Nuclear Reactor Physics

Key words: neutron interaction, nuclear reactor theory, thermal reactor, one-group diffusion equation, one-group reactor equation

Reference:

- John Lamarsh and Anthony Baratta, Introduction to Nuclear Engineering, 3rd edition, Pearson, Chapters 2-7.

Q1: Answer the following questions

(1) Explain what a physical quantity named "cross-section" used in nuclear engineering means, and the difference between "microscopic cross-section" and "macroscopic cross-section."

(2) Explain what a physical quantity named "neutron flux" used in nuclear engineering means, and the difference between "neutron flux" and "neutron current."

(3) Explain the meanings of each factor in the four-factor formula, and the difference between the "four-factor formula" and "six-factor formula."

(4) Explain what is "NR approximation" used to calculate neutron moderation, and the difference between "NR approximation" and "NRIM approximation."

(5) Explain the characteristics of "fissile nuclide," and the difference between "fissile nuclide" and "fissionable nuclide".

Q2: Briefly explain the following words used in nuclear reactor physics

(1) burnable poison

(2) Doppler effect

(3) isotope

(4) reflector

(5) control rod worth

Q3: Consider a one-dimensional plane medium A with a thickness of *a*, an infinitely thin plane neutron source that emits S neutrons per second located at the center of medium A. and an infinitely large medium B that sandwiches medium A. Obtain the neutron flux ϕ in media A and B as a function of the distance from the neutron source, x ($x \neq 0$). Note that the neutron flux satisfies following one-dimensional governing equations:

$$\frac{d^2\,\phi_A}{dx^2} - \frac{\phi_A}{{L_A}^2} = 0$$

$$\frac{d^2\,\phi_B}{dx^2} - \frac{\phi_B}{{L_B}^2} = 0$$

where subscripts A and B denote physical quantities in media A and B, respectively.

Q4: Assume a cuboid bare reactor whose dimension in x, y, and z directions are a, b, and c, respectively. The thermal output of the reactor, macroscopic fission cross-section, and energy released per fission are given as P, Σ_f, and E, respectively. When the neutron flux in the reactor ϕ follows

$$\frac{d^2\phi}{dx^2} + \frac{d^2\phi}{dy^2} + \frac{d^2\phi}{dz^2} + B^2\phi = 0,$$

obtain the distribution of neutron flux in the reactor, criticality condition, and power peaking factor of the reactor. Ignore extrapolation distance in the derivations.