ENGINEERING PHYSICS 4D3/6D3

DAY CLASS Dr. Wm. Garland

DURATION: 3 hours

McMASTER UNIVERSITY FINAL EXAMINATION December 1995

Special Instructions:

1. Open Book. All calculators and reference material permitted.
2. Do all 8 questions.
3. The values of each question is as indicated.
4. Point form is sufficient for discussion type questions.

TOTAL Value: 100 marks

THIS EXAMINATION PAPER INCLUDES 3 PAGES AND 8 QUESTIONS. YOU ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR INVIGILATOR.

---

1. [10 Marks]
What is the obvious error in the following expressions? Explain briefly.

a) Steady state one-group neutron balance equation:

$$-\nabla D(r)\nabla\varphi(r) - \Sigma_a(r)\varphi(r) = \nu\Sigma_f(r)\varphi(r)$$

b) I^{135} decays with a half life of 9.17 hours to Xe^{135} which decays with a half life of 6.58 hours.

c) Neutron current is defined as: $\underline{J} = -D\ \nabla\varphi$

d) In a reactor experiment a reactivity, $\rho > \beta$, resulted in the power rising with a period of 100 seconds.

e) For the same power, the smaller the reactor, the lower the flux.

2. [10 marks]
Consider a planar thermal neutron source, S neutrons / cm^2 in the middle of a slab of concrete of thickness, a cm.

a) What is the probability that the neutron will pass from the centre to the edge without a collision?

b) What is the probability that it will ultimately diffuse from the centre to the edge?

---

continued on page 2...

3. [12 marks]
The general multigroup neutron diffusion equations with delayed precursors are given by:

$$\frac{1}{v_g}\frac{\partial \varphi_g}{\partial t} = \nabla\cdot D_g \nabla \varphi_g - \Sigma_{a_g}\varphi_g - \Sigma_{s_g}\varphi_g + \sum_{g'=1}^{G} \Sigma_{s_{g'g}}\varphi_{g'}$$
$$+ \chi_g \left[\sum_{g'=1}^{G} \nu_{g'}(1-\beta_{g'})\Sigma_{f_{g'}}\varphi_{g'} + \sum_{i=1}^{N} \lambda_i C_i \right] + S_g^{ext}$$

$$\frac{\partial C_i}{\partial t} = -\lambda_i C_i + \sum_{g=1}^{G} \beta_{i_g}\nu_g \Sigma_{f_g}\varphi_g$$

the poison equations are:

$$\frac{\partial I}{\partial t} = \gamma_I\, \Sigma_f\, \varphi(\underline{r},t) - \lambda_I\, I(\underline{r},t)$$
$$\frac{\partial X}{\partial t} = \gamma_X\, \Sigma_f\, \varphi(\underline{r},t) + \lambda_I\, I(\underline{r},t) - \lambda_X\, X(\underline{r},t) - \sigma_a^X\, \varphi(\underline{r},t)\, X(r,t)$$

and the fuel depletion equations are:

$$\frac{\partial N_f}{\partial t} = -N_f(\underline{r},t)\, \sigma_a^f\, \varphi(\underline{r},t)$$

a) Show the effect of the delayed precursors on the steady state flux solution.

b) How does the poison concentration affect the other equations (just indicate which terms are affected and how, do not attempt to solve the differential equations)? Illustrate by estimating the negative reactivity worth as a function of poison concentration.

c) How does the fuel concentration affect the other equations (just indicate which terms are affected and how, do not attempt to solve)? Illustrate by discussing the time constant for fuel depletion compared to other processes.

d) In the flux equations, what does "directly coupled" imply?

e) What does "no upscattering" imply?

4. [12 Marks Total]
Write down the multi-group diffusion equations for the following case:
Steady state, 3 groups (fast, epithermal and thermal), no upscatter, no fission neutrons born in the thermal energy group, fission only occurs in the lowest two groups.

continued on page 3...

5. [12 marks total]
What must the reactivity insertion be for a reactor undergoing a power excursion with a measured period, T, of 1 second ($\omega = 1/T$)? To simplify the calculation, assume the presence of only one delayed precursor group with half life of 20 seconds. Assume a neutron lifetime, ℓ, of 5 x 10^{-5} seconds and the delayed fraction, β, is 0.007.

6. [12 marks total]
What is the steady state spatial distribution of delayed precursors in a homogeneous slab reactor? *Hint: Start with the transient one group flux equation and the delayed precursor equations. Impose the steady state condition and derive the precursor concentration.*

7. [12 Marks]
Using the Inverse Method, show that if the neutron density slowly decays, ie

$$n(t) = n_0 \, e^{-\alpha t}$$

and if there is only one delayed precursor group with decay constant λ such that $\alpha < \lambda$, then the reactivity insertion must be:

$$\rho = -\frac{\alpha\beta}{\lambda-\alpha} - \alpha\Lambda$$

8. [20 marks total]
Outline a computer program to solve the 1 group neutron steady state neutron diffusion and the temperature equations <u>numerically</u> in a three-dimensional rectangular reactor. The reactor is composed of an array of vertical fuel / coolant assemblies arranged in a 10 by 10 array. The reactor is bare. Let the vertical direction be z and the horizontal directions be x and y. A 10x10x10 grid is sufficient. Coolant enters the bottom of each fuel assembly at temperature T_{in} and exits at the top. Assume a mass flow of W kg/s for each assembly and that sufficient mixing takes place within each assembly to make the coolant temperature uniform in that assembly at a given elevation (ie T is not a function of x or y in the assembly but it will vary with z). Heat conduction between assemblies is negligible. Ignore temperature feedback to the flux equations. The program should produce the outlet coolant temperature in each assembly for a given steady state bulk power. Focus on:

a) the governing equations;
b) the boundary conditions;
c) the finite difference scheme;
d) the solution algorithm.

<u>Do not</u> get hung up on details.

THE END