ENGINEERING PHYSICS 4D3/6D3

DAY CLASS — Dr. Wm. Garland

DURATION: 3 hours —

McMASTER UNIVERSITY FINAL EXAMINATION — December 10, 1990

Special Instructions:

1. Open Book. All calculators and reference material permitted.
2. Do all questions.
3. The values of each question is as indicated.
   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.

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1. [15 Marks Total]

a) Define the following: (8 Marks)

Neutron Current
Neutron Flux
Neutron Density
Neutron Fluence

b) Relate B_g^2 to B_m^2 for the 3 distinct criticality classifications (critical, sub-critical and super-critical). Explain the physical meaning of each case. (3 marks)

c) Construct a general and comprehensive depletion / buildup rate equation for a nuclide, accounting for self decay, parental decay, neutron capture and transmutation. Explain each effect briefly. (4 marks)

2. [10 marks total]

A bare, homogeneous cylindrical reactor can be characterized by:

one group neutron diffusion
D = 10 cm.
Σ_a = 0.15 cm.$^{-1}$
H = height = R = radius = 100 cm.

What is the neutron leakage probability?

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3. [15 marks total]

a) (7 marks) Explain the difference between DESIGN and ANALYSIS within the context of this course. You may elect to formulate your response around the following statement: "For a trivial case, like a bare, homogeneous slab reactor modelled by 1 group diffusion, the criticality condition can be expressed by a single, simple algebraic equation relating material properties to reactor size. For any realistic case, however, such a simple relation does not exist."

b) (8 marks) You are the design engineer in charge of reactor physics for a new and smaller core than your company has been designing in the past. The core must deliver the rated power or the company will be penalized. Past designs have been successful and your computer flux and criticality predictions agree with the larger core measurements to roughly 5% for the most part. What will you do to ensure that your design is adequate?

4. [15 marks total]

Many coolant materials become radioactive as they pass through a reactor. Consider a circulating liquid which spends an average of t_1 seconds in a reactor and t_2 seconds in the external circuit. While in the reactor, the coolant becomes radioactive at a rate of R atoms/cm^3-sec. Show that the activity, Y, added per cm^3 of the coolant per transit of the reactor is given by:

$$Y = R(1-e^{-\lambda_A t_1})$$

where λ_A is the decay constant for the activated particles.

5. [10 marks total]

A typical fuel channel in a CANDU reactor puts out a nominal power of 6.5 MW. The channel is 6 m. long and consists of 12 bundles, each weighting roughly 20 kg. The fuel heat capacity is 221 J/(kg °K). <u>Estimate</u> how long it would take to start melting the fuel once cooling was completely lost to the fuel. Assume that the melting point of UO_2 is 1000°C above the nominal operating temperature of the fuel.

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6. [15 marks total]

a) The general multigroup neutron diffusion equations with delayed precursors are given by:
(5 marks)

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

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

Define each variable. Explain the significance of each term.In these equations, what does "tightly coupled" imply? What does " no upscattering imply"?

b) Write an expression for $\Sigma_{ag}(\underline{r})$ in terms of $\Sigma_a(\underline{r},E)$ and $\varphi(\underline{r},E)$.
(5 marks)

c) Given this convolution, how does one proceed to solve this set of equations? Focus your discussion on the fact that you need to know φ in order to calculate φ!
(5 marks)

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7. [10 marks total]

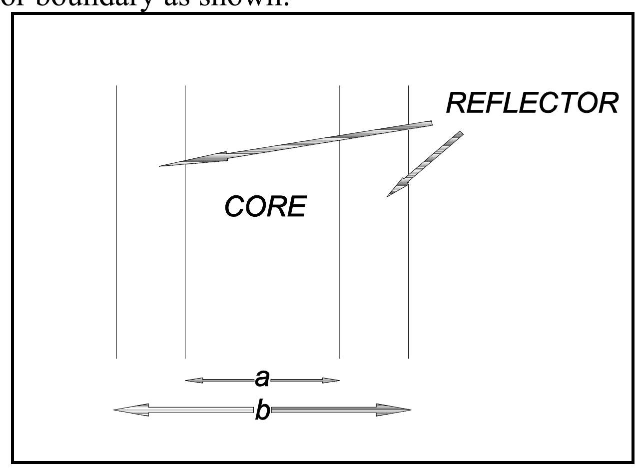
Outline a computer program to solve the 2 group neutron space-time diffusion equations in a one-dimensional slab reactor with a heterogeneous core /coolant /moderator, ie, space-time dependent parameters. Focus on:

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

Include 1 delayed precursor group. Ignore thermalhydraulic effects but consider the possible effects of burnup, poisoning and control. Remember, this is a space-time problem. Do not get hung up on details.

8. [10 marks total]

For an infinite slab reactor with a reflector boundary as shown:



a) State the 2 group diffusion equations for the core and reflector regions.

b) State and justify your boundary conditions.

c) Solve the above equations. This is quite time consuming so at least indicate how you would proceed. Indicate how you would find the criticality equation.

d) Sketch the flux distributions. Explain any significant features.

THE END