet metal and drawing, joining design, and economics. Overall view of manufacturing systems. Introduction to numerical control programming and projects on numerical control equipment.

504. *Materials and Processing Systems Design.* 3 Hr. PR: IENG 302 and IENG 303. The engineering design process, material design properties and selection systems, decision making and problem analysis techniques for materials and processing. Economic and cost systems, expert systems, failure analysis, and quality systems for materials and process selection.

505. *Computer Integrated Manufacturing.* 3 Hr. PR: Graduate standing. Several aspects of computerized manufacturing systems will be covered. Emphasis will be placed on computer fundamentals, computer- aided design and manufacturing, numerically-controlled (NC) machine tools, part programming, system devices, and direct digital control. (2 hr. lec., 1 hr. lab.)

506. *Computer Aided Process Planning.* 3 Hr. PR: Consent. Computer aided process planning for manufacturing applications; selection of processes and parameters; machining, casting, and forming; development of process plans from design data; analysis of effect of changes in design on manufacturability in concurrent engineering.

507. *Robotics and Flexible Automation.* 3 Hr. PR: Graduate standing. This course will provide an understanding of the principles, capabilities, and limitations of industrial robots and other flexible automation tools. Emphasis will be placed on kinematic analysis, trajectory planning, machine vision, and manufacturing automation. (2 hr. lec., 1 hr. lab.)

508. *Advanced Problems in Manufacturing Engineering.* 1-3 Hr. PR: IENG 593 or IENG 502; Graduate standing. Special problems relating to one of the areas of manufacturing engineering, such as manufacturing processes, robotics, CAD/CAM, group technology, and manufacturing systems engineering.

509. *Computational Methods for Manufacturing Engineers.* 3 Hr. PR: Graduate standing. Computational techniques applicable to manufacturing systems engineering problems; emphasis on use of personal computers. (2 hr. lec., 1 hr. lab.)

514. *Design of Industrial Experiments.* 3 Hr. PR: ENGR 314 or Consent. Continuation of IENG 314. More complex experimental design especially useful to engineering and industrial researchers, including factorials and optimum-seeking design. Emphasis on use of existing digital computer routines and interpretation of results.

518. *Technology Forecasting.* 3 Hr. Various procedures used in forecasting technical developments.

525. *Engineering Management.* 3 Hr. Unique problems of engineering organizations including project planning, managing creativity, coordinating design and development, and other topics relevant to engineering organizations.

542. *Advanced Production Control.* 3 Hr. PR: IENG 350. Different mathematical models useful in the design of effective production control systems. The various models include: static production control models under risk and incertainty; dynamic models under certainty, under uncertainty, and under risk.

551. *Quality and Reliability Engineering.* 3 Hr. PR: Graduate standing. Introduction to quality and reliability engineering. Special emphasis on Taguchi Design and Markov Models for determining system reliability and availability.

553. *Applied Linear Programming.* 3 Hr. PR: IENG 350 or Consent. Application of the assignment, transportation, and simplex algorithms to typical industrial problems. The methods and computational efficiencies of the revised simplex and other algorithms are also studied.

554. Applied Integer/Heuristic Programming. 3 Hr. PR: IENG 350 or IENG 553 and knowledge of a computer programming language. Applications of integer and heuristic programming techniques for solving combinatorial optimization problems. Topics include computational complexity, relaxations, branch and bound, cutting planes, simulated annealing, tabu search, and genetic algorithms.

555. *Scheduling and Sequencing Methods.* 3 Hr. PR: IENG 350. Theory and applications of analytical models used in the scheduling models; flow shop models; job shop models; and assembly line balancing methods.

556. Supply Chain Management. 3 Hr. PR: IENG 350 or IENG 553. Principles and methods for designing and managing supply chain systems. Topics include: forecasting demand, strategies, aggregate planning, inventory control, outsourcing, transportation networks, and locating facilities within the supply chain network.

561. *Industrial Hygiene Engineering.* 4 Hr. Introductory course in industrial hygiene with laboratory. Topics include: recognition, evaluation, and control of occupational and environmental contaminants and physical agents; basic IH quantitative analysis; PPE selection and evaluation.

564. *Industrial Ergonomics.* 3 Hr. PR: IENG 360 or Consent. Practical experience in the application of ergonomic principles to industrial problems. Safety and production implications of work physiology, industrial biomechanics, and circardian rhythms, as well as current interest topics.

593 A-Z. *Special Topics.* 1-6 Hr. A study of contemporary topics selected from recent developments in the field.

595. *Independent Study*. 1-6 Hr. Faculty supervised study of topics not available through regular course offerings.

660. *Human Factors System Design.* 3 Hr. PR: IENG 360 or Consent. Theoretical aspects and practical applications of man/machine relationships as they influence future system design. The student will examine human limitations with respect to acceptance of information, decision making, and ability to transmit the result of such decisions to controlled equipment systems to obtain design optimization. (2 hr. lec., 3 hr. lab.)

662. *Systems Safety Engineering.* 3 Hr. PR: IENG 461 or Consent. Analysis of manufacturing methods, processes, and properties of materials from a system safety engineering viewpoint. Emphasis will be on hazard analysis techniques (fault tree, MORT, failure modes, and effects) and machine guarding methods.

668. *Advanced Problems in Human Factors.* 1-3 Hr. PR: IENG 360 or IENG 660 and graduate standing. Special problems relating to one of the areas of human factors, such as ventilation, ergonomics, controls, vigilance, safety, and occupational health.

677. Advanced Engineering Economy. 3 Hr. PR: Consent. Special emphasis on depreciation, engineering and economic aspects of selection and replacement of equipment; relationship of technical economy to income taxation; effect of borrowed capital and pricing model.

678. Costing and Estimating for Manufacturing. 3 Hr. PR: IENG 377 or Consent. Analysis of overhead, cost indexes, cost capacioty factors, improvement curves; costing for materials with design considerations; conceptual cost estimating; costing for maching, joining, casting and forming; facility cost estimation.

687. *Materials Engineering.* 3 Hr. A study of material engineering fundamentals emphasizing semiconductor, polymer, metal, and ceramic/cementiutious material systems. Mechanical and physical properties, theoretical aspects, testing, design criteria, manufacturing, and economics of material systems. Laboratory testing and evaluation. (Equivalent to CE 687, CHE 687, EE 687, MINE 687, and MAE 687.)

691. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

693 A-Z. *Special Topics.* 1-6 Hr. A study of contemporary topics selected from recent developments in the field.

698. *Thesis.* 2-4 Hr. PR: Consent. Note: this is an optional course for programs that believe that this level of control and supervision is needed during the writing of their student's reports, thesis, or dissertations. (Grading may be S/U.)

751. *Nonlinear Programming.* 3 Hr. PR: IENG 350 or Consent. Advanced study of the techniques of nonlinear programming and their applications. Topics include steepest descent, Newton's method, Fletcher-Powell, conjugate gradients, Powell's method, and penalty function methods.

752. *Queueing Theory.* 3 Hr. PR: IENG 213 and IENG 350 or Consent. Analytical modeling of waiting line systems with emphasis on determining the best operating conditions for those systems. Single-channel and multichannel models. Computational methods (including Monte Carlo techniques) are examined. Applications to problems such as maintenance and inventory control.

753. *Theory of Linear Programming.* 3 Hr. PR: IENG 350 or Consent. Study of procedures available for solving large-scale problems using linear programming. Topics include decomposition techniques, multiple pricing, cycling, inverse generation and storage, ranging procedures, and upper bound algorithms.

754. *Inventory Theory.* 3 Hr. PR: IENG 213 and IENG 350 or Consent. Techniques used in optimization of inventory systems. Elements of static, deterministic inventory models, and static, stochastic inventory models. Selected inventory models. Selected topics related to inventory analysis.

755. *Advanced Digital Simulation.* 3 Hr. PR: IENG 455 or Consent. Analysis and comparison of special purpose digital simulation languages such as GPSS, SLAM, SIMAN, SIMSCRIPT, CSMP, DYANOMO, and JOB SHOP simulation.

756. *Applied Stochastic Processes.* 3 Hr. PR: Consent. Stochastic systems with emphasis on application to inventory and queueing theory. Conditional probability, Poisson processes, renewal processes, Markov chains with discrete and continuous parameters.

757. *Dynamic Programming.* 3 Hr. PR: IENG 350 or Consent. Introduction to basic structure and computational aspects of dynamic programming and applications including sequential decision problems, deterministic and probabilistic models over finite and infinite planning horizons, and Markovian decision processes.

758. *Integer Programming and Applied Networks.* 3 Hr. PR: IENG 350 or Consent. Introduction to application of integer programming and maximum flow networks to engineering and operations research problems. Emphasis on problem formulation and solution.

790. *Teaching Practicum.* 1-3 Hr. PR: Consent. Supervised practice in college teaching of Industrial and Management Systems Engineering. Note: this course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.)

791. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

792. *Directed Study.* 1-6 Hr. PR: Consent. Directed study, reading, and/or research.

793. *Special Topics.* 1-6 Hr. PR: Consent. A study of contemporary topics selected from recent developments in the field.

794 A-Z. *Seminar.* 1-6 Hr. PR: Consent. Seminars arranged for advanced graduate students.

795. *Independent Study.* 1-6 Hr. PR: Consent. Faculty supervised study of topics not available through regular course offerings.

796. *Graduate Seminar.* 1 Hr. PR: Consent. It is anticipated that each graduate student will present at least one seminar to the assembled faculty and graduate student body of his/her program.

797. *Research.* 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. Grading may be S/U.

798. *Dissertation.* 2-4 Hr. PR: Consent. Note: this is an optional course for programs that believe that this level of control and supervision is needed during the writing of their student's reports, thesis, or dissertations. (Grading may be S/U.)

799. *Graduate Colloquium.* 1-6 Hr. PR: Consent. For graduate students not seeking coursework credit but who wish to meet residence requirements, use the University's facilities, and participate in its academic and cultural programs. Note: graduate students not actively involved in coursework or research are entitled, through enrollment in his/her department's graduate colloquium, to consult with graduate faculty, participate in both formal and informal academic activities sponsored by his/her program, and retain all of the rights and privileges of duly enrolled students. (Grading is S/U; colloquium credit may not be counted against credit requirements for master's programs.)

Industrial Hygiene & Safety (IHS)

527. *Noise Measurement and Control.* 3 Hr. PR: Senior or graduate standing. Includes noise physics, effects of noise on hearing and well-being, noise exposure regulations, and engineering of noise control. Practical experience with noise dosimeters and sound level meters is provided by a field trip.

621. *Epidemiology: Principles and Practices.* 2 Hr. PR: STAT 511 or Equivalent. Principles and methods of epidemiology with emphasis on descriptive and analytical epidemiological methods.

628. *Ventilation Control Technology.* 3 Hr. PR: IMSE 561 or Consent. The course will demonstrate techniques for the recognition, evaluation, and control of noise and ventilation problems. Students will use monitoring equipment to evaluate situations and perform several design projects.

685. *Internship.* 3-6 Hr. PR: Consent. (May be repeated.) Professional internship providing on-the-job training under supervision of a previously approved environmentalist in settings appropriate to professional objectives.

691 A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

692. *Directed Study.* 1-6 Hr. Directed study, reading, and/or research.

693. *Special Topics.* 1-6 Hr. PR: Consent. A study of contemporary topics selected from recent developments in the field.

694. *Seminar.* 1-6 Hr. PR: Consent. Seminars arranged for advanced graduate students.

695. *Independent Study.* 1-6 Hr. PR: Consent. Faculty supervised study of topics not available through regular course offerings.

696. *Graduate Seminar.* 1 Hr. PR: Consent. It is anticipated that each graduate student will present at least one seminar to the assembled faculty and graduate student body of his/her program.

697. *Research.* 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading will be S/U.)

698. *Thesis.* 2-4 Hr. PR: Consent. Note: this is an optional course for programs that believe that this level of control and supervision is needed during the writing of their student's reports, thesis, or dissertations. (Grading may be S/U.)

699. *Graduate Colloquium.* 1-6 Hr. PR: Consent. For graduate students not seeking coursework credit but who wish to meet residence requirements, use the University's facilities, and participate in its academic and cultural programs. Note: graduate students not actively involved in coursework or research are entitled, through enrollment in his/her department's graduate colloquium, to consult with graduate faculty, participate in both formal and informal academic activities sponsored by his/her program, and retain all of the rights and privileges of duly enrolled students. (Grading is S/U; colloquium credit may not be counted against credit requirements for master's programs.)

720. *Foundations of Environmental Health Practice.* 4 Hr. PR: Consent. Designed to enable the environmentalist to recognize and identify environmental stresses and the effect of these stresses on man. Topics include occupational health, physical stress, safety, and basic and broad principles of toxicology.

725. *Industrial Hygiene Sampling and Analysis.* 4 Hr. PR: IMSE 561 and Consent. Calibration and use of sampling and analytical equipment used by industrial hygienists to evaluate the work environment. Advantages and disadvantages of different equipment under various conditions. Biological monitoring as an evaluation tool.

790. *Teaching Practicum.* 1-3 Hr. PR: Consent. Supervised practice in college teaching of occupational hygiene and safety. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience.

Safety Management (SAFM)

501. *Safety Management Integration.* 3 Hr. PR: Consent. Consideration of integrated arrangements, staff roles, management theory, staff liaison, project improvement, effectiveness, audits, and collaboration needed to assure success of the safety function.

502. *Controlling Environmental and Personnel Hazards.* 3 Hr. PR: Consent. Investigation of hazard control principles relating to environmental facilities and equipment including control procedures recommended by authorities from the fields of engineering, medicine, and public health as well as from the field of safety.

505. *Safety Legislation and Compliance.* 3 Hr. PR: Consent. Comprehensive study and analysis of federal and state legislation which mandates compliance with certain safety conditions and practices related to work performed in occupational and comparable settings.

528. *Safety Evaluation and Research.* 3 Hr. An introduction to the nature and purpose of research as it applies to safety; research designs and concerns; basic statistical procedures; evaluation and interpretation of safety data; and measurement and evaluation of safety performance.

533. *Disaster Preparedness.* 3 Hr. Major elements involved in disasters and emergencies, preparedness planning, systems utilization, and attention to essential human services, with emphasis on community action.

534. *Fire Safety Management.* 3 Hr. Analysis of fire services usually provided under safety manager jurisdiction, with special attention to legal bases, organizational structure, services rendered, training needs, and management techniques.

539. *Security Management.* 3 Hr. PR: Consent. Safety manager responsibilities for security of persons and property including organizational patterns, personnel competencies expected, surveillance and monitoring methods, and occupational problems among security personnel.

550. *Loss Control and Recovery.* 3 Hr. PR: Consent. Identifying and elimination areas of loss or recovering from losses of people, property, and efficacy via management practices, insurance and worker's compensation, and other management techniques and resources effective in controlling those losses.

552. *Safety & Health Training.* 3 Hr. Analysis of safety and health performance discrepancies, developing and conducting training programs to eliminate those discrepancies and the evaluation of program effectiveness in terms of cost effectiveness and organizational impact.

578. *Substance Abuse in the Workplace.* 3 Hr. PR: Consent. The problem, nature, and effects of alcohol and drug use in the workplace; approaches for treatment and avoidance such as EAP's, community programs, and testing; development of management approaches and programs.

580. *Fundamentals of Environmental Management.* 3 Hr. An introductory but comprehensive overview of topics related to Environmental Technology as it applies to Safety Management. Focuses on regulation and technology relative to Environmental Management. Includes field trip.

581. *Environmental Management Systems.* 3 Hr. Ecological, legal, and economic pressures toward environmental management systems (EMS). ISO standards. Design, implement, improve EMS beyond compliance to proactive due diligence protection against expanding liability. Product life cycle and stewardship, pollution prevention, risk communication.

595. Independent Study. 1-6 Hr. Faculty supervised study of topics not available through regular course offerings

640. *Instrumentation for Safety Managers.* 3 Hr. PR: Consent. Anticipation, recognition, evaluation of industrial hygiene topics encountered by safety managers. Fundamental instrumentation techniques are presented in laboratory and lecture formats. Management-oriented control and remediation programs are developed.

642. *Biomechanics of Safety Management.* 3 Hr. PR: Consent. Applying the laws of physics to describe the abilities and limitations of the human body biomechanically and physiologically in order to maintain safety, quality, and productivity objectives; based on safety management principles.

689. *Professional Field Experience.* 1-18 Hr. PR: Must have completed 12 hours in SAFM and Consent. Prearranged experiential learning program, to be planned, supervised, and evaluated for credit by faculty and field supervisors. Involves temporary placement with public or private enterprise for professional competence development.

691 A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

692 A-Z. Directed Study. 1-6 Hr. PR: Consent. Directed study, reading, and/or research.

693 A-Z. *Special Topics.* I, II, S. 1-6 Hr. A study of contemporary topics selected from recent developments in the field.

695. *Independent Study.* I, II, S. 1-6 Hr. Faculty supervised study of topics not available through regular course offerings.

697. *Research.* 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading will be S/U.)

721. *Essential Safety Management Information.* 3 Hr. Examination of information needed for safety management success, harm investigation procedures, evaluation techniques, nonrealized profit calculations, and decision-making which should enhance improvement of all safety function affairs.

753. *Human Resources & Safety.* 3 Hr. Safety positions and human resources, needs, and problems in relation to efforts by business, industrial, governmental, and educational agencies to provide effective human resources for safety.

790. *Teaching Practicum.* 1-3 Hr. PR: Consent. supervised practice in college teaching of safety and environmental management. Note: this course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.)

791 A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

792. *Directed Study.* 1-6 Hr. PR: Consent. Directed study, reading, and/or research.

793. *Special Topics.* 1-6 Hr. PR: Consent. A study of contemporary topics selected from recent developments in the field.

794. *Seminar.* 1-6 Hr. PR: Consent. Seminars arranged for advanced graduate students.

795. *Independent Study.* 1-6 Hr. PR: Consent. Faculty supervised study of topics not available through regular course offerings.

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798. *Dissertation.* 2-4 Hr. PR: Consent. Note: this is an optional course for programs that believe that this level of control and supervision is needed during the writing of their student's reports, thesis, or dissertations. (Grading may be S/U.)

799. *Graduate Colloquium.* 1-6 Hr. PR: Consent. For graduate students not seeking coursework credit but who wish to meet residence requirements, use the University's facilities, and participate in its academic and cultural programs. Note: graduate students not actively involved in coursework or research are entitled, through enrollment in his/her department's graduate colloquium, to consult with graduate faculty, participate in both formal and informal academic activities sponsored by his/her program, and retain all of the rights and privileges of duly enrolled students. (Grading is S/U; colloquium credit may not be counted against credit requirements for master's programs.)

Department of Mechanical and Aerospace Engineering
Ever J. Barbero, Ph.D., Chair
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http://www.mae.cemr.wvu.edu/

Degrees Offered

Master of Science in Mechanical Engineering
Master of Science in Aerospace Engineering
Master of Science in Engineering with a major in Mechanical or Aerospace Engineering
Doctor of Philosophy in Engineering with a major in Mechanical or Aerospace Engineering

Faculty

Faculty members in the department have extensive industrial and teaching experience and have published widely. Their combined experience helps them assist students in selecting relevant courses and research topics to meet their educational goals. The department has extensive laboratory space in the Engineering Sciences Building and in the Engineering Research Building to provide support for both instructional and research activities. The department has several special laboratories located nearby, which include the engine research center, the wind tunnel laboratory, and the aircraft-flight test hangar at the Morgantown Municipal Airport (Hart Field). Funded research allows the department to maintain up-to-date instrumentation, equipment, and facilities, including computer-controlled data acquisition systems for laboratory use.

Graduate Programs

The objectives of the departmental graduate-level programs are: 1.) to provide master's- level education for students in or entering the engineering profession and/or 2.) to provide an advanced graduate educational experience for students pursuing the doctoral degree. Three master's degrees are offered in the department: the master of science in aerospace engineering (M.S.A.E.), the master of science in mechanical engineering (M.S.M.E.), and the master of science in engineering (M.S.E.) with a major in mechanical engineering or aerospace engineering. The department also offers the doctor of philosophy (Ph.D.) degree with majors in mechanical engineering or aerospace engineering.

An application package can be obtained from the Graduate Program Director, Department of Mechanical and Aerospace Engineering, West Virginia University, P.O. Box 6106, Morgantown, WV 26506-6106. Application material and information are also accessible on line at www.mae.cemr.wvu.edu

Admission to Master's Programs

To be eligible for admission into the M.S.A.E. or M.S.M.E. degree program, a candidate must hold or expect to receive (by the enrollment date) a B.S.A.E. or B.S.M.E. degree from either an accredited ABET curriculum or an internationally recognized program. Candidates with superior academic records in baccalaureate degrees in other engineering fields, mathematics, or science may be eligible for admission into any of the master's programs offered by the department but will normally be required to attain a baccalaureate level of proficiency in certain engineering areas of the department. An engineering technology (non-calculus based) degree is not sufficient qualification for admission into any of the graduate programs offered by the department.

Admission to Doctor of Philosophy Program

To be eligible for admission into the doctor of philosophy degree program, a candidate must hold or expect to receive (by the enrollment date) a M.S. degree in some discipline of and engineering discipline from an institution which has an ABET accredited undergraduate program in engineering or an internationally recognized program in engineering. Qualified candidates holding a M.S. degree in applied sciences can also be considered for admission into the Ph.D. program.

Regular Admission Requirements

The other requirements for admission into the graduate programs of the department are summarized as follows:

- To be admitted as a regular graduate student, an applicant must have a grade point average of 3.0 or better (out of a possible 4.0) in all previous college work and must meet all other requirements listed below.
- The applicant must first submit a completed application, application fee, and transcripts of all college work (directly from the institution) to the WVU Office of Admissions and Records.
- Each applicant is required to have three reference letters (using standard forms available from the department) sent directly to the department; at least two of the three references should be from the institution last attended.
- A minimum score of 550 on the paper-based TOEFL or a 213 on the computer-based TOEFL is required of all applicants from countries where the native language is not English. (This requirement will be waived for applicants who have completed a recent four-year bachelor's degree in the USA.)
- All international applicants who have not received their undergraduate degree in the USA are required to submit GRE general test scores with the engineering subject test score being optional.

Provisional Admission

An applicant not qualifying for the regular graduate student admission status, either due to insufficient grade point average, incomplete credentials, or inadequate academic background, can be admitted as a provisional student. Requirements for attaining regular student status must be stated in a letter of admission. Provisional students must sign a contract, which lists in detail all requirements to be met for attaining regular student status, no later than their first registration.

All of the degree programs require the student to attain an overall grade point average of 3.0 or higher in order to meet graduation requirements. The grade point average is calculated on the basis of courses and excludes credit for research, for which a grade of S or U may be received.

Courses

Only courses with grades of C or higher are acceptable for graduate credit, although all coursework taken will be counted in establishing the student's grade point average. No more than nine hours of 400-level credit can be counted toward meeting the coursework requirements for the M.S. degree. For the Ph.D., requirement degree even though the absolute minimum set by the college is 18 hours of coursework at the 500-level or higher taken at WVU, the actual minimum is set by the student's Advisory and Examining Committee and is based on the student's background and the area of dissertation. No more than 20 percent of the coursework for a doctoral degree can be at the 400 level. A minimum of 24 semester hours of research credit at the Ph.D. level is required to meet dissertation requirements. Two semesters of full-time attendance at the WVU campus in Morgantown are necessary to meet residency requirements in the Ph.D. program.

Math Requirements

The Department of Mechanical and Aerospace Engineering requires that the graduate coursework include six hours of advanced mathematics for the M.S. programs of study and a minimum of six additional hours of mathematics for the Ph.D. programs. A list of mathematics courses approved for graduate credit can be obtained from the graduate program director of the department.

Time Limitations

All requirements for a master's degree must be completed within eight years preceding the student's graduation. Students should petition for admission to candidacy for the graduate degree during the first semester of residency by filing a plan of study approved by his or her Advisory and Examining Committee. A minimum of 30 credit hours of coursework (including research) is required for the M.S. degree. Students must pass a final examination administered by their Advisory and Examining Committee before being certified for the degree.

Doctor of Philosophy

The doctorate is a research or performance degree which requires the accumulation of only 18 credit hours of coursework. The remaining requirements for the degree are: passing of the qualifying examination, admission to candidacy, residency, completion of dissertation research, and defense of a research dissertation. At least one member of the graduate faculty from outside the department is required to serve on the Advisory and Examining Committee.

The Ph.D. degree signifies that the holder has the competence to function independently at the highest level in the chosen field. Hence, the number of years involved in attaining or retaining competency cannot be readily specified, nor can an exact program of study be defined. The coursework taken should be sufficient to broaden the student's background in at least one other area of the department in addition to the major area of study.

Ph.D. Qualifying Exam

The Ph.D. qualifying/candidacy examination is the method of assessing whether the student has attained sufficient knowledge of the discipline and supporting fields in order to undertake independent research or practice. Students are required to pass a qualifying examination administered by the department which tests for a minimum level of proficiency expected of all students in a given area. It is expected that students will take the qualifying exam during their first semester of enrollment in the Ph.D. program; however it is required that full-time students pass the qualifying examination no later than the end of the second semester of their Ph.D. program. As the student progresses, his or her Advisory and Examining Committee is charged with evaluating the student's competency in the specific area of study through the evaluation of a dissertation

proposal for the research to be completed and the evaluation of the student's plan of study and associated coursework. After these requirements are completed, the student is formally admitted to candidacy for the Ph.D. degree. Only at this point can a student be called a doctoral candidate; admission to the graduate program for the purpose of pursuing the Ph.D. is not equivalent to becoming a Ph.D. candidate. Doctoral candidates are allowed no more than five years to complete the remaining degree requirements after admission to candidacy. An extension of time can be obtained only by repeating the qualifying examination and meeting any other requirements specified by the student's Advisory and Examining Committee.

M.S.A.E. Degree

Students wishing to pursue a program leading to an M.S.A.E. degree are required to have a B.S.A.E. or B.S.M.E. from an accredited ABET curriculum or the equivalent. Students with an engineering background other than aerospace or mechanical engineering or holding a B.S. degree in applied science, normally will be required to strengthen their background. Plans of study must comply with the rules and regulations outlined in the general requirements for graduate work in the College of Engineering and Mineral Resources. The student's plan of study is formulated jointly by the student and his or her Advisory and Examining Committee. Normally, a thesis is required of all candidates for the degree of master of science in aerospace engineering.

Course Requirements

The plans of study for the M.S.A.E. degree must include six semester-hours of advanced mathematics beyond a first course in differential equations, and at least 12 semester hours of courses taken from any area of the MAE department. The remainder of the coursework may consist of other courses from mechanical and aerospace engineering, other departments in the College of Engineering and Mineral Resources, or advanced coursework in mathematics, chemistry, and physics. A maximum of six hours of research credit is counted toward degree requirements for thesis work.

M.S.M.E. Degree

Students wishing to pursue a program leading to an M.S.M.E. degree are required to have a B.S.M.E. or B.S.A.E. from an accredited ABET curriculum or its equivalent. Students with an engineering background other than mechanical or aerospace engineering or holding a B.S. degree in applied science, normally will be required to strengthen their background.

The plan of study must include at least six hours of advanced mathematics beyond a first course in differential equations, and at least 12 semester hours of courses from selected areas of study in mechanical engineering. Students are normally required to write a thesis. On occasion, part-time off-campus students may be given permission to substitute a problem report for a thesis when they can present compelling evidence of equivalent experience. A maximum of six hours of research credit is counted toward meeting degree requirements for the thesis option; a maximum of three hours of research credit is counted for the problem report option. The student's plan of study is formulated jointly with his or her Advisory and Examining Committee based upon the interests and educational goals of the student.

M.S.E. Degree

The M.S.E. programs with a major in mechanical engineering or in aerospace engineering are intended for students who wish to pursue graduate work in these areas but do not have an undergraduate degree in either discipline. Students desiring to pursue such a program in the department must meet similar general requirements as for the M.S.A.E. and M.S.M.E. degree programs.

Each plan of study in the M.S.E. program must include six hours of advanced mathematics and nine hours from each of any two academic areas in the department. Students are normally required to write a thesis. On occasion, part-time on-campus students may be given permission to substitute a problem report for a thesis when they can present compelling evidence of equivalent experience. A maximum of six hours of research credit is counted toward meeting degree requirements for the thesis option; a maximum of three hours of research credit is counted for the problem report option. The student's plan of study is formulated jointly with his or her Advisory Committee based upon the interests and educational goals of the student.

Ph.D. Degree

Students intending to pursue a doctoral program in the College of Engineering and Mineral Resources with an emphasis in mechanical or aerospace engineering should have earned a B.S. or an M.S. degree in some engineering discipline. Qualified candidates holding a M.S. degree in applied sciences can also be

considered for admission into the Ph.D. program. While it is possible for a student with a B.S. degree to enroll directly in the Ph.D. program, it is very rarely permitted, only for exceptional student.

The doctoral courses of study are selected to fit the individual interests and objectives of the student, with proper attention given to broadening related areas of study. The research work for the doctoral dissertation may entail a fundamental investigation into a specialized area or a broad and comprehensive study in a related subject.

Academic Areas

Courses in the department are organized under four academic areas: aerodynamics and fluids; materials and structures; design and manufacturing; and thermal sciences and controls systems. Students who are pursuing an advanced degree in either mechanical or aerospace engineering may work in one of these areas. In addition, students may pursue studies leading to a specialization in bioengineering.

Fluids and Aerodynamics

A variety of courses and facilities support graduate research in aerodynamics and fluid mechanics. Laboratories are located in college buildings and remote sites. Flow facilities include instrumented subsonic and supersonic wind tunnels, shock tubes, and several flow loops mainly used for research in gas-solid and density stratified flows. Available instrumentation includes eight channels of hot wire/film anemometry, two single-component and one three-component, laser doppler velocimeter (LDV) systems. The department owns well-instrumented V/STOL flight test aircraft housed in hangar facilities at Hart Field. A significant portion of the current activity involves numerical solutions to flow problems and is supported by a computing facility dedicated to graduate research.

Although the faculty background and interests in the areas of aerodynamics and fluid mechanics are broad, recent research has been concentrated on problems in multiphase and density-stratified flows, low-speed aerodynamics, shock phenomena in two-phase systems, flow in microgravity, boundary layer control, and high-speed aerodynamics. These research areas include topics such as fluidized bed combustion, aerosol sampling, flow metering, flow distribution systems, numerical solutions to gas-solid flows, and fluid-particle turbulence interactions, including deposition on solid surfaces. The low-speed aerodynamics work is related to the design of vertical axis wind turbines and STOL airfoils. The research in high-speed aerodynamics deals with viscous-inviscid interactions in transonic, supersonic, and hypersonic flow.

Structures and Materials

The materials and structures area encompasses the theoretical, numerical, and experimental study of solid bodies, from concentration on local behavior of deformable bodies to the global response of structural elements. Hence, students may explore the mechanical behavior of materials in the neighborhood of micro-scale defects such as cracks, or investigate the behavior of large-scale bodies such as aerospace structures.

The faculty carries out basic and applied research related to problems in engineering using state-of-the-art computational and experimental techniques. The areas of research include aeroelasticity, fracture mechanics, nonlinear dynamics and vibrations, composite materials, biomechanics, computational methods such as finite-element and boundary-element, and experimental techniques, including optical methods. Furthermore, in cooperation with the Department of Civil and Environmental Engineering, MAE graduate students may pursue studies related to civil engineering. A large array of research facilities includes laboratories (materials, structures, vibrations, photomechanics, biomechanics, fracture mechanics, and computer-aided engineering), computers (work stations, personal computers, and supercomputers), and shop facilities.

Regardless of the chosen topic of specialty, the student is required to take six hours of courses from a core group consisting of MAE 543, MAE 641, and an introductory FEM course. This requirement may be waived for students who can demonstrate that they possess equivalent knowledge. These courses, combined with the entire plan of study, including research credits, prepare the SMMS student to apply mechanics to modern engineering challenges.

Design and Controls

The system control and design area offers instructional and research opportunities for students who want to challenge themselves to attain the expertise required to design or control the behavior of a system in a dynamic environment. Instructional offerings furnish students with a foundation for developing prototype systems and for improving the performance of existing systems. Selected examples of research areas include

flight simulation and controls instrumentation and testing, elastodynamic analysis, computerized design, active control in automated machines, and manufacturing systems engineering.

The research endeavors of the faculty reflect a close association with current industrial-type situations. Faculty are entirely performing research in the areas of engine modeling, energy systems, CAD, process control, microprocessor applications, and computer-aided manufacturing.

Thermal Sciences

The thermal sciences and engineering area encompasses the fields of thermodynamics, combustion, heat transfer, and power and energy systems. Graduate course offerings cover a wide range of topics in this area with applications to both aerospace and mechanical engineering problems. Recent research efforts include topics such as the analysis of fluidized bed combustion, energy analysis of buildings, oscillating jet combustion, alternative fuels testing, internal combustion engine performance and emissions, heat transfer, numerical analysis of thermal systems, deposition on turbine blades, and reactor design.

Research facilities include a high-altitude simulation chamber for ablation and wear studies, a fluidized bed combustion laboratory, thermal analyzers, an electrically-heated, natural convection water facility, Schlieren systems for flows with varying density, recording thermocouple data-acquisition systems, a water reservoir for thermal stratification studies, an engine research laboratory, and an emissions research laboratory.

Bioengineering

Areas of research specialization related to bioengineering include respiratory and diseased tissue mechanics, orthopedic mechanics, bone growth and fracture, and the application to rehabilitation of computer-aided design and microprocessor-based instrumentation. Research facilities include an aerosol inhalation exposure system, laser-based holographic and moire interferometric equipment, a lung acoustic impedance measurement system, and modern orthopedic, rehabilitation, and computer research laboratories.

Mechanical and Aerospace Engineering (MAE)

515. *Analytical Methods in Engineering.* 3 Hr. PR: Consent. Index notation for determinants, matrices, and quadratic forms; linear vector spaces, linear operators including differential operators; calculus of variations, eigenvalue problems, and boundary value problems.

521. *Advanced Thermodynamics 1.* 3 Hr. PR: MAE 321 or MAE 426. First and second laws of thermodynamics with emphasis on entropy production and availability (energy); Maxwell's relationships and criteria for stability; equations of state and general thermodynamic equations for systems of constant chemical composition.

531. *Fluid Mechanics 1.* 3 Hr. PR: MAE 331 or Equivalent. Advanced dynamics and thermodynamics of fluids. Basic laws of conservation of mass and momentum in differential, vector, and integral forms. Application to internal flows, fluid machinery, and structures.

532. *Dynamics of Viscous Fluids.* 3 Hr. PR: Consent. Derivation of and exact solutions for the Navier-Stokes equations; laminar boundary-layer theory, similarity solutions, and integral methods.

534. *Fluid Flow Measurements.* 3 Hr. PR: MAE 336 or Consent. Principles and measurements of static and dynamic pressures and temperatures, velocity, and Mach number and forces. Optical techniques and photography. Design of experiments. Review of selected papers from the literature. 2 hr. lec., 3 hr. lab.

543. *Advanced Mechanics of Materials.* 3 Hr. PR: Consent. Shear flow and shear center; curved beams; unsymmetric bending, energy methods in structural analysis; theories of failure; instability of structures; beams on elastic foundation.

593 A-Z. *Special Topics.* I, II, S. 1-6 Hr. A study of contemporary topics selected from recent developments in the field.

615. *Nonlinear Analysis in Engineering.* 3 Hr. PR: Consent. Special topics in nonlinear analysis of various types of engineering systems. Various numerical approximate and analytical techniques chosen to suit the needs and interests of advanced graduate students.

621. *Advanced Thermodynamics 2.* 3 Hr. PR: MAE 521 or Consent. Thermodynamics of multi-component inert and reacting systems; equilibrium analysis; introduction to irreversible processes involving diffusion and chemical kinetics; application of concepts to heterogeneous systems.

623. *Conduction Heat Transfer.* 3 Hr. PR: MAE 423 or Consent. Analytical and numerical solutions of steady and non-steady heat conduction problems in one-, two-, and three -dimensional bodies; solution of linearized equations; applications include extended surfaces, moving surfaces, moving heat sources, and instrumentation techniques.

624. *Convection Heat Transfer.* 3 Hr. PR: MAE 423 or Consent. Laminar and turbulent flows in forced and free convection systems; external and internal flows with application to heat exchanger design; introduction to aerodynamic heating.

625. *Radiation Heat Transfer.* 3 Hr. PR: MAE 423 or Consent. Classical derivation of black body radiation laws; gray body and non-gray analysis; radiant properties of materials, radiant transport analysis, specular-diffuse networks, gas radiation, thermal radiation measurements; analytical, numerical solutions, and study of selected publications. 3 hr. lec.

631. *Gas Dynamics.* 3 Hr. PR: MAE 336 or equivalent. Nonsteady gas dynamics and shock interactions; compressible flow theory in subsonic, transonic, and supersonic regimes, and their numerical treatment.

633. *Computational Fluid Dynamics.* II. 3 Hr. PR: MAE 532 or equivalent. Finite difference methods; convergence and stability; Navier-Stokes equations; discretization methods; grid distribution; solution of difference equations; pressure coupling; application to conduction/convection, boundary layers, and recirculating flows; introduction to general purpose CFD codes.

635. *Turbomachinery.* 3 Hr. PR: MAE 320 or Consent. Flow problems encountered in design of water, gas, and steam turbines, centrifugal and axial flow pumps and compressors, design parameters.

637. *Multiphase Flows.* 3 Hr. PR: MAE 331. Particle dynamics including particle-particle and particle-surface interactions; fluidized bed concepts; mathematical models and numerical methods as applied to multiphase flows; design and instrumentation pertaining to multiphase units.

640. *Continuum Mechanics.* 3 Hr. PR: MAE 242 and MAE 243. Mathematical preliminaries including index notation; analysis of stress; analysis of deformation; fundamental laws, field equations, and constitutive equations; application to fluids and solids.

641. *Theory of Elasticity 1.* 3 Hr. PR: MAE 132 or Consent. Cartesian tensors; plane stress and plane strain; 2-D problems in Cartesian and polar coordinates; stress and strain in 3-D; general theorems; torsion of noncircular sections.

642. *Intermediate Dynamics.* 3 Hr. PR: MAE 242. Newtonian and Lagrangian mechanics. Dynamics of discrete systems and rigid bodies analyzed utilizing Newtonian and Lagrangian formulations.

643. *Inelastic Behavior of Engineering Materials.* 3 Hr. PR: MAE 543 or Consent. Characterization and constitutive relations of engineering materials; nonlinear elasticity, plasticity, viscoelasticity and creep; numerical implementation.

644. *Fracture Mechanics.* 3 Hr. PR: MAE 641. Linear-elastic and elastic-plastic fracture mechanics; fatigue, dynamic, and creep crack growth; fracture mechanics models for composite materials.

645. *Energy Methods in Applied Mechanics.* 3 Hr. PR: Consent. Variational principles of mechanics and applications to engineering problems; principles of virtual displacements, minimum potential energy, and complementary energy, Castigliano's theorem, Hamilton's principle. Applications to theory of plates, shells, and stability.

646. *Advanced Mechanics of Composite Materials.* 3 Hr. PR: MAE 446 or Consent. Manufacturing, testing, and diagnostics of composite materials. Anisotropic plates with cutouts. Inelastic behavior of polymer matrix composites. Analysis of advanced composites such as metal matrix, ceramic matrix, and textile.

648. *Experimental Stress Analysis.* 3 Hr. PR: MAE 132 or Consent. Strain gage techniques and instrumentation; stress analysis using optical methods such as photoelasticity and interferometric techniques; NDE and NDT or problems involving stress analysis. (2 hr. lec., 3 hr. lab.)

649. *Microscopy of Materials.* 3 Hr. PR: CHE 366 or Consent. Optical and electron microscopic principles and techniques. Sample preparation methods. Microstructures of engineering materials. Laboratory demonstrations and experiments.

650. *Mechanical Metallurgy.* 3 Hr. PR: MAE 52 and MAE 132 or Consent. Elastic behavior and plastic theory. Dislocation theory. Strengthening mechanisms and fracture. Mechanical properties from materials testing including tension, torsion, fracture toughness, fatique, and creep.

652. *Advanced Kinematics of Mechanisms.* 3 Hr. PR: MAE 452 or Consent. Analytical synthesis of mechanisms with up to five accuracy points; Burmester curve theory and path curvature theory; force and moment balancing of mechanisms; computer-aided dynamic analysis of mechanisms and inverse dynamic analysis.

653. *Advanced Vibrations.* 3 Hr. PR: MAE 122 or Consent. Dynamic analysis of multiple degree-of-freedom discrete vibrating systems; Lagrangian formulation; matrix and numerical methods; impact; mechanical transients.

654. *Advanced Machine Design.* 3 Hr. PR: MAE 135 or Consent. Design for extreme environments, material selection, lubrication and wear, dynamic loads on cams, gears, and balancing of multiengines and rotors, electromechanical components.

656. *Advanced Computer Aided Design.* I. 3 Hr. PR: MATH 156 (C or better) or consent. MAE 493C Professional Engineering CAD or consent.Geometric modeling; finite element meshing; design approaches, case studies using CAD principles; projects utilizing state-of- the-art CAD packages. (2 hr. lec., 3 hr. lab.)

660. *Feedback Control in Mechanical Engineering.* 3 Hr. PR: MAE 122 or Consent. Emphasis on design of control systems using classical, frequency domain, and time domain methods; advanced mathematical modeling of physical systems, compensation, stabilization, pole placement, state estimation; extensive use of computerized design tools, especially Matlab.

662. *Robot Mechanics and Control.* 3 Hr. Kinematic and dynamic behavior of industrial robot manipulators; formulation of equations of motion for link joint space and end effector Cartesian space; path planning and trajectory motion control schemes.

663. *Instrumentation in Engineering.* 3 Hr. PR: Consent. Theory of instrumentation suitable for measuring rapidly changing force, pressure, strain, temperature, vibration, etc.; computerized acquisition, analysis, and transmission of data; methods of noise reduction. (2 hr. lec., 3 hr. lab.)

687. *Materials Engineering.* 3 Hr. A study of materials engineering fundamentals emphasizing semiconductor, polymer, metal, and ceramic/cementitious material systems. Mechanical and physical properties, theoretical aspects, testing, design criteria, manufacturing, and economics of material systems. Laboratory testing and evaluation. (Equivalent to CE 687, CHE 687, EE 687, MINE 687, and IMSE 687.)

691. *Advanced Topics.* I, II, S. 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

693 A-Z. *Special Topics.* I, II, S. 1-6 Hr. A study of contemporary topics selected from recent developments in the field.

694. *Seminar.* I, II, S. 1-6 Hr. PR: Consent. Seminars arranged for advanced graduate students.

695. *Independent Study.* I, II, S. 1-6 Hr. PR: Consent. Faculty supervised study of topics not available through regular course offerings.

697. *Research.* I, II, S. 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

721. *Fundamentals of Combustion.* 3 Hr. PR: MAE 321 or MAE 426. Thermodynamics, chemical kinetics, and diffusion of reacting gases; laminar and turbulent flames; flame stability and ignition.

731. *Fundamentals of Turbulent Flow.* 3 Hr. PR: MAE 532 or Consent. Basic experimental data. Application of semi-empirical theories to pipe, jet, and boundary layer flow. Turbulent heat and mass transfer. Statistical theory of turbulence and recent applications.

733. *Perfect Fluid Theory.* 3 Hr. PR: Consent. Conformal mapping including Schwarz-Christoffel and Joukowski transformations. Inviscid flows over airfoils, spheres, cones, wedges, and bodies of revolution. (3 hr. lec.)

735. *Hydrodynamic Stability Theory.* 3 Hr. PR: MAE 532 or MAE 733 or Consent. Response of flow field to disturbances; classical instability mechanisms; inviscid centrifugal instabilities; inviscid parallel shear flow stability; viscous boundary layer stability, the Orr-Sommerfield equation; Rayleigh-Benard flow; introduction to nonlinear stability theory.

741. *Theory of Elasticity 2.* 3 Hr. PR: MAE 641. Complex variable methods, stress couples, nonlinear elasticity, numerical methods, potential methods, boundary value problems, various special topics.

742. *Advanced Dynamics.* 3 Hr. PR: MAE 642 or Consent. Analytical mechanics. Stability of autonomous and nonautonomous systems considered and analytical solutions by perturbation techniques introduced. Hamilton-Jacobi equations developed. Problems involving spacecraft, gyroscopes, and celestial mechanics studied.

743. *Theory of Elastic Stability.* 3 Hr. PR: ME 641. Stability of discrete mechanical systems, energy theorems, buckling of beams, beam columns and frames, torsional buckling, buckling of plates and shells, special topics.

744. *Theory of Plates and Shells.* 3 Hr. PR: MAE 543 or Consent. Classical and modern theories of plates; dynamic response, nonlinear effects, and exact and approximate solutions of plates; application to rectangular and circular plates; membrane shells; shells with bending stiffness.

760. *Advanced Topics in Control Theory.* 3 Hr. PR: MAE 660 or MAE 465. State feedback through eigenstructure assignment; Observers and Kalman filters; multiple-model adaptive estimation and control; parameter estimation; direct and indirect model-reference adaptive-control algorithms; introduction to neural networks.

790. *Teaching Practicum.* I, II, S. 1-3 Hr. PR: Consent. Supervised practice in college teaching of College of Engineering and Mineral Resources. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.)

791. *Advanced Topics.* I, II, S. 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

795. *Independent Study.* I, II, S. 1-6 Hr. Faculty supervised study of topics not available through regular course offerings.

797. *Research.* I, II, S. 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

798. *Dissertation.* 2-4 Hr. PR: Consent. Note: This is an optional course for programs that believe that this level of control and supervision is needed during the writing of their student's reports, thesis, or dissertations. (Grading may be S/U.)

799. *Graduate Colloquium.* I, II, S. 1-6 Hr. PR: Consent. For graduate students not seeking coursework credit but who wish to meet residence requirements, use the University's facilities, and participate in its academic and cultural programs. Note: graduate students not actively involved in coursework or research are entitled, through enrollment in his/her department's graduate colloquium, to consult with graduate faculty, participate in both formal and informal academic activities sponsored by his/her program, and retain all of the rights and privileges of duly enrolled students. (Grading is S/U; colloquium credit may not be counted against credit requirements for master's programs.)

Department of Mining Engineering
Christopher John Bise, Ph.D., Chairperson
365A Mineral Resources Building
http://www.cemr.wvu.edu/%7Ewwwmine/

Degree Offered

Master of Science in Mining Engineering
Doctor of Philosophy in Engineering with a major in Mining Engineering

Master of Science in Mining Engineering (M.S.Min.E.)

Students desiring to take courses for graduate credit at the master's level in the College of Engineering and Mineral Resources must first apply for admission and state a major field.

Applicants with a baccalaureate degree from institutions other than WVU in mining engineering will be admitted on the same basis as graduates of WVU. Lacking these qualifications, the applicant must first fulfill the requirements of the Department of Mining Engineering.

Academic Standards

Each student will, with the approval of the student's Graduate Committee (appointed with the consent of the student within the first semester of registration), follow a planned program. The program contains a minimum of 24 hours of coursework and six hours of independent and original study in mining engineering leading to a master's thesis. At least 60 percent of the course credits must be from 600-level or 700-level courses while the remainder can be made up of 400-level courses.

Approval for candidacy for a graduate degree by faculty action is required to establish eligibility for a degree. A graduate student may request approval by formal application after completing a minimum of 12 semester hours of graduate courses with a grade point average of at least 3.0 (B), based on all graduate courses in residence for which final grades have been recorded.

No credits are acceptable toward an advanced degree which are reported with a grade lower than C. To qualify for an advanced degree, students must have a grade point average of at least 3.0 based on all courses completed in residence for each graduate credit. Each candidate for a degree must select a major subject and submit a thesis showing independent, original study in mining engineering.

Doctor of Philosophy in Engineering (Ph.D.MinE)

The principal objective of the Doctor of Philosophy program in mining engineering is the education and training of graduates so that they are capable of attaining the highest levels in the mineral engineering profession and performing the professional roles of developing and improving the efficient extraction of solid mineral resources. The three areas of specialization are mine systems, rock mechanics and ground control, and mineral/coal processing.

All applicants must have earned an M.S. degree in mining engineering with a GPA of 3.5 or higher. For all foreign applicants whose native language is not English, a TOEFL test score of 550 or better is required. In addition, each applicant is required to submit at least three letters of recommendation, one of which must be from the applicant's previous thesis advisor or an academic equivalent. All letters of recommendation should evaluate the student's potential for performing independent doctoral-level research.

The Ph.D. program in mining engineering consists of 54 hours of coursework and 30 hours of independent research beyond a bachelor's degree in mining engineering. The successful completion of a qualifying examination and an approved dissertation are also required.

Mining Engineering (MINE)

611. *Advanced Ground Control-Coal Mines.* I, II. 3 Hr. PR: MINE 411 or Consent. Ground and strata control for underground and surface coal mining, including slope stability and subsidence.

612. *Surface Subsidence Engineering.* II. 3 Hr. PR: MINE 411. Elements of surface subsidence engineering due to underground mining: theories of surface subsidence, characteristics and prediction of surface movements, and effects of surface movements.

613. Ground Control Failures. 3 Hr. PR: MineE 611 or Consent. Case studies of ground control failures on coal pillar, roof bolting, roof fall, cutter, floor heave, mulitple-seam mining, and longwall mining.

616. *Advanced Rock Mechanics.* I. 3 Hr. PR: MINE 414 or Consent. Testing techniques and interpretation, strength and fracture, classification, anisotropy, friction, jointed rock, fluid pressure, fragmentation, and excavation.

620. *Mobile Excavating and Materials Handling.* I. 3 Hr. PR: Graduate standing and Consent. Mobile mining equipment will be systematically analyzed as to functional, failure, production, and operational aspects. Included will be routine and innovative methods, and surface and underground applications, such as the hydraulic shovel and impactors.

621. *Integrated Excavating and Materials Handling.* II. 3 Hr. PR: Graduate standing and consent. Integrated mining equipment will be systematically analyzed as to functional, production, failure, and operational aspects. Included will be routine and innovative methods, and surface and underground applications, such as the longwalls and monorails.

625. *Advanced Mineral Processing.* I. 3 Hr. PR: MINE 327 or Consent. Theory and technology of separation. Triboelectrostatic and magnetic dry ore and coal separation. Engineering and scientific aspects of column flotation of fines in coal and mineral industries.

627. *Advanced Coal Preparation.* I. 3 Hr. PR: MINE 427 or Consent. Coal preparation design and analysis. Fine coal column flotation, agglomeration, and dewatering. Biotechnology and others for HAPs removal. Coking and coal utilization. Instrumentation for process control.

628. *Comput Fluid Flow Mineral Engineering*. 3 Hr. PR: Grad Standing or Consent. Applications of appropriate theories for solving fluid transportation problems in mineral engineering. Newtonian and non-Newtonian slurries applications to mineral engineering are emphasized.

629. *Mine Wastes Management/Closure.* 3 Hr. PR: Graduate Standing or Consent. Planning and design to control, detoxificate and contain mine openings for mine and mill closure in mineral industry. Regulatory frameworks.

631. *Mine Ventilation Network Analysis.* II. 3 Hr. PR: MINE 331 and MINE 281 or consent. Theory and computational techniques for mine ventilation network problems with emphasis on computer-aided analysis of complex mine ventilation systems.

632. *Advanced Mine Ventilation.* II. 3 Hr. PR: MINE 331. Advanced topics in mine atmospheric control including control of methane, dust, humidity, and heat. Also covers leakage characteristics, fan selection, analysis of ventilation networks, and planning of mine ventilation system.

633. *Coal Mine Methane Control.* 3 Hr. PR: Graduate standing or Consent. Control of explosive gas emissions in coal mines. Procedures for measurement, mitigation, capture, and utilization of mine-generated gases. Techniques for gas emission forecasting.

642. *Advanced Mine Health and Safety.* I. 3 Hr. PR: MINE 342 or Graduate standing. Special emphasis will be placed on mine rescue, mine disaster prevention and organization, and mine property and equipment loss prevention.

651. *Explosive Engineering Design.* II. 3 Hr. PR: MINE 251 or Consent. Rock drilling, total blast systems simulation, experimental studies in blast design, rock fracturing, chemical thermodynamics, kinetics, and reaction rates.

661. Num Analysis for Mine Design. 3 Hr. PR: Graduate Standing or Consent. An introduction to the formulation and application of boundary-element, finite-differance, and discrete element methods for geomechanical design of mines and geologic structures.

662. Disp Disc Modeling in Mining. 3 Hr. PR MINE 661 or Consent. An indepth look into the formulation and application of the displacement discontinuity method for modeling stresses and displacements in single and multi-seam coal mines.

663. Geomech Modeling with FLAC. 3 Hr. PR: MINE 661 or Consent. An indepth study of the application of the finite-difference program, FLAC, for modeling static and dynamic scenarios in mining, geologic and soil structure.

665. *Deterministic Methods for Mineral Engineers.* I. 3 Hr. PR: Graduate standing or Consent. Analysis and solution of mineral engineering problems which require use of deterministic models. Application of deterministic methods to mineral transportation, mineral resource allocation and extraction problems, and mine planning and equipment utilization problems.

666. *Stochastic Methods for Mineral Engineers.* II. 3 Hr. PR: Graduate standing or consent. Application of stochastic methods to mineral engineering problems in equipment selection, renewal processes, mine ventilation, mine production, and mineral extraction.

671. *Mine Production and Cost Management.* I, II. 3 Hr. PR: MINE 281, MINE 471. Planning manpower and material requirements for different mining methods, forecasting productivity from production sections, analysis of mine cost components, scheduling and control of mine operations, integrated optimization of mine cost and productivity.

685. *Graduate Seminar in Coal Mining.* 3-6 Hr.

686. *Graduate Seminar Coal Mine.* 3-6 Hr.

687. *Materials Engineering.* 3 Hr. A study of materials engineering fundamentals emphasizing semiconductor, polymer, metal, and ceramic/cementitious material systems. Mechanical and physical properties, theoretical aspects, testing, design criteria, manufacturing, and economics of material systems. Laboratory testing and evaluation. (Equivalent to CE 687, CHE 687, EE 687, IMSE 687, and MAE 687.)

688. *Advanced Mine Design 1.* 1-6 Hr. PR: MINE 482. Detailed design of the components of coal mine subsystems including ground control, excavation and handling, and life support subsystems. (1-6 hr. lec.)

689. *Advanced Mine Design 2.* 1-6 Hr. PR: MINE 482. Examination of the broad aspects of mine design for non-coal deposits. Consideration of deposits of various shapes, materials, and qualities including country rock. Comparison of principles established for coal mine design. (1-6 hr. lec.)

691. *Advanced Topics.* I, II, S. 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

693 A-Z. *Special Topics.* I, II, S. 1-6 Hr. A study of contemporary topics selected from recent developments in the field.

695. *Independent Study.* I, II, S. 1-6 Hr. Faculty supervised study of topics not available through regular course offerings.

697. *Research.* I, II, S. 1-15 Hr. PR: Consent. Research activities leading to a thesis, problem report, research paper, or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

711. *Theories of Surface Subsidence.* 3 Hr. PR: MINE 612. Theories of surface subsidence due to underground coal mining including empirical, profile function, theoretical and physical modeling methods, and time factors. (3 hr. lec.)

712. *Theory of Pilar Design.* 3 Hr. PR: MINE 411 and MINE 611. Examination of various theories of pillar design for room and pillar mining and longwall mining including chain pillars, barrier pillars, and bleeder pillars.

713. Theory of Roof Bolting. 3 HR. PR: MINE 611 or Consent. Review and discuss various theories of roof bolting. Review select papers representative of recent development of design of roof bolts, and selection of materials.

716. *Theory of Rock Failure.* I. 3 Hr. PR: MINE 414 or Consent. Friction, elasticity, strength of rock, mechanism of brittle failure, factors affecting failure process, theories of failure, fracture propagation in rock, fracture toughness of rock and coal, fluid pressure, size, stress gradient, and time-dependent effects.

717. *Laboratory and Field Instrumentation.* I. 3 Hr. PR: MINE 411 and MINE 414 or Consent. Principles and applications of strain gages and photoelasticity for stress analysis in rock/coal; displacement/velocity gages and accelerometer for ground motion; holography and acoustic emission for nondestructive tests.

718. *Rock Mechanics in Mine Design.* II. 3 Hr. PR: MINE 411 and MINE 414 or Consent. Design process in mining engineering; design approaches for excavations in rock; input parameters for design; empirical, observational, and analytical methods of design; integrated designs. (1 hr. lec., 2 hr. lab.)

731. *Mine Ventilation Network Optimization.* I. 3 Hr. PR: MINE 631 or Consent. Application of mathematical optimization techniques to mine ventilation network problems, including linear and nonlinear optimization for controlled-flow and generalized networks.

751. *Theory of High Explosives.* II. 3 Hr. PR: MINE 651 or Consent. The application of chemical thermodynamics and the hydrodynamic theory to determine properties of high explosives, chemical equilibria, and calculation of detonation and explosion-state variables.

765. *Optimization Applications in Mining.* 3 Hr. PR: Graduate standing and MINE 367. Detailed study and use of optimization techniques to solve mining problems, including programming techniques for large-scale linear, mixed-integer and 0-1, dynamic, nonlinear, and heuristic programming.

769. *Expert Systems in Mining.* II. 3 Hr. PR: Graduate standing. An overview of expert systems applications in mining, a detailed study of two mining applications, study of shells and their components, and study of a specific shell used to develop a project.

790. *Teaching Practicum.* I, II, S. 1-3 Hr. PR: Consent. Supervised practice in college teaching of mining engineering. Note: this course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading may be S/U.)

791 A-Z. *Advanced Topics.* I, II, S. 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

792. *Directed Study.* I, II, S. 1-6 Hr. Directed study, reading, and/or research.

793. *Special Topics.* I, II, S. 1-6 Hr. A study of contemporary topics selected from recent developments in the field.

794. *Seminar.* I, II, S. 1-6 Hr. Seminars arranged for advanced graduate students.

795. *Independent Study.* I, II, S. 1-6 Hr. Faculty supervised study of topics not available through regular course offerings.

796. *Graduate Seminar.* I, II, S. 1 Hr. PR: Consent. It is anticipated that each graduate student will present at least one seminar to the assembled faculty and graduate student body of his/her program.

797. *Research.* I, II, S. 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

798. *Dissertation.* 2-4 Hr. PR: Consent. Note: this is an optional course for programs that believe that this level of control and supervision is needed during the writing of their student's reports, thesis, or dissertations. (Grading may be S/U.)

799. *Graduate Colloquium.* I, II, S. 1-6 Hr. PR: Consent. For graduate students not seeking coursework credit but who wish to meet residence requirements, use the University's facilities, and participate in its academic and cultural programs. Note: graduate students not actively involved in coursework or research are entitled, through enrollment in his/her department's graduate colloquium, to consult with graduate faculty, participate in both formal and informal academic activities sponsored by his/her program, and retain all of the rights and privileges of duly enrolled students. (Grading is S/U; colloquium credit may not be counted against credit requirements for master's programs.)

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Degrees Offered

Master of Science in Petroleum and Natural Gas Engineering
Doctor of Philosophy in Engineering with a major in Petroleum and Natural Gas Engineering

Master of Science in Petroleum and Natural Gas Engineering

A student desiring to take courses for graduate credit at the master's level in the College of Engineering and Mineral Resources must first apply for admission and state their major field.

An applicant with a baccalaureate degree or its equivalent in petroleum or natural gas engineering from another institution will be admitted on the same basis as graduates of WVU. Lacking these qualifications, the

applicant must first fulfill the CEMR requirements of the Department of Petroleum and Natural Gas Engineering.

Each student will, with the approval of the student's Advising and Examining Committee—appointed with the consent of the student within the first semester of registration—follow a planned program. The program contains a minimum of 24 hours of coursework and six hours of independent and original study in the petroleum and natural gas engineering field leading to a master's thesis or 30 hours of coursework and three hours of independent study leading to a comprehensive problem report. At least 60 percent of the course credits must be from 500- or 700-level courses while the remainder can be made up of 400-level courses.

Doctor of Philosophy in Engineering with a Major in Petroleum and Natural Gas Engineering

A candidate for the degree of doctor of philosophy (Ph.D.) must comply with the rules and regulations of the College of Engineering and Mineral Resources and the University. In addition the applicants must meet the following requirements.

- B.S. or M.S. degree in petroleum engineering from an ABET accredited or an internationally recognized petroleum engineering program or equivalent; with a grade point average (GPA) equal to or greater than 3.0 and 3.2, respectively.
- A score of at least 75 percentile for Graduate Record Examination (GRE) quantitative analysis.
- A score of 213 or better on computer-based TOEFL or 550 or better on the paper-based TOEFL is required for international applicants whose native language is not English.
- At least three recommendation letters, one of which must be from the applicant's previous thesis advisor or an academic equivalent.

Each student will develop a program with a major in petroleum engineering, designed to meet her/his needs and objectives in consultation with an advisor and the Advisory and Examining Committee (AEC). A minimum of 54 hours of coursework and 30 hours of independent research above and beyond a bachelor degree; or 30 hours of coursework and 24 hours of independent research beyond a M.S. degree are required. The student must take and pass a written qualifying examination no later than one semester after completion of the required courses. In order to be admitted to candidacy, the student must pass the candidacy exam which is designed to evaluate the student's overall ability to engage in high-level research. At the completion of the dissertation research, the candidate must prepare a dissertation and defend it.

Petroleum and Natural Gas Engineering (PNGE)

501. *Petroleum Engineering Problems.* 1-3 Hr. PR: Senior standing. Investigation of a special problem in petroleum engineering.

532. *Introduction to Reservoir Simulation.* 3 Hr. PR or CONC: PNGE 434 or Consent. Partial differential equations for fluid flow in porous media and the use of finite-difference equations in solving reservoir flow problems for various boundary conditions. Study of individual well pressures and fundamentals of history matching.

533. *Secondary Recovery of Oil by Water Flooding.* 3 Hr. PR: PNGE 333. Theory of immiscible fluid displacement mechanism, evaluation and economics of water flood projects, and oil field flooding techniques.

601. *Fluid Flow in Porous Media.* 3 Hr. PR: PNGE 434 and MATH 261 or consent. Theoretical and practical aspects of the physical principles of hydrodynamics in porous media. (3 hr. lec.)

632. *Reservoir Simulation and Modeling.* 3 Hr. PR: PNGE 532 or Consent. Application of finite-difference equations to multi-phase fluid flow in porous media in two or three dimensions with gravity and capillary pressure effects. Simulation of waterflood performance and enhanced recovery techniques.

633. *Advanced Secondary Recovery.* 3 Hr. PR: PNGE 533. Secondary recovery of oil by gas flooding, miscible fluid injection, in-situ combustion, and heat injection.

634. *Pressure Transient Analysis.* 3 Hr. PR: PNGE 434 or Consent. Methods of analysis of pressure transient data obtained from well testing for the purpose of determining in-situ reservoir conditions including porosity, lateral extent, average reservoir pressure, and formation permeability.

691 A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

693 A-Z. *Special Topics.* 1-6 Hr. A study of contemporary topics selected from recent developments in the field.

695. *Independent Study.* I, II, S. 1-6 Hr. Faculty supervised study of topics not available through regular course offerings.

697. *Research.* I, II, S. 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

701. *Environmental Issues in Petroleum Engineering.* 3 Hr. PR: Graduate standing. Environmental impacts of petroleum exploration and production, methods to minimize or eliminate potential environmental impacts, treatment and disposal of the drilling and production wastes, and remediation methods for petroleum contaminated sites.

710. *Advanced Drilling Engineering.* 3 Hr. PR: PNGE 310. Drilling optimization, methods for estimating formation pore and fracture pressures, air drilling, application of directional drilling and deviation control, horizontal drilling, coiled tubing applications.

711. *Advanced Productions Engineering.* 3 Hr. PR: PNGE 420. Advanced well completion methods, problem well analysis, well remediation and workover planning, multi-phase flow in pipes, system approach for oil and gas wells, application of NODAL analysis, surface and subsurface production equipment.

734. *Advanced Reservoir Engineering.* 3 Hr. PR: PNGE 434. Modeling and simulation of heterogeneous reservoirs, predicting the performance of the heterogeneous reservoirs during primary, secondary, and enhanced recovery production.

735. *Advanced Formation Evaluation.* 3 Hr. PR: PNGE 450. Advanced methods for interpreting well logs, shaly sand analysis, and production logging methods.

770. *Advanced Natural Gas Engineering.* 3 Hr. PR: PNGE 470. Application of reservoir modeling, history matching, and type curves techniques to analyze and predict the performance of conventional and unconventional gas reservoirs.

790. *Teaching Practicum.* 1-3 Hr. PR: Consent. Supervised practice in college teaching of petroleum and natural gas engineering. Note: this course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading may be S/U.)

791 A-Z. *Advanced Topics.* 1-6 Hr. PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

792. *Directed Study.* 1-6 Hr. Directed study, reading, and/or research.

793 A-Z. *Special Topics.* 1-6 Hr. A study of contemporary topics selected from recent developments in the field.

794. *Seminar.* 1-6 Hr. Seminars arranged for advanced graduate students.

795. *Independent Study.* 1-6 Hr. Faculty supervised study of topics not available through regular course offerings.

796. *Graduate Seminar.* 1 Hr. PR: Consent. It is anticipated that each graduate student will present at least one seminar to the assembled faculty and graduate student body of his/her program.

797. *Research.* 1-15 Hr. PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

798. *Dissertation.* 2-4 Hr. PR: Consent. Note: this is an optional course for programs that believe that this level of control and supervision is needed during the writing of their student's reports, thesis, or dissertations. (Grading may be S/U.)