Interactions, Measurement and Theory of Radiation: Examination Topics

The Interactions, Measurement and Theory of Radiation Examination, one of the Ph.D. Qualifying Examinations in the Department of Nuclear Engineering, tests the student's understanding of basic principles of nuclear reactions, radiation sources, radiation interactions with matter, transport of radiation through matter, and radiation detection. The following outline describes the material covered by this exam.

I. Production and Decay of Radionuclides; Nuclear Reactions

a. Balance equations and probability functions
b. Decay chains
c. Production and burnup in a reactor
d. Neutron cross sections and reaction rates
e. Modes of decay (α, β^-, β^+, γ, ε, e^-, IT, SF)
f. Decay schemes
g. Disintegration energies and Q-values
h. Conservation of E and **p**, relativistic and non-relativistic
i. Theory of alpha decay
j. Theory of beta decay
k. Binding energy
l. Coulomb barrier
m. Statistical considerations in production and decay processes
n. Neutron Activation Analysis
o. Applicability of various models describing nuclear interactions (energy ranges, charged particles vs. neutral particles, etc.)

II. Primary Radiations from a Reactor

a. Energy spectrum of fission neutrons
b. Prompt fission and fission-product gammas
c. (n,γ) and other neutron-induced reactions
d. Energy released from fission and how it is partitioned among products

III. Photon Interactions: Photoelectric absorption, pair production, Compton and Raleigh scattering

a. Cross sections as a function of E
b. Annihilation photons
c. Klein-Nishina formula
d. Linear attenuation and energy absorption coefficients

IV. Neutron Interactions: Fission, Capture, Elastic and Inelastic Scattering, etc.

a. Cross sections as functions of E
b. Reactions involving compound-nucleus formation
c. (n,γ) and other neutron-induced binary reactions
d. Threshold reactions
e. Two-body elastic collisions
f. Differential and double-differential scattering cross sections

V. Neutron and Photon Transport through Matter

a. Angular and scalar fluxes
b. Angular, partial, and net current densities
c. Calculations of uncollided fluxes and current densities
    1. Boltzmann transport equation
    2. Solutions in one dimension
    3. Planar and volume sources
d. Integral transport method
    1. Point, line, plane, and volume sources
    2. Application of buildup factors to flux and exposure estimates
e. Monte Carlo method for flux, exposure, and buildup factors
    i. Distributed and discrete probability functions
    ii. Rejection technique

VI. Dosimetry

a. Major dosimetry units (Roentgen, rad, rem, sievert, gray, etc.)
b. Maximum permissible dose limits
c. Kernel method for buildup factors
d. Kerma factors
e. Quality factors

VII. Radiation detection

a. Operation and applicability of gas-filled detectors for neutron, gamma, and mixed radiation fields.
    i. proportional counters
    ii. Geiger-Mueller counters
    iii. ion chambers
    iv. BF_3 and similar neutron counters
    v. fission chambers
b. Analysis of gamma-ray spectra in scintillator and semiconductor detectors
c. Measurement of neutron fields via foil activation
d. Counting statistics