This question paper contains 3 printed pages.

3427-A

Your Roll No. ....

M. Tech. / VI Sem.

A

NUCLEAR SCIENCE AND TECHNOLOGY

Paper NST 622— Nuclear Reactor Physics and Reactor Design

Time : 3 hours

Maximum Marks : 70

(Write your Roll No. on the top immediately on receipt of this question paper.)

Answer any seven questions. Each question carries 10 marks.

PART A

1. How do you define operator adjoint to fission operator in a multiplying system? Calculate the change in reactivity when there is a change only in the fission source. Take the change as 1 % of the original fission source.

2. Describe discrete ordinates formulation. Taking the example of slab geometry, explain the meaning of vacuum and reflective boundary conditions.

3. Obtain the condition on mesh size in diamond (linear) difference scheme. Assume source free region. The minimum μ in a certain S_N approximation is 0.1. What should be minimum mesh size if the mean free path is 2.0 cm. Explain why the mesh size can not be chosen freely ?

PART B

4. Using one-group model, solve the eigen-value problem of time-dependent neutron diffusion equation for an infinite slab reactor. Find out the expression for the fundamental mode of its eigen function.

5. (a) Write down the multi-group time independent neutron diffusion for a critical reactor and explain each term. Discuss how source term due to fission is computed.

   (b) Discuss various steps of FBR core physics design.

6 (a) Neutron flux distribution in a finite bare spherical reactor is given by the expression

$$\phi(r) = A\frac{\sin\left(\frac{\pi r}{\tilde{R}}\right)}{r},$$

where $\tilde{R}$ is the radius of the reactor, including the extrapolation length. If 'P' is the reactor power, find out the normalization constant 'A'.

(b) Show that the ratio of maximum flux to average flux $\left(\frac{\phi_{max}}{\bar{\phi}}\right)$ in the above reactor is equal to $\frac{\pi^2}{3}$.

PART C

7. a) What are Eigen Values, and what is Eigen Value Separation, in the context of neutronic coupling in core? On what basis the applicability of Point Kinetics or Space Time Kinetics determined? (Marks 4)

b) When a thermal reactor is shut down, how does xenon build up influence the re-starting of the reactor? (Marks 4)

c) What is temperature coefficient of reactivity and power coefficient of reactivity? What is the advantage of power coefficient over temperature coefficient? (Marks 1 + 1)

8. a) With fuel burn up, the isotopic concentration changes as follows

$$\frac{dN_f}{dt} = -\sigma_a \Phi N_f - \lambda_f N_f$$

where N_f is the number density of the fuel atoms, ϕ is the flux λ_f is the decay constant and σ_a is the absorption cross section. Using this formulation, derive the rate equations for the following conversion chain:

$$Th^{232} \xrightarrow{(n,\gamma)} Th^{233} \xrightarrow{\beta} Pa^{233} \xrightarrow{\beta} U^{233}$$

(Hint: The number density of first element changes only due to absorption and decay, while for other elements there is also formation from the previous element, by means of absorption/decay)

b) What is effective delayed neutron fraction? How does it compare in thermal and fast reactor ?

c) How Doppler reactivity feedback is related to temperature? In LMFBR, explain how Doppler feedback changes between Oxide, Carbide and Metalic Fuels?

9. a) For step change in reactivity, considering one group of delayed neutrons, the relative neutron density changes with time as,

$$\frac{n}{n_0} \approx \frac{\beta}{\beta-\rho} e^{\frac{\lambda \rho t}{\beta-\rho}} - \frac{\rho}{\beta-\rho} e^{-(\beta-\rho)\frac{t}{l}}$$

where t is the time, n_0 is the initial neutron density (at t = 0); n is the neutron density at time t, β is the effective delayed neutron fraction, λ is the one group decay constant, l is the prompt neutron life time, and ρ is the reactivity. Taking $\rho = +0.0022$, $l = 10^{-3}$ s, β = 0.0065, and λ = 0.08 s^{-1}, discuss how the power evolves after step insertion of reactivity, with contribution of the two terms. (Marks 5)

b) Considering one gram of fissile material establish the relationship between burnup units MWd/Kg and atom percent. (Marks 3)

c) What is prompt jump approximation? How this approximation is useful? (Marks 1 + 1)