NUCLEAR ENGINEERING, PH.D.

The Graduate School has general requirements Ph.D. students that must be met by all degree candidates (including earning at least 60 credit hours beyond the bachelor's degree for doctoral degrees). The nuclear engineering program has additional requirements (some of which are described below) that must be met before students can complete their degrees. Consult the department for complete, current requirements.

## Learning Outcomes

1. Students will describe, explain, and compute the magnitude of radioactivity associated with nuclear reactions and reactor operation.
2. Students will calculate the critical size of a nuclear reactor based on the specification of materials present in the reactor.
3. Students will describe and compute reactivity effects of control materials, temperature changes, and fission product poisoning.
4. Students will describe and compute neutron slowing down and thermalization processes for generating neutron cross data needed in modern reactor physics codes for designing and analyzing nuclear reactors.
5. Students will evaluate fuel cycles in terms of processing, costs, and relative benefits.
6. Students will evaluate fuel cycles for sustainability including resource availability and external costs such as environmental impact.
7. Students will evaluate fuel management and refueling options in terms of cost and resource requirements.
8. Students will describe the mechanisms involved in and compute quantities related to the interaction of various forms of radiation with matter and the methods of characterizing radiation fields and sources.
9. Students will design radiological shielding for radioactive sources, accelerators, and nuclear reactors.
10. Students will describe and explain the current PWR and BWR power plants’ operating and protection systems.
11. Students will describe and explain the new generation of PWR and BWR power plants’ enhanced systems’ features and capabilities.
12. Students will thermodynamically analyze current reactor system, plus future concepts being proposed and developed.
13. Students will use one- and two-group diffusion theory to compute the critical size of a nuclear reactor based on the specification of materials present in the reactor.
14. Students will describe and compute the time-dependent behavior of a nuclear reactor, including computation and control of reactivity changes.
15. Students will describe, explain, and compute the effect of irradiation on materials behavior.
16. Students will describe, explain, and compute quantities related to the in-reactor material degradation.
17. Students will describe, explain, and compute how neutronics and thermal-hydraulics are coupled through heat generation rate and its distribution for both full power and shutdown conditions.
18. Students will describe, explain, and compute the individual thermal-hydraulic behavior of key reactor system components (e.g., core, steam generator, containment, condenser, etc.) and their interaction with neighboring components within a power cycle.
19. Students will compute pressure drops and heat transfer coefficients within single to two-phase flow channels under forced convection conditions.
20. Students will compute fuel element temperatures (e.g., fuel centerline) and thermal transition criteria (e.g., critical heat flux) within reactor core “Hot” Channels.
21. Students will analyze of the safety of nuclear energy facilities focusing on reliability and probabilistic risk analysis.
22. Students will assess the reliability of an energy system from its basic elements.
23. Students will describe the major features of nuclear reactors. Describe, explain, and compute fundamental materials behavior including phase equilibria, crystal structure, mechanical properties, and chemical thermodynamics.
24. Students will calculate quantities related to heat transfer in a fuel pin, mass diffusion within cladding, radiation damage, uranium enrichment, and thermomechanical behavior in oxide fuels.
25. Students will describe, explain, and compute the behaviour of irradiated nuclear fuel.
26. Students will identify and explain the design criteria for materials selection in nuclear reactor systems.
27. Students will describe, explain, and compute atomic and nuclear physics concepts such as nuclear structure and radioactive decay, and radiation sources in general.
28. Students will describe, explain, and compute irradiation effects on materials at the microscopic level.
29. Students will describe, explain, and compute radiation effects on materials at the macroscopic level.
30. Students will describe, explain, and compute materials degradation mechanisms due to irradiation in nuclear cladding and structural materials.
31. Students will combine experiments and computations, including associated uncertainties to predict best-estimate results with reduced uncertainties.
32. Students will apply the adjoint method for computing sensitivities of model results to model parameters, initial and boundary conditions.
33. Students will describe, explain, and compute radiation interaction with matter.
34. Students will describe, explain, and compute quantities related to radiation detection and measurement, and nuclear instruments and detectors.
35. Students will describe and explain an aspect of nuclear fuel properties and behavior.
36. Students will explain the underlying principles of thermodynamics and the concepts of energy, enthalpy, entropy, and heat capacity.
37. Students will use equilibrium calculations to predict behavior and be able to draw and interpret phase diagrams from free energy curves.
38. Students will use a chemical equilibrium software package, FactSage, and apply it to practical problems.
39. Students will compute uncertainties (variances, covariances) in model parameters and propagate these to compute uncertainties in model responses (results).
40. Students will have the ability to identify pertinent research problems, and formulate a research plan.
41. Students will have the ability to execute a research plan, to generate and analyze original results, and to communicate those results through oral presentations and written publications.

42. The students will demonstrate the ability to access reliable information sources outside of those made available through the normal coursework channels.