Nuclear Reactor Theory

2006 년 1 학기

Final Examination

(주한규 교수님)

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1. Give the following. Then answer the related question as concisely as possible. (15 Points)
   a) One-group neutron diffusion equation in a general form. Define each term.
   b) Neutron slowing down equation in a general form. Define each term.
   c) Flux shape in a critical cylindrical reactor. Sketch the derivation process starting from the Helmholtz equation. No need for thorough derivation.
   d) Neutron spectrum in the slowing down range in a general form. Explain each factor.

2. Plot the following with clear indications of the variables and points in the abscissa (횡축) and ordinate (종축) which are essential to explain your plot. Then answer the related question. (15 Points).
   a) One group neutron flux shape in a superproductive medium, in a subproductive medium, and then in a critical reflected slab reactor. Explain your choice of the shape for the superproductive medium.
   b) Typical thermal reactor neutron spectrum in the entire energy range. Explain the major events occurring in the three typical energy ranges.
   c) Scattering Kernel in both energy and lethargy scales. Derive the scattering kernel in the lethargy scale.

3. Find the flux distribution for the following problems starting from appropriate one group neutron diffusion equation in a multiplying medium. (15 Points)
   a) Point source located at the origin with the strength of S neutrons/cm^3–sec Microscopic cross section.
   b) In a long subcritical square pipe (exponential pile) whose width and length are *a* and *c* cm, respectively. A nonuniform source is being injected at the left side of the pipe, such that the peak flux of ϕ_0 occurs at the center of the left side square. Apply only this boundary condition for the left side.

4. Suppose that you are given a nuclear material whose composition yields the following one-group cross sections:

$$\Sigma_a = \frac{\pi^2}{100} cm^{-1} \ ; \nu\Sigma_f = \frac{13\pi^2}{1000} cm^{-1} \ ; D = 2.5cm .$$

   You want to design a critical reactor with this material employing various configurations. Answer the following questions. (20 Points)
   a) What is the infinite multiplication factor and material buckling? If necessary, give the answer in terms of π .
   b) Determine the width of a cube when employing a cubic shape.
   c) What would be the volume of a cylinder which minimizes the volume in case of a cylinder? Derive the first the relation between the height and diameter of the cylinder for the, optimum cylinder. In this optimum case, what would be the ratio between the neutron leakage through the radial surface of the cylinder compared to that through the two side surfaces?
   d) What would be the minimum volume of the reactor in any possible shape?

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5. Answer the following questions regarding a one-dimensional slab reactor with reflector. (10 Points)
   a) Explain the solution process of this one-group two region problem by emphasizing the factors and conditions that determine the eigenvalue.
   b) Explain the concept of reflector saving

6. Answer the following [redacted] regarding neutron slowing down. (15 Points)
   a) Derive the two-group neutron slowing equation from the continuous energy form of the slowing down equation including the leakage term. Assume that the thermal cutoff energy is chosen large enough to neglect the upscattering from the thermal to the fast group. Define proper group average cross sections in terms of group fluxes. Indicate that which term corresponds to the slowing down density at the thermal cutoff energy.
   b) Explain the solution process of the slowing down equation involving general absorption but and scattering only in hydrogen. No need for complete solution.

7. Answer the following questions regarding the Maxwellian spectrum in the thermal energy range. (10 Points)
   a) Derive the Maxwellian FLUX spectrum from the probability density function for velocity given as $P(v_x, v_y, v_z) = C_1 e^{-\beta E}$ where $\beta = \frac{1}{kT}$ and $E = \frac{1}{2} m(v_x^2 + v_y^2 + v_z^2)$.
   b) Explain the concept of absorption hardening and neutron temperature.