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Reactor Theory and Experimentation: Examination Topics

The Reactor Theory and Experimentation Examination tests the students understanding of how neutrons behave in reactors, of mathematical modeling of neutrons in reactors, and of basic experimental techniques associated with reactor neutronics. The following outline describes the material covered by this exam.

I. Neutron-nucleus interactions

a. Microscopic and macroscopic cross sections
b. Differential and double-differential scattering cross sections
c. Products of fission (particles, electromagnetic radiation, and energy carried by each)
d. Delayed neutrons (basics; precursors; groups; decay constants; fractions)
e. Neutron moderation in infinite medium (quantitative and qualitative slowing-down problems)
f. Reaction rates of thermal neutrons
g. Data that are needed for reactor analysis.
h. “Evaluated” data (origins and how it is used)
i. Multigroup cross sections

II. Diffusion Theory (one energy group as well as multi-group)

a. Diffusion equations, boundary conditions, and interface conditions
b. Approximations made in diffusion theory; physical conditions for which these are valid
c. Solutions of basic diffusion problems (steady-state, time-dependent, eigenvalue)
d. Obtaining physical quantities (reaction rates, leakage rates, non-leakage probabilities, etc.) from diffusion solutions
e. Multiplication factor and neutron distribution of bare and reflected reactors of various shapes

III. Transport Theory

a. Transport equations and boundary conditions for modeling neutronics problems
b. Approximations usually made in transport theory; physical conditions for which these are valid
c. Angular flux, scalar flux, net current density, partial current
d. Solutions of very basic transport problems (steady-state)
e. Obtaining physical quantities (reaction rates, leakage rates, non-leakage probabilities, etc.) from transport solutions

IV. Reactor Theory and Reactor Physics

a. Multiplication factor (six- and four-factor formulas; “generational” concept; *k* in terms of production and loss rates)
b. Neutron distribution in reactors (in position, energy, and direction; fundamental mode; other modes; approximations leading to simple results; assessment of these approximations for particular reactors; power distribution)
c. Peaking factors

d. Qualitative understanding of behavior of neutrons in reactors; effects of various changes upon multiplication factor, neutron distribution, power, etc.
e. Reactor kinetics (Point reactor kinetics equations; approximations they contain; approximate solutions thereof; quantitative and qualitative behavior of solution; relation of solution to physical observables; effective delayed-neutron parameters)
f. Feedback from temperature changes and isotopic changes (Doppler broadening, temperature coefficients of reactivity, power coefficient of reactivity, xenon poisoning, samarium poisoning)
g. Estimation of reactivity changes using perturbation theory

V. Reactor Analysis

a. Basic steps and approximations in modern analysis of light-water reactors (LWRs) (from evaluated data all the way to multiplication factors and detailed power distributions)
b. Spatial homogenization techniques
c. Spectral averaging techniques (group-collapse)

VI. Reactor experimentation

a. Determination of reactivity changes (such as control-rod worths)
b. Determination of “age” or slowing-down length
c. Determination of isotopic content by neutron activation
d. Determination of delayed-neutron parameters
e. Determination of feedback coefficients
f. Determination of neutron distribution