

Ph.D. Qualifying Examination
 Reactor Theory and Experimentation

1. (15 min.) A power reactor operates at 3000 MW_{thermal} for a period of one year. Calculate the number of Curies of Kr-85 produced. Disregard the decay of Kr-85 during the year of production. Assume about 0.3% of the fission products are Kr-85. Half-life of Kr-85 = 10.76 years.
2. (20 min.) Given a critical finite reflected reactor,
 - a) Write the multigroup diffusion equation for both the core and reflector in terms of the general group g ;
 - b) define the terms in the equation for the core;
 - c) simplify the equation for the core in part a) for the highest energy group;
 - d) state all boundary conditions which will be used to solve for the fluxes in both the core and reflector.
3. (15 min.) Calculate the material buckling for a mixture of 250 moles of graphite per mole of 5 percent enriched uranium. The core temperature is 20°C. For a critical core of these materials, what is the thermal non-leakage probability?

$$\begin{aligned}
 K_{\infty} &= 1.198 \text{ for the mix of materials} \\
 \rho_{\text{graphite}} &= 1.6 \text{ gm/cm}^3 \\
 \rho_{\text{uranium}} &= 18.9 \text{ gm/cm}^3
 \end{aligned}$$

Cross sections

$$\begin{array}{l}
 \sigma_s \text{ carbon} = 4.8 \text{ barns} \\
 \sigma_s \text{ U} = 8.3 \text{ barns}
 \end{array}
 \left. \vphantom{\begin{array}{l} \sigma_s \text{ carbon} \\ \sigma_s \text{ U} \end{array}} \right\} \text{Scattering}$$

$$\begin{array}{l}
 \sigma_a^{235} = 694 \text{ barns} \\
 \sigma_a^{238} = 2.73 \text{ barns} \\
 \sigma_a \text{ carbon} = 0.0034 \text{ barns}
 \end{array}
 \left. \vphantom{\begin{array}{l} \sigma_a^{235} \\ \sigma_a^{238} \\ \sigma_a \text{ carbon} \end{array}} \right\} \text{Absorption}$$

4. (15 min.) The following data were taken during the loading of a core in a reactor:

<u>Number of Elements</u>	<u>Count rate (absorber rods out)</u>
0	32
3	40
6	54
8	68
10	98
12	164

- a) (60%) Estimate the minimum number of fuel elements required for criticality. Show clearly how you obtained this value.
- b) (40%) What is the value for k_{eff} with 10 elements in the core? How did you obtain this result?

5. (30 min.)

a) (40%) Derive the in-hour equation starting from the standard form of the point-kinetics equations.

b) (40%) Give a graphical representation of the roots of the in-hour equation and qualitatively describe the neutron population behavior for:

(i) Negative reactivity insertions

(ii) Positive but sub-prompt critical reactivity insertions, and

(iii) Super-prompt critical reactivity insertions.

c) (20%) Describe the limitations of the point kinetics equations, if any.

6. (25 min.)

a) Write the monoenergetic, steady state neutron diffusion equation and identify neutron production and removal terms. Name all the variables and state their units.

b) A volumetrically uniform neutron source of radius r_0 is located at the center of a spherical diffusing medium of radius R . Determine the neutron flux distribution if the source emits S neutrons per second. Neglect extrapolation distance.

c) Determine the neutron leakage and absorption in the sphere and verify neutron conservation (ie production = removal).

5. (20 min) Consider a deuterium plasma that radiates energy like a black body at a constant temperature. The density of the deuterium is 10^{21} ions/cm³. The Stefan-Boltzmann constant is $35.6 \text{ MeV}/(\text{cm}^2\text{-sec} \cdot \text{K}^4)$. The minimum of $T^4/\langle \sigma v \rangle$ occurs at $T = 10 \text{ keV}$ with $\langle \sigma v \rangle = 8.6 \times 10^{-19} \text{ cm}^3/\text{sec}$.

Recall: $\text{D} + \text{D} \rightarrow {}^3\text{He} (0.82 \text{ MeV}) + \text{n} (2.45 \text{ MeV})$ (50%)

$\text{D} + \text{D} \rightarrow \text{T} (2.01 \text{ MeV}) + \text{p} (3.02 \text{ MeV})$ (50%)

$\text{D} + \text{T} \rightarrow \alpha (3.5 \text{ MeV}) + \text{n} (14.1 \text{ MeV})$

- a) (60%) Assuming that all of the tritium formed by the D-D reactions fuses, find the minimum radius of the plasma.
- b) (20%) Find the kinetic pressure of the plasma in units of atmosphere.
Note: $1 \text{ atm} = 1.013 \times 10^5 \text{ N/m}^2$.
- c. (20%) Discuss the significance of this problem to the design of a practical fusion system.