

## ENGINEERING PHYSICS 4D3/6D3

DAY CLASS

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DURATION: 3 hours

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McMASTER UNIVERSITY FINAL EXAMINATION

December 1994

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### Special Instructions:

1. Open Book. All calculators and reference material permitted.
2. Do questions 1 through 7 and either 8 or 9.
3. The values of each question is as indicated.

**TOTAL Value:** 100 marks

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**THIS EXAMINATION PAPER INCLUDES 3 PAGES AND 9 QUESTIONS. YOU ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR INVIGILATOR.**

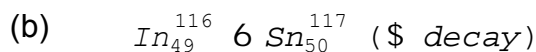
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1. [15 Marks]
  - (a) Distinguish between neutron flux and neutron current.
  - (b) Distinguish between temperature coefficient and power coefficient of reactivity.
  - (c) Distinguish between  $\Sigma_s(E_1 \rightarrow E_2)$  and  $\Sigma_s(E_2 \rightarrow E_1)$ .
  - (d) Distinguish between  $\eta$  and  $f$  of the four factor formulae.
  - (e) Distinguish between reactivity,  $\rho$ , and multiplication factor,  $k$ .

2. [15 Marks]

What is the obvious error in the following expressions? Explain briefly.

(a)  $D(r) \nabla^2 \phi(r) + [v\Sigma_f(r) - \Sigma_a(r)] \phi(r) = 0$



- (c) Boundary Conditions at interface of region "a" and region "b":

$$N_{a \text{ interface}}^* = N_{b \text{ interface}}^*$$

$$LN_{a \text{ interface}}^* = LN_{b \text{ interface}}^*$$

- (d) In a reactor experiment a reactivity,  $\rho$ , of + 2.0 was achieved.
- (e) For the same power, the smaller the reactor, the lower the flux.

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3. [10 marks]

Consider a two stage delayed neutron production process:

Fission product A  $\beta$  B  $\beta$  C + delayed neutron. Assume there are no other fission products. A and B beta decay.

- (a) Write the rate equations for A and B. Assume that the absorption cross sections for A and B are not negligible.
- (b) Given the flux, solve for the steady state values of A and B.
- (c) Write the accompanying delayed neutron balance equation.

4. [10 marks total]

A flux of  $1 \times 10^{13}$  n/cm<sup>2</sup>-s impinges on an absorbing slab ( $\Sigma_a = 1$  cm<sup>-1</sup>). Assume the neutrons are thermal. Calculate the energy absorption rate due to neutrons at a point 10 cm inside the shield.

**[HINT: What is the energy of a thermal neutron?]**

5. [10 Marks Total]

Write down the multi-group diffusion equations for the following case:  
steady state, 5 groups, no upscatter, no fission neutrons born in the 3 lowest energy groups, fission only occurs in the lowest group.

6. [10 marks total]

MNR uses a stainless steel regulating rod for "fine tuning" i.e., small reactivity adjustments. Our operating license states that the worth of the regulating rod shall be less than 6 mk; our operating policy states that the worth shall be greater than 4 mk. Comment. Speculate on how we ensure the rod worth is within these limits.

7. [10 marks total]

An infinite slab reactor, thickness  $a$ , is critical. What happens if the slab is divided into 2 halves (each of thickness  $a/2$ ) and separated to open up a gap,  $b$ , between the two halves? Assume a vacuum in the gap. Specifically, what is the new flux distribution and are the halves critical, subcritical or supercritical?

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**NOTE: DO EITHER QUESTION 8 OR 9**

8. [20 Marks]

Consider a reactor composed of long thin fuel pencils (with no cladding) suspended uniformly in a water coolant. Assume that the thermal conductivity of the fuel,  $k_f$ , is so large that the temperature distribution in the fuel is virtually flat. The only significant resistance to heat transfer is at the fuel/coolant interface, where the heat transfer coefficient is  $h_s$ . Assume also that the reactor has a negative temperature coefficient of reactivity,  $\alpha$ . The reactor was initially operating at a steady state power,  $P_o$ , fuel temperature  $T_o$ , coolant Temperature  $T_c$ . Assume that the coolant is flowing so quickly that it stays at constant temperature even though the power changes. Assume also that the flux is space independent.

- (a) What is the new steady state temperature if 1 mk of reactivity is added by control rod action?
- (b) What is the power at this new steady state condition?

9. [20 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 and 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.

**THE END**