Dec. 16, 2003 Name: ____________________________

Final Examination

NE-630: NUCLEAR REACTOR THEORY

PART A: Closed books and notes. Hand in before beginning Part B.

1. Explain how and why each of the four factors in the four-factor formula for k_∞ changes if a heterogeneous core is converted into a homogeneous core with the same fuel-to-moderator ratio. *[6 points]*

2. Consider a bare spherical reactor surrounded by vacuum and operating at a very low power (i.e., fuel burnup and other feedback effects are negligible). Indicate which factors in the six-factor formula for k_{eff} change and whether they increase or decrease for each of the following changes. Explain your reasoning. Also indicate whether the reactor remains critical, becomes subcritical, or becomes supercritical.

   (a) the thermal fission cross section increases

   (b) boron is added to the core

   (c) a person stands next to the reactor

   (d) a beam of 20-MeV electrons impinges on the core

   (e) the core is deformed into a cube of the same volume

   [10 points]

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Part B: Open books and notes. Begin only after handing in Part A.

3. Two infinite homogeneous slabs each of thickness T and composed of the same purely diffusing material with a thermal diffusion length L and placed a distance a apart. A void surrounds both slabs. There is a plane source of neutrons of strength S_o neutrons cm^{-2}s^{-1} placed midway bewteen the two slabs. In addition, there is a volumetric neutron source of strength $S(x) = xe^{\alpha x}$ neutrons cm^{-3}s^{-1} in the lefthand slab where x is measured from the outer face. Finally, the outer face of the second slab is illuminated normally by a uniform beam of neutrons with intensity I_o neautron cm^{-2}s^{-1}. (a) Write the appropriate form of the one-speed diffusion equation that determines the flux density in each slab. (b) What is the most general solution of these equations (including any particular solution)? (c) What boundary conditions would you use to find values of any arbitrary constants in your general solution? Assume the validity of one-speed diffusion theory. *[15 points]*

4. A uniformly distributed source of 1-MeV neutrons of strength 10^{12} neutrons cm^{-3} s^{-1} is embedded in an infinite graphite medium. If absorption of neutrons during slowing down is negligible, calculate the energy-dependent flux density at 1 eV in this medium. DATA: at 1 eV, $\sigma_s^C = 4.9$ b. *[20 points]*

5. (a) What value of k_∞ is necessary for criticality of an infinite homogeneous medium composed of ^{239}Pu and graphite at room temperature? *[5 points]*

   (b) Consider a bare core shaped as a cube 5 m on a side and composed of a homogeneous mixture of ^{239}Pu and graphite. What moderator-to-fuel ratio is required to make the core critical when the core temperature is 20 C. *[15 points]*

   (c) What is the critical mass of fuel needed? *[5 points]*

   (d) To verify your analysis, what are the values of the six factors in the six-factor formula for k_{eff}. What is $kinf$? *[5 points]*

   (e) A 1-m thick layer of pure graphite is placed around a cubical core composed of the same fuel-to-moderator ratio as you calculated in part (b). What is the the critical size of the reflected core? What is the new critical mass? (HINT: Recall the concept of *reflector savings*). *[5 points]*