Dec. 17, 1993 Name: ____________________________

Final Examination

NE-630: APPLIED REACTOR THEORY

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

1. Define in words the physical meaning of k_∞ and of each factor in the six-factor formula for k_{eff}. *[10 points]*

2. Make a sketch of the neutron life cycle in a thermal reactor. Start with N fast neutrons and complete the cycle to obtain the number of second generation fast neutrons. Show all neutron losses and gains and identify them with short labels and with expressions using the symbols of the 6-factor formula for k_{eff}. *[10 points]*

3. 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 neutron source is brought near the reactor

   (e) the core is deformed into an ellipsoidal shape

   [10 points]

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

4. For the following one-speed, steady-state diffusion problem (i) sketch the geometry showing your coordinate system, (ii) write the appropriate form of the diffusion equation for each region in which this equation holds, (iii) write the general solution for each region including any particular solution, and (iv) write the boundary/source conditions you would use to determine the values of the arbitrary constants in your general solution.

   (a) an infinite homogeneous slab of thickness $2T$ is irradiated uniformly on its left surface by a neutron beams of intensity I_o cm^{-2} s^{-1}. The slab contains a volumetric source $S(x)$ which varies with the distance x from the left surface as

$$S(x) = \begin{cases} S_o e^{\alpha x} & \text{for} 0 < x < T \\ 0 & \text{for} T < x < 2T \end{cases}$$

   where α is a constant. Finally, at a distance $x = 3T/2$ from the left surface, there is an infinite plane isotropic neutron source of strength S_p cm^{-2} s^{-1}. Assume the slab is surrounded by vacuum. *[15 points]*

5. A homogeneous infinite slab of a non-absorbing moderating material has a thickness a and contains a monoenergetic fast neutron source of strength

$$S(x) = S_o \sin(\pi x/a) \ \ \text{cm}^{-3}\ \text{s}^{-1}$$

   where x is measured from the left face of the slab. Calculate the slowing down density $q(x, \tau)$ in the slab. Assume the slab thickness a includes the extrapolation distances. HINT: The Fermi age equation may be solved in many ways, but the easiest for this problem is to use Laplace transforms. However, you may use any method you like. *[15 points]*

6. Calculate the minimum concentration (fuel-to-moderator atom density ratio) of pure ^{233}U mixed homogeneously with graphite for a large mass of the mixture to be critical at room temperature, i.e., for k_∞ to equal unity. *[15 points]*

7. What is k_{eff} for a bare sphere, 500 cm in diameter, that is composed of the critical material of Problem 6? *[10 points]*

8. For the 500-cm sphere of the previous problem to become critical, what fuel-to-moderator atom ratio would be needed? What would be the critical mass (in kg) of ^{233}U in such a critical sphere? *[15 points]*