NUCLEAR ENGINEERING

The nuclear engineering graduate program offers the master of science, the doctor of engineering, and the doctor of philosophy degrees. B.S. in a field of engineering or suitable physical science is a prerequisite for admission into the nuclear engineering graduate program. The master’s degree program is designed to provide training and expertise in the design of nuclear energy systems, as of nuclear technology for medical as well as industrial applications. Both thesis and without thesis options are available for M.S. degree program with a minimum of 30 credit hours required for successful completion. Research areas of specialization include:

- Reactor design and safety
- Thermal hydraulics
- Radiation effects
- Radiation dosimetry, protection and health physics
- Radiation transport and shielding
- Space nuclear power
- Materials for nuclear applications
- Nuclear fuel cycle
- Radioactive waste management
- Radiation imaging and its applications in medicine and industry
- Radiation measurements and spectroscopy

For the Ph.D. program, a research project with a written dissertation of high caliber demonstrating candidate’s capacity to conduct independent and original research, to critically analyze results and to infer sound conclusions is necessary. The dissertation must produce original research results acceptable for publication in a refereed journal. To facilitate high quality research, the nuclear engineering program has the following laboratory facilities:

Nuclear Reactor
The Missouri University of Science and Technology Nuclear Reactor (MSTR) is a Nuclear Regulatory Commission (NRC) licensed 200 kW pool-type reactor that is used to support the engineering and science activities on campus. Using the facility, the reactor staff provides hands-on laboratory, research and development and project opportunities. The reactor itself uses uranium fuel and is cooled by natural convection in a pool containing approximately 30,000 gallons of water.

The open pool design allows access to the reactor core where experiments and samples to be irradiated can be positioned. The facility is equipped with a pneumatics sample irradiation system, a neutron beam port that provides a collimated neutron beam, and a thermal column.

Internet-Accessible Hot Cell Facility
A dual-chambered internet-accessible heavily shielded facility with pneumatic access to the Missouri S&T 200 kW Research Nuclear Reactor (MSTR) allows authorized distance users to remotely manipulate and analyze neutron irradiated samples. The system consists of two shielded compartments, one for multiple sample storage, and the other dedicated exclusively for radiation measurements and spectroscopy. The second chamber has multiple detector ports, with graded shielding, and has the capability to support gamma spectroscopy using radiation detectors such as an HPGe detector. Both these chambers are connected through a rapid pneumatic system with access to the MSTR nuclear reactor core.

The total transportation time between the core and the hot cell is less than 3.0 seconds.

Radiation Measurement and Spectroscopy Laboratory (RMSL)
The Radiation Measurement and Spectroscopy Laboratory is equipped for measurement of alpha, beta and gamma particles with the help of various detectors such as Geiger-Mueller counters, NaI(Tl) scintillation detectors, HPGe Semiconductor detectors, Ortec Ultra charged particle detectors, and Ortec partially depleted silicon surface barrier detectors. Detection systems including pre-amplifiers, amplifiers, single channel analyzers, counters, timers, multi-channel analyzers are also included in the laboratory. RMSL contains neutron and X-ray measurement modules using He-3 isotopic detectors and ion chambers respectively. All of the detectors in RMSL are compatible with state-of-the-art software and Lynx digital data analysis systems which allows remote web-based experimental capability. All of these things allows the RMSL tremendous potential for collaborative experiments and discoveries with local researchers and researchers around the world.

Nuclear Materials Laboratory
The facilities of the Materials Research Center, metallurgical engineering, and nuclear engineering programs are also available for nuclear materials-related research. These facilities include state of the art SEM/EDX, TEM, STEM, FIB/FESEM, and XRD.

Computer Laboratory
Students have the opportunity to use large computer codes commonly used in the nuclear industry for reactor core design, radiation transport, and thermal hydraulics analysis. The nuclear engineering program maintains an excellent laboratory with personal computers with access to a campus cluster of numerically intensive computing (NIC) systems.

Two-phase Flow and Thermal-Hydraulics Laboratory (TFTL)
The nuclear engineering TFTL is designed to perform both fundamental and advanced two-phase flow experiments simulating prototypic nuclear reactor conditions. The TFTL is equipped with state-of-the-art instrumentation such as a micro multi-sensor conductivity probe, a high-speed digital motion-corder, various flow measurement devices, and a data acquisition system and software. Topics of research studied in the TFTL include advanced two-phase flow modeling, two-phase flow characterization in various flow channel geometries, air-water two-phase bubble jet experiment, secondary flow analysis in liquid film flow, and development of two-phase flow instrumentation.

Advanced Radiography and Tomography Lab
The laboratory is designed to perform radiation imaging for medical or industrial purpose. Students have opportunities of running Monte Carlo simulation codes for radiation imaging systems and experimenting with digital x-ray radiography, x-ray computed tomography, neutron imaging, etc. The technologies developed in the lab can be applied to
either medical imaging or non-destructive inspection of various materials or objects.

**Neutron Generator Laboratory**
The neutron generator laboratory has a D-D neutron generator that produces approximately $10^9$ neutrons/sec. The neutron generator is available for both graduate and undergraduate research and education at Missouri S&T. Examples of research using the neutron generator are reactor kinetics research, the study of two-phase flow, research in nuclear forensics and radiochemistry, particle tracking in complex flows, and the photon-neutron tomography for mechanical testing of structural materials.

**Muthanna Hikmat Al Dahhan**, Professor  
DSc Washington University  
Multiphase reaction and reactor engineering flow systems; transport-kinetic integration; advanced measurement and computational techniques; applications to green technology and sustainable development in energy, products, and environment.

**Ayodeji Babatunde Alajo**, Assistant Professor  
PHD Texas A&M University  
High fidelity nuclear systems design and modeling, advanced fuel cycles, radioactive waste management, and nuclear systems safety.

**Carlos Henry Castano**, Associate Professor  
PHD University of Illinois Urbana-Champaign  
Plasma material interactions and vacuum breakdown, nuclear materials, and radiochemistry.

**Arvind Kumar**, Professor Emeritus  
PHD University of California-Berkeley  
Nuclear materials, radiation damage, and mechanical properties.

**Hyoung Koo Lee**, Associate Professor  
PHD University of California-Berkeley  
Radiation imaging systems (x-ray, gamma, and neutron), digital image processing and CT reconstruction, medical and industrial applications of radiation imaging.

**Xin Liu**, Assistant Professor  
PHD University of Wisconsin-Madison  
Radiation detection and measurement, medical imaging system, Monte Carlo simulation, advanced nuclear energy system design.

**Gary Edward Mueller**, Associate Professor  
PHD University of Missouri-Rolla  
Nuclear power safety analysis, heat transfer and fluid flow, packed bed characteristics.

**Joshua P Schlegel**, Assistant Professor  
PHD Purdue University  
Two-phase flows, interfacial area transport, heat transfer and fluid mechanics, nuclear reactor safety.

**Joseph D Smith**, Professor  
PHD Brigham Young University  
Lauffer Chair of Energy. Hybrid energy generation, gas flare design, process modeling, and control.

**Shoaib Usman**, Associate Professor  
PHD University of Cincinnati  
Turbulence and dispersion, environmental radon measurement, radiation measurement and effects on materials, and radiation interaction with fluids.

**NUC ENG 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in he department. Consent of instructor required.

**NUC ENG 5001 Special Topics** (IND 0.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

**NUC ENG 5203 Reactor Physics I** (LEC 3.0)  
Study of neutron interactions, fission, chain reactions, neutron diffusion and neutron slowing down; criticality of a bare thermal homogeneous reactor. Prerequisite: Nuc Eng 3205.

**NUC ENG 5207 Nuclear Fuel Cycle** (LEC 3.0)  
Nuclear fuel reserves and resources; milling, conversion, and enrichment; fuel fabrication; in-and-out-of core fuel management; transportation, storage, and disposal of nuclear fuel; low level and high level waste management; economics of the nuclear fuel cycle. Prerequisite: Nuc Eng 3205.

**NUC ENG 5241 Nuclear Materials I** (LEC 3.0)  
Fundamentals of materials selection for components in nuclear applications; design and fabrication of UO2 fuel; reactor fuel element performance; mechanical properties of UO2; radiation damage and effects, including computer modeling; corrosion of materials in nuclear reactor systems. Prerequisites: Civ Eng 2210; Nuc Eng 3205: Nuc Eng 3223; Met Eng 2110. (Co-listed with Met Eng 5170).

**NUC ENG 5251 Reactor Kinetics** (LEC 3.0)  
Derivation and solutions to elementary kinetics models. Application of the point kinetics model in fast and thermal reactor dynamics, internal and external feedback mechanisms, rigorous derivation and solutions of the space dependent kinetics model fission product and fuel isotope changes during reactor operation. Prerequisite: Nuc Eng 3205.

**NUC ENG 5257 Introduction to Nuclear Thermal Hydraulics** (LEC 3.0)  
An introductory course in the application of thermal-hydraulic principles to energy systems, with emphasis on nuclear energy issues. Will include the development of constitutive models and applications to power systems, fluid mechanics, and heat transfer problems (including multiphase flows). Prerequisite: Graduate standing.

**NUC ENG 5257 Introduction to Nuclear Thermal Hydraulics** (LEC 3.0)  
An introductory course in the application of thermal-hydraulic principles to energy systems, with emphasis on nuclear energy issues. Will include the development of constitutive models and applications to power systems, fluid mechanics, and heat transfer problems (including multiphase flows). Prerequisite: Graduate standing.

**NUC ENG 5281 Probabilistic Risk Assessment I** (LEC 3.0)  
A study of the techniques for qualitative and quantitative assessment of reliability, safety and risk associated with complex systems such as those encountered in the nuclear power industry. Emphasis is placed on fault tree analysis. Prerequisite: Nuc Eng 3205.

**NUC ENG 5312 Nuclear Radiation Measurements and Spectroscopy** (LEC 2.0 and LAB 1.0)  
Contemporary radiation detection theory and experiments with high resolution gamma-ray spectroscopy, solid state detectors, neutron detection and conventional gas filled detectors. Neutron activation analysis of unknown material, statistical aspects of nuclear measurements. Prerequisite: Nuc Eng 3205.
NUC ENG 5347 Radiological Engineering (LEC 3.0)

NUC ENG 5350 Advanced Nuclear Medical Science (LEC 3.0)
Advanced level of technologies involved in medical modalities, such as digital radiography, digital mammography, modern computed tomography, gamma camera, SPECT and PET will be covered. Prerequisites: Nuc Eng 4312 or equivalent.

NUC ENG 5363 Applied Health Physics (LEC 3.0)
Radiation sources; external and internal dosimetry; biological effects of radiation; radiation protection principles; regulatory guides; radioactive and nuclear materials management. Prerequisite: Nuc Eng 3103 or Physics 2305.

NUC ENG 5365 Radiation Protection Engineering (LEC 3.0)

NUC ENG 5367 Radioactive Waste Management And Remediation (LEC 3.0)
Sources and classes of radioactive waste, long-term decay, spent fuel storage, transport, disposal options, regulatory control, materials issues, site selection and geologic characterization, containment, design and monitoring requirements, domestic and foreign waste disposal programs, economic and environmental issues, history of disposal actions, and conduct of remedial actions and clean up. Prerequisite: Math 3304. (Co-listed with Geology 4421).

NUC ENG 5370 Plasma Physics I (LEC 3.0)
Single particle orbits in electric and magnetic fields, moments of Boltzmann equation and introduction to fluid theory. Diffusion of plasma in electric and magnetic fields. Analysis of laboratory plasmas and magnetic confinement devices. Introduction to plasma kinetic theory. Prerequisite: Aero Eng 3131 or Mech Eng 3131 or Physics 3211 or Nuc Eng 3221 or Elec Eng 3600. (Co-listed with Aero Eng 5570, Mech Eng 5570, Physics 4543).

NUC ENG 5428 Reactor Laboratory I (LEC 1.0 and LAB 1.0)
Acquaints the student with neutron flux measurement, reactor operation, control rod calibration, reactor power measurement and neutron activation experiments. Experiments with the thermal column and neutron beam port are also demonstrated. Prerequisites: Nuc Eng 4312, 3205.

NUC ENG 5438 Reactor Laboratory II (LEC 1.0 and LAB 1.0)
A continuation of Nuclear Engineering 304 with experiments of a more advanced nature. Prerequisite: Nuc Eng 4428.

NUC ENG 5456 Reactor Operation II (LAB 1.0)
The operation of the training reactor. The program is similar to that required for the NRC Reactor Operator's license. Students from other disciplines will also benefit from the course. Prerequisite: Nuc Eng 2105, 2406.

NUC ENG 6000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

NUC ENG 6001 Special Topics (LEC 0.0-6.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

NUC ENG 6010 Seminar (RSD 0.0-6.0)
Discussion of current topics.

NUC ENG 6040 Oral Examination (IND 0.0)
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

NUC ENG 6050 Continuous Registration (IND 1.0)
Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

NUC ENG 6085 Internship (IND 0.0-15)
Students working toward a doctor of engineering degree will select with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

NUC ENG 6099 Research (IND 0.0-15)
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

NUC ENG 6203 Advanced Reactor Physics (LEC 3.0)
Transport and diffusion theory; multigroup approximation; criticality calculations; cross-section processing; buildup and depletion calculations; delayed neutrons and reactor kinetics; lattice physics calculations; full core calculations; analysis and measurement of reactivity coefficients. Prerequisite: Math 5325.

NUC ENG 6205 Linear Transport Theory (LEC 3.0)
Monoenergetic Boltzmann equation for neutral particles by the method of singular eigen-functions and polynomial expansions. Prerequisites: Nuc Eng 4203, Math 5358.

NUC ENG 6211 Computational Methods In Nuclear Engineering (LEC 3.0)
Numerical solution of the neutron diffusion and transport equations utilizing the computer. The Sn and Pn methods are studied in detail. Prerequisites: Nuc Eng 4211 and Comp Sci 3200.

NUC ENG 6221 Advanced Nuclear Reactor Design (LEC 3.0)
Complete design of a nuclear power reactor, including analysis of reactor physics and engineering; layout and design of primary and secondary cooling systems, pressure vessel and thermal shields, control systems; introduction to the economics of nuclear power. Prerequisites: Nuc Eng 4211 and 3229.

NUC ENG 6223 Nuclear Reactor Safety (LEC 3.0)
Study of safety criteria; reactor characteristics pertinent to safety; reactor transient behavior; loss of coolant accident analysis; emergency core cooling; fuel behavior during accident conditions; reactor risk analysis; current reactor safety issues. Prerequisites: Nuc Eng 4203 and 3229.

NUC ENG 6241 Effects Of Radiation On Solids (LEC 3.0)
The theories of the interaction of nuclear radiation with matter. Experimental approaches to radiation studies, including the sources and dosimetry. Nature and properties of crystal imperfections. The influence of radiation on physical, mechanical and surface properties of metals and alloys. Radiation effects on materials other than those incorporated in nuclear reactors. The annealing of defects. Prerequisite: Met Eng 5170.
NUC ENG 6257 Advanced Nuclear Thermal Hydraulics (LEC 3.0)
Treatment of advanced topics in nuclear reactor thermal-hydraulics including analysis of fuel elements and fuel melting, multiphase flow dynamics and two-fluid models, interfacial transfer of mass, momentum, and energy, multiphase flow scaling, and numerical applications. Prerequisite: Math 5325.

NUC ENG 6281 Probabilistic Risk Assessment II (LEC 3.0)
A continuation of Nuc Eng 4281 with emphasis on reliability, importance, availability and frequency of occurrence. Advanced topics of phased mission analysis and dynamic fault tree analysis will be considered. The use of fault tree results with respect to risk calculations will be studied. Prerequisite: Nuc Eng 4281.

NUC ENG 6325 Plasma Physics (LEC 3.0)
Fundamentals of kinetic, theory, fluid equations, MHD equations, and applications: wave propagation, shielding effect, diffusion, stability, and charged particle trajectories. Prerequisite: Nuc Eng 4361 for Nuc Eng; Physics 4211 for Physics.

NUC ENG 6331 Radiation Shielding (LEC 3.0)
Radiation sources; interactions of radiation with matter; dosimetry and radiation protection guidelines. The particle transport equation and methods of solving it; the Monte Carlo Method; special computational methods for neutron and gamma attenuation. Computer codes used in shielding. Shielding materials, shield design. Prerequisite: Nuc Eng 4203.