Dec. 19, 2002 Name: _____

Final Examination

NE-630: NUCLEAR 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 four-factor formula $k_\infty = \epsilon p \eta f$. *[8 points]*

2. Make a sketch of how k_{eff} and each of the four factors in the four-factor formula for k_∞ varies with the moderator-to-fuel ratio N_F/N_M in a homogeneous system. Use the same figure for all four factors and indicate an approximate vertical scale. NOTE: the origin represents a system composed of only moderator. *[6 points]*

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

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

4. An infinite homogeneous slab of thickness T and composed of a purely diffusing material with a thermal diffusion length L. The slab contains a volumetric source of strength

$$S(x) = S_o \cos\left(\frac{\pi x}{2T}\right) \quad \text{neutrons cm}^{-3}\ \text{s}^{-1}$$

where x is measured perpendicularly from the left face of the slab. In the center of the slab there is a plane source parallel the the faces emitting S_o neutrons $\text{cm}^{-2}\text{s}^{-1}$. The slab is surrounded by a vacuum. (a) Write the appropriate form of the one-speed diffusion equation that determines the flux density in the slab. (b) What is the most general solution of this equation (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]*

5. A uniformly distributed source of 3-MeV neutrons of strength 10^8 neutrons $\text{cm}^{-3}\ \text{s}^{-1}$ 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]*

6. (a) What value of k_∞ is necessary for criticality of an infinite homogeneous medium composed of ^{235}U and water? *[5 points]*

   (b) Would a spherical core composed of a homogeneous mixture of ^{235}U and water with a moderator-to-fuel ratio of 500 be critical if the tank has an extrapolated radius of 25 cm at room temperature. Assume the tank is surround by a vacuum. Assume room temperature. *[15 points]*

7. You have just be hired as a nuclear safety officer for XYZ fuel reprocessing company. One of your first assignments involves the transfer of liquids containing fissile nuclides. A solution of uranium (50 atom-% enriched) and water at 20^o C must be moved in a tank, with a 50-cm square cross section, from one building to another. The solution may contain up to 10% uranium by weight. What is the maximum depth of the tank to ensure a critical configuration does not occur. *[25 points]*