

22.05 Neutron Science and Reactor Physics

Exam 2 (Fall 2008)

Question 1 (Short Answers) [14 points, 2 points/each]

- Give and describe briefly two roles of control mechanisms in a PWR
- Describe how the pressurizer will maintain the primary loop pressure in the event of a fuel temperature increase
- Describe how the coolant flow of a BWR can be used to control the core power
- Name the main advantage of using heavy water as a moderator in the CANDU reactor
- Name 3 advantages of online refuelling
- Why do fast reactors usually have hexagonal fuel lattices?
- Define breeding ratio.

Question 2 [6 points]

Write down the four and six factor formulas and explain the differences between them.

Question 3 [15 points]

A hypothetical critical power reactor uses a uranium fuel with 93% U-235 and 7% U-238

- How would the factors of the 6 factor formula be affected if the fuel was switched to 20% U-235 and 80% U-238?
- How would the factors of the 6 factor formula be affected if the fuel was switched to 93% Pu-239 and 7% U-238?
- After making some changes to the fuel of the reactor, the reactor becomes sub-critical. Suggest two design modifications to compensate this drop in reactivity and make the reactor critical again (other than replacing the fuel)?

Question 4 [25 points]

- When deriving the transport equation from a neutron balance in a volume element, one important assumption was made that makes the neutron transport equation linear. Name that assumption and describe why it is valid in a typical nuclear reactor. [4 points]
- Write down the diffusion equation in a sub-critical reactor and describe how each term contributes to a neutron balance in a volume element. [10 points]
- Name two situations where the approximation of weak angular dependence of the diffusion equation breaks down. [6 points]

- d) Explain why the interface condition between two materials can only be approximated using diffusion theory and write down the interface condition in diffusion. [5 points]

Question 5 [25 points]

- a) Starting from the point kinetics model for an initially critical reactor, derive the inhour equation for a step change in reactivity with a single precursor group. (Show the details of the derivation) [10 points]
- b) Plot the reactivity step as a function of the roots and discuss the sign of the roots for both a positive and negative step reactivity change. [4 points]

- c) For the following parameters [6 points]

$$\beta = 0.006$$

$$\Lambda = 0.00001 \text{ s}$$

$$\lambda = 0.1 \text{ s}^{-1}$$

$$\rho = 0.5 \text{ \$}$$

(you can use the approximate solution)

- a. Evaluate the prompt reactor period and define its meaning.
- b. Evaluate the stable reactor period and define its meaning.
- c. Plot qualitatively the reactor power variation over time
- d) Discuss the importance of delayed neutrons in nuclear reactors. [5 points]

Question 6 [15 points, 5 points/each]

Use the following parameters for this problem

$$\beta = 0.007$$

$$\Lambda = 0.0001 \text{ s}$$

$$\lambda = 0.1 \text{ s}^{-1}$$

- a) Using the prompt jump approximation, evaluate the power 20 seconds following a reactivity insertion of $+0.25\beta$ if the power before the insertion was 2 GW_{th} .
- b) After the 20 seconds has passed, a reactivity insertion of -0.25β occurs. Use the prompt jump approximation again to determine the power of the reactor after this second insertion occurs.
- c) What approximation was used to simplify the solution to the one effective delayed neutron group point kinetics equation down to the prompt jump approximation? Does it hold for both cases presented above?

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