ENGINEERING PHYSICS 4D3/6D3

DAY CLASS — Dr. Wm. Garland

DURATION: 3 hours —

McMASTER UNIVERSITY FINAL EXAMINATION — December 1994

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

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 $\Sigma_s(E_1 \; 6 \; E_2)$ and $\Sigma_s(E_2 \; 6 \; E_1)$.

   (d) Distinguish between η and f of the four factor formulae.

   (e) Distinguish between reactivity, ρ, and multiplication factor, k.

2. [15 Marks]

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

   (a) $D(\underline{r}) \, L^2 \, \varphi(\underline{r}) + [\, \nu\Sigma_f(\underline{r}) - \Sigma_a(\underline{r}) \,] \, \varphi(\underline{r}) = 0$

   (b) $In_{49}^{116} \; 6 \; Sn_{50}^{117} \; (\$ \; decay)$

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

   $$N_a *_{interface} \, ' \, N_b *_{interface}$$

   $$LN_a *_{interface} \, ' \, LN_b *_{interface}$$

   (d) In a reactor experiment a reactivity, ρ, 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 6 B 6 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 1×10^{13} n/cm^2-s impinges on an absorbing slab (Σ_a = 1 cm^{-1}). 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, α. 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