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. *[7 points]*

2. Briefly discuss the effect of (i) absorption and (ii) leakage on the thermal neutron energy spectrum in a small homogeneous bare reactor. Give reasons for your answers. *[8 points]*

3. Define in words the physical significance of the following quantities: *[10 points]*

   (a) thermal neutron flux density, ϕ_T

   (b) the inhour equation

   (c) the reactor period

   (d) reflector savings

   (e) the Fermi age

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

4. Three infinite homogeneous slabs each of thickness T and composed of the same purely diffusing material with a thermal diffusion length L are stacked together. A void surrounds the slabs. There is a plane source of neutrons of strength S_o neutrons cm^{-2}s^{-1} placed on both surfaces of the middle slab. In addition, the middle slab has a uniform volumetric neutron source of strength S_V neutrons cm^{-3}s^{-1}.

   (a) What symmetry can you use to reduce the number of regions in which you must solve the one-speed diffusion equation? (b) Write the appropriate form of the one-speed diffusion equation that determines the flux density in each region. (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]*

5. An experimental bare reactor is to be constructed in the form of a square cylinder with the diameter D equal to the height H such that $D = H = 150$ cm. The core is composed of graphite impregnated with highly enriched ^{235}U. Calculate (a) the moderator/fuel ratio N_C/N_U for criticality at room temperature, (b) the critical mass of ^{235}U, and (c) the values of the constants in the six-factor formula for k_{eff}. *[15 points]*

6. The above reactor is to operate at a power of 15 milliwatts. What is the average thermal neutron flux in the reactor? *[15 points]*

7. A monoenergetic source emitting 10^6 neutrons per cm^3 per second with energies of 2 MeV is uniformly distributed in an infinite graphite medium. If absorption is negligible, calculate the flux density of 2-eV neutrons, i.e., $\phi(E)$. Data: for graphite, $\sigma(2eV) = 5$ b. *[15 points]*

8. A homogeneous, non-absorbing sphere of extrapolated radius R contains a distributed volumetric source of monoenergetic fast neutrons. Calculate the slowing down density $q(r,\tau)$ in the sphere is the source is distributed as

$$S(r) = \frac{S_o}{r} \sin \frac{\pi r}{R}.$$

   HINT: Mathematically this problem can be solved several ways, but the "quickest" is to use Laplace transforms. However, use whatever way you prefer. *[15 points]*