Dec. 14, 1994 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. A small sample of a single isotope is placed in the core of a thermal reactor at a point where the 2200 m/s flux density is 5×10^{13} cm^{-2} s^{-1}. The 2000 m/s absorption cross section of the sample isotope is 100 barns. What fraction of the isotope is transmuted by neutron absorption if the sample remains in the reactor for 1 year? Assume fast neutron absorption is negligible and that the isotope is a "1/v" thermal absorber. *[10 points]*

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Part B: Open books and notes. Begin this section 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) A homogeneous sphere of radius R contains a uniformly distributed volumetric source of strength S_o neutrons cm^{-3} s^{-1}. A homogeneous spherical shell of thickness T and of a different diffusing material surrounds the central sphere. On the outer surface of this shell is a uniformly-distributed isotropic surface source of strength S_a neutrons cm^{-2} s^{-1}. Assume a vacuum surrounds this compound assembly, and that no fissionable material is present. *[10 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

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

   where x is measured from the center of the slab and perpendicular to the slab surfaces. 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 ^{239}Pu mixed homogeneously with beryllium for a large mass of the mixture to be critical at room temperature, i.e., for k_∞ to equal unity. *[15 points]*

7. A homogeneous multiplying material composed of fuel (F) and moderator (M) has the following nuclear properties:

$\epsilon = 1.04$	$p = 0.910$	$\bar{\nu} = 2.30$
$\overline{\Sigma}_a^F = 0.102$ cm^{-1}	$\overline{\Sigma}_f^F = 0.085$ cm^{-1}	$\overline{\Sigma}_a^M = 0.050$ cm^{-1}
$L_T^M = 35$ cm	$\tau_T = 110$ cm^2	

   What is k_∞ for this material? *[5 points]*

   If a thermal neutron absorber or poison (P) of atomic density $N^P = 1.3 \times 10^{18}$ cm^{-3} and a thermal-averaged absorption cross section σ_a^P of 7,500 barns is added uniformly to this multiplying material, what is the fractional change in k_∞? *[10 points]*

8. What is the critical dimension of a cube composed of the unpoisoned material described in the previous problem. *[15 points]*