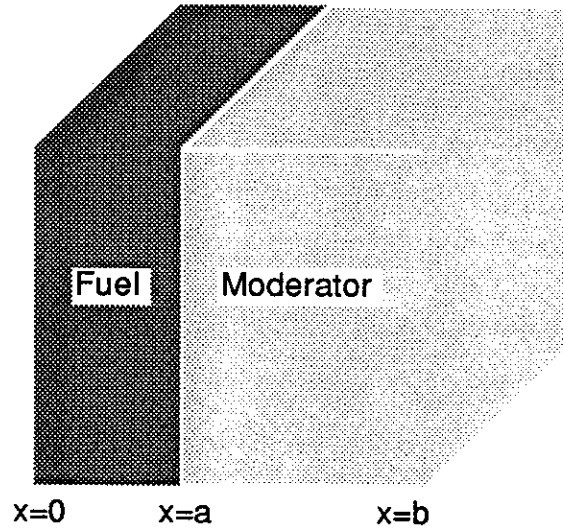


Ph.D. Qualifying Examination
Reactor Theory and Experimentation

[minutes]

- [20] 1. a) (50%) Write (**don't solve!**) the two-group diffusion equations for the scalar flux in the piece of an infinite reactor lattice that is shown below. [Write the k -eigenvalue equations (sometimes called the "criticality equations"), not the time-dependent equations.]



Assume one thermal group and one fast group. You may assume that group boundaries are chosen in the usual way, so that certain terms in certain groups can be ignored.

- b) (50%) Specify *all* boundary and interface conditions for your two-group diffusion equation. Assume mirror-image symmetry at $x=0$ and at $x=b$.
- [10] 2. A bare critical homogeneous slab reactor, infinite in the y and z directions, is compressed to half its original thickness (where thickness = dimension in the x direction), and thus twice its original density. Is it now supercritical, critical, or subcritical?

[Don't just give an answer — show how you got it, or you will not get much credit.]

Hint: you may use
$$k_{\text{eff}} = \frac{v\Sigma_f/\Sigma_a}{1 + L^2B^2} .$$

[20] 3. A nuclear engineering student claimed she could measure the diffusion coefficient, D , and the diffusion length, L , of the water moderator above a subcritical assembly. Her plan was to add known amounts of boron and plot the relationship between γ and Σ_B . (Here Σ_B is the boron cross section, and γ is the inverse of the axial relaxation length.) Investigate this idea and present the pertinent equations. You may assume that the radial buckling is known.

[20] 4. a. (70%) Start from the standard form of the point kinetics equation with one delayed neutron group, make the prompt jump approximation, and obtain an analytic solution for the transient power and one-group precursor concentration.

b. (30%) Assuming you know the six-group kinetics parameters, how would you evaluate the one-group delayed neutron decay constant λ ? Explain.

[20] 5. One kg of $^{209}_{83}\text{Bi}$ is irradiated for 100 days in a thermal flux of 10^{14} [neutrons/(cm²-sec)] at a temperature of 200 °C. What mass of $^{210}_{84}\text{Po}$ will be present when the sample is removed?

Use the following information:

- Half-lives: $^{210}_{83}\text{Bi}$ — 5 days; $^{210}_{84}\text{Po}$ — 138 days.
- Atomic masses: $^{209}_{83}\text{Bi}$ — 208.98 amu; $^{210}_{84}\text{Po}$ — 210 amu.
- $^{209}_{83}\text{Bi}$ 2200 m/sec absorption cross section = 0.015 barns.

See next page for question #6.

[30] 6. A monoenergetic point neutron source that emits S neutrons/sec is placed at the center of a large spherical diffusing medium of extrapolated radius R' .

- a. (70%) If the diffusion coefficient of the medium is D and the macroscopic absorption cross section of the medium is Σ_a , determine the neutron flux distribution within the diffusing medium. [You will receive significant partial credit for correctly solving the equation with the correct boundary conditions, even if you do not evaluate the constants.]

Hint 1: $\nabla^2 \phi = \frac{1}{r^2} \frac{d}{dr} \left(r^2 \frac{d\phi}{dr} \right)$ in 1-D spherical coordinates.

Hint 2: To get the boundary condition at the origin, consider an infinitesimal sphere around the point source.

- b. (15%) Assume the answer to part (a), $\phi(r)$, is given. In terms of $\phi(r)$, what is the neutron leakage rate from the sphere if its actual radius is R ?
- c. (15%) Assume the answer to part (a), $\phi(r)$, is given. In terms of $\phi(r)$, what is the rate at which neutrons are absorbed within the sphere?