ENGINEERING PHYSICS 4D3/6D3

DAY CLASS — Dr. Wm. Garland

DURATION: 3 hours —

McMASTER UNIVERSITY FINAL EXAMINATION — December 1996

Special Instructions:

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

TOTAL Value: 100 marks

THIS EXAMINATION PAPER INCLUDES 4 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]
Briefly describe the following:

a. neutron current

b. prompt criticality

c. void coefficient of reactivity

d. fast fission

e. geometric buckling

f. material buckling

g. resonance escape probability

h. precursor

i. reactivity

j. fission poison.

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2. [10 marks]
What is the obvious error in the following expressions? Explain briefly.

a) Steady state one-group neutron balance equation: $D(r)\nabla^2\varphi(r) - \Sigma_a(r)\varphi(r) = \nu\Sigma_f(r)\varphi(r)$

b) For neutron group g, $\Sigma_{removal} < \Sigma_{absorption}$

c) The gradient of the flux is continuous at an interface

d) $\rho = 2$

e) For a reactor operating at constant power, as the fuel is burned up, the flux remains constant over time.

3. [12 Marks Total]

a) How does a control rod work, i.e. what parameters in the governing equations of question 8 are affected?

b) Where should the control rod or rods be placed? Would more than one rod be necessary or desirable? Consider possible undesirable effects of control rods on the flux distributions. How could you achieve flux <u>shape</u> control as well as flux amplitude control?

c) How fast does the control rod movement need to be?

d) Consider the following algorithm to control the rod(s) position change:

$$\Delta z_{inward} = a_0 \, (\varphi_{measured} - \varphi_{setpoint}) + a_1 \frac{d\varphi_{measured}}{dt}$$

where a_0 and a_1 are positive constants. Would it work? If so, how? If not, why not? Explain the function of the two terms on the right hand side. Would it be better to use thermal power instead of flux? Why or why not?

e) Where should the flux be measured? Why?

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4. [12 Marks]
Consider an infinite planar neutron source, emitting S neutrons/cm^2-s, surrounded by a homogeneous infinite mixture of absorbing material and fissile material. The mixture is sub-critical. In essence, this is an infinite subcritical pile with a planar source. Assume one group diffusion applies.

a) Derive the steady state flux distribution as a function of space.

b) What happens as the mixture approaches criticality?

5. [12 marks total]
Consider a rectangular tank that is 100 cm square at the base and contains a homogeneous mixture of fuel and moderator. Known parameters are Σ_a = 0.500 cm^{-1}, D = 10.0 cm. The tank was slowly filled with the mixture until criticality was achieved at a height of precisely 100 cm. Then, a small amount of absorber material was added uniformly to the mixture, causing the reactor to go subcritical. More fuel / moderator mixture was added to bring the reactor back to criticality at a height of 110.0 cm. Assume that the absorber does not displace any mixture material. Use one-group diffusion theory to find:

a) the inferred value of $\nu\Sigma_f$,

b) the effective macroscopic cross section of the absorber.

6. [12 marks total]
Using the Inverse Method, calculate the reactivity insertion to cause the neutron density to slowly decay, ie $n(t) = n_0 e^{-\alpha t} = n_0 e^{-0.01t}$. Assume there is only one delayed precursor group with decay constant λ = 0.02 sec^{-1}, Λ = 5x10^{-5} sec and β = 0.007.

7. [12 marks total]
Consider a long fuel pencil in an axially flowing coolant. The flux shape is a cosine in the axial direction. Derive an expression for the steady state temperature of the fuel pencil as a function of axial position. Assume that the fuel pencil has no sheath. *[Hint: You can get the centerline temperature of the fuel as a function of local power and coolant temperature. Also, you can get the coolant temperature as a function of axial position independent of fuel temperature.]*

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8. [20 marks]

The general multigroup neutron diffusion equations with delayed precursors are given by:

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

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

the poison equations are:

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

and the fuel depletion equation is:

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

From the above set of equations, set up the equations that need to be solved (but do not attempt to solve) for the following special cases. State your simplifying assumptions and any initial or boundary conditions that you deem relevant. For each case, the focus is different. Look to eliminate unnecessary equations and complications so as to speed up the simulation. Give reasons for your answers. Assume two neutron groups (fast and thermal), no upscatter, no fast fissions, no thermal births.

a) Simulation of the steady state flux distribution. What role do the delayed precursors play in the steady state? What role do the poisons play? How is fuel depletion treated in the short term?

b) Simulation of xenon transient as a result of startup from a fresh core. Assume that the ramp up from zero to 100% full power takes places over a short time period compared to the xenon transient time constant. Do you need to simulate the flux distribution? Do you need to track fuel depletion?

c) Simulation of a short term reactor transient (for times up to a few minutes). What can you assume about the flux equations in order to speed up the simulation without loss in accuracy?

d) Simulation of fast transients (for times up to a few seconds). What can you assume about the precursors, poisons and fuel equations?

THE END