Nuke 301 Study Problems for Final Exam 2013
Note: Data/formula sheet is appended

1. All problems from **all previous study sheets.**

2. All **homework problems and previous test problems.**

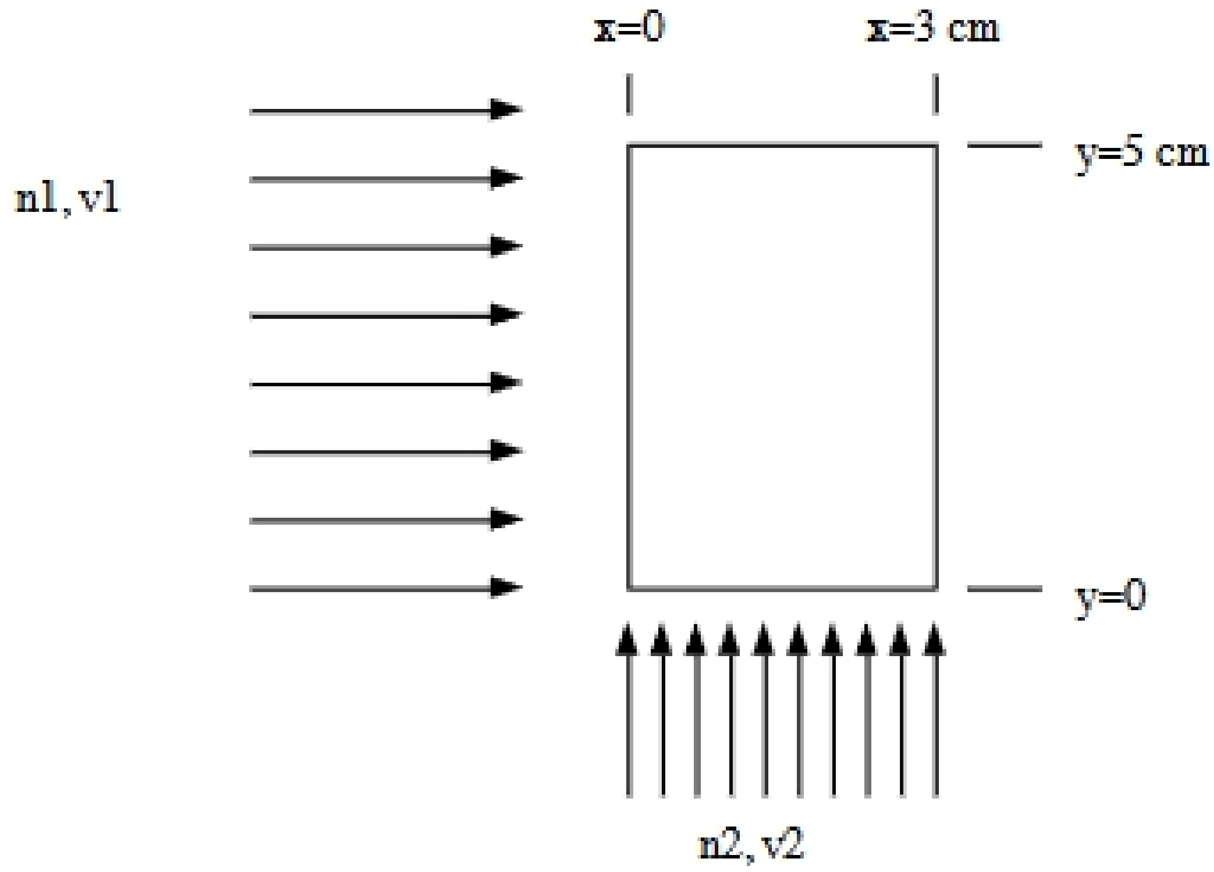
3. A spherical container holds a mixture of water and uranium. The interaction of the container walls with neutrons is negligible. The container is surrounded by vacuum. The radius of the container is one meter. There are "Q" atoms of ^{235}U per molecule of water; Q is much less than 1 — the mixture is dilute. The number density of water molecules is essentially the same as if the ^{235}U were not present. The mixture is at 20°C. You should be able to figure out from this information the number of water molecules per cubic cm.
   a) Approximately what is the fast nonleakage probability in this reactor? (Hint: you will need age to thermal for the mixture. You should be able to estimate it using approximations in the notes and data you've been given.)
   b) Look at your answer to part (a). Does the ^{235}U concentration (Q) influence it at all? Discuss this. Thinking in terms of physics (not necessarily math), how would you expect Q to influence the answer?
   c) What is your estimate of the resonance-escape probability in this reactor, as a function of Q?
   e) What is the thermal diffusion length in this reactor, as a function of Q?
   f) What is the thermal non-leakage probability in this reactor, as a function of Q?
   g) What is the thermal utilization in this reactor, as a function of Q?
   h) What is the thermal reproduction factor in this reactor, as a function of Q?
   i) What is the multiplication factor in this reactor, as a function of Q? Generate a number for the particular value $Q = 0.005$.

4. Estimate the Q in problem 3 that would make the reactor critical. [Hint: plot k as a function of Q.]

5. Consider an ∞ **medium** of ^{12}C, with a source emitting S_0 n/cm^3-s in the medium. The emitted neutrons are distributed uniformly in energy between 18 keV and 20 KeV.
   a. To solve parts b and c, you will have to make reasonable assumptions about the interactions between neutrons and carbon in the energy ranges of interest. **State them.**
   b. What is the energy-dependent scalar flux of neutrons that have had no collisions yet? [Call it $\phi_0(E)$.] **Spell it out for all E between zero and ∞.**
   c. What is the energy-dependent scalar flux of neutrons that have had exactly one collision? [Call it $\phi_1(E)$.] **Spell it out for all E between zero and ∞.**

6. You are given a homogeneous mixture of C and low-enriched U such that k_∞ is 1.10. (The ratio of carbon to uranium atoms is pretty high. The ratio of U-235 atoms to total U atoms is 0.04.) Design a cubical reactor using this material, such that it is critical when surrounded by a vacuum. (That is, find the critical width.) Use the data sheet and your finely tuned engineering judgment. [Hint: your judgment may say that P_{TNL} is close to 1, and if you multiply a small term by something close to 1 you don't make much error if you are adding it to a larger term . . .]

7. Two monoenergetic and monodirectional neutron beams strike a block of material. Each beam completely covers the face it strikes. The block is **2 cm deep** in the z direction.



The following data apply:

Σ_t = **4 cm^{-1}** given a relative speed of 10^8 cm/s between neutron and nucleus;
$\Sigma_\gamma = \Sigma_t$;
n1 = neutron density in first beam = **2×10^3** n/cm^3 ;
v1 = neutron speed in first beam = **10^8** cm/s ;
n2 = neutron density in second beam = **10^4** n/cm^3 ;
v2 = neutron speed in second beam = **10^8** cm/s ;
the target is **cold**.

a) What is $\phi(x,y,z)$, for $0 \le x \le 3$ cm and $0 \le y \le 5$ cm and $0 \le z \le 2$ cm ?
b) What is $\underline{J}(x,y,z)$, for $0 \le x \le 3$ cm and $0 \le y \le 5$ cm and $0 \le z \le 2$ cm ?

Compute:

c) Probability that a neutron in the first beam penetrates past x=2 cm,
d) Inleakage rate [n/s] into the block,
e) Absorption rate [n/s] in the block,
f) Rate [n/s] at which neutrons cross the plane at y=2 cm.

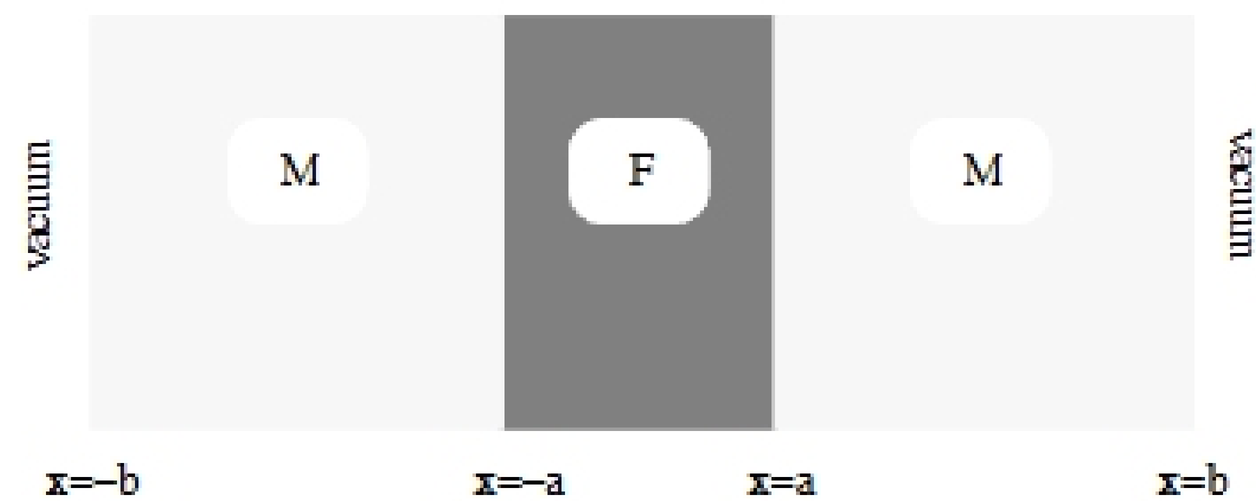
8. Consider a bare homogeneous cubical reactor of width a. The reactor is **critical** and operating in **steady state**. Suppose the reactor is producing "P" power, and each fission produces "w" energy. Assume that the macroscopic thermal cross sections ($\Sigma_{x,th}$ for all reaction types (x)) are known and properly averaged over all neutron and nucleus velocities, and further assume that the fast-fission factor (ε) is known. In terms of P, w, $\Sigma_{x,th}$, and ε:

a) What is the thermal scalar flux at the center of the reactor (i.e., **at $x=y=z=0$**)? [Hint: what is the fundamental mode for this geometry? Can you integrate it? Can you relate that integral to the known power?]

b) At what rate [n/s] are neutrons leaving the reactor through the top face (i.e., **at $z=a/2$**)?

9. Consider the following three-region slab reactor composed of two uniform moderator regions with a uniform fuel region in between. (The two moderator regions are identical.)

infinite in y and z



Suppose there is a spatially-uniform **source** emitting S_0 n/cm^3-s in the "M" regions. Suppose further that all neutrons move with the **same speed** and that the problem is **steady-state**.

a) Write (don't solve) the diffusion equation(s) for the scalar flux in this problem.

b) Write all boundary and other conditions required to fully specify the problem.

Your answers to (a) & (b) should completely specify the problem mathematically.

c) Pretend someone solved your diffusion problem and found expressions for all the unknown functions (scalar fluxes) in the problem. In terms of these functions and the properties of the materials, what is the **net rate per unit area** at which neutrons are flowing **from moderator to fuel**?

10. Consider a mixture of ^{235}U and heavy water (D_2O) with the following parameters:

N_O = 3×10^{22} atoms/cm^3 ;
N_{235} = $N_O/2000$,
T_n = "neutron temperature" = 200 °C ,
T_{mix} = mixture temperature = 100 °C ,
n = thermal-neutron density = 10^5 n/cm^3,

a) At what rate per cm^3 are thermal neutrons being absorbed in the mixture?

b) At what rate per cm^3 are thermal neutrons causing fission in the mixture?