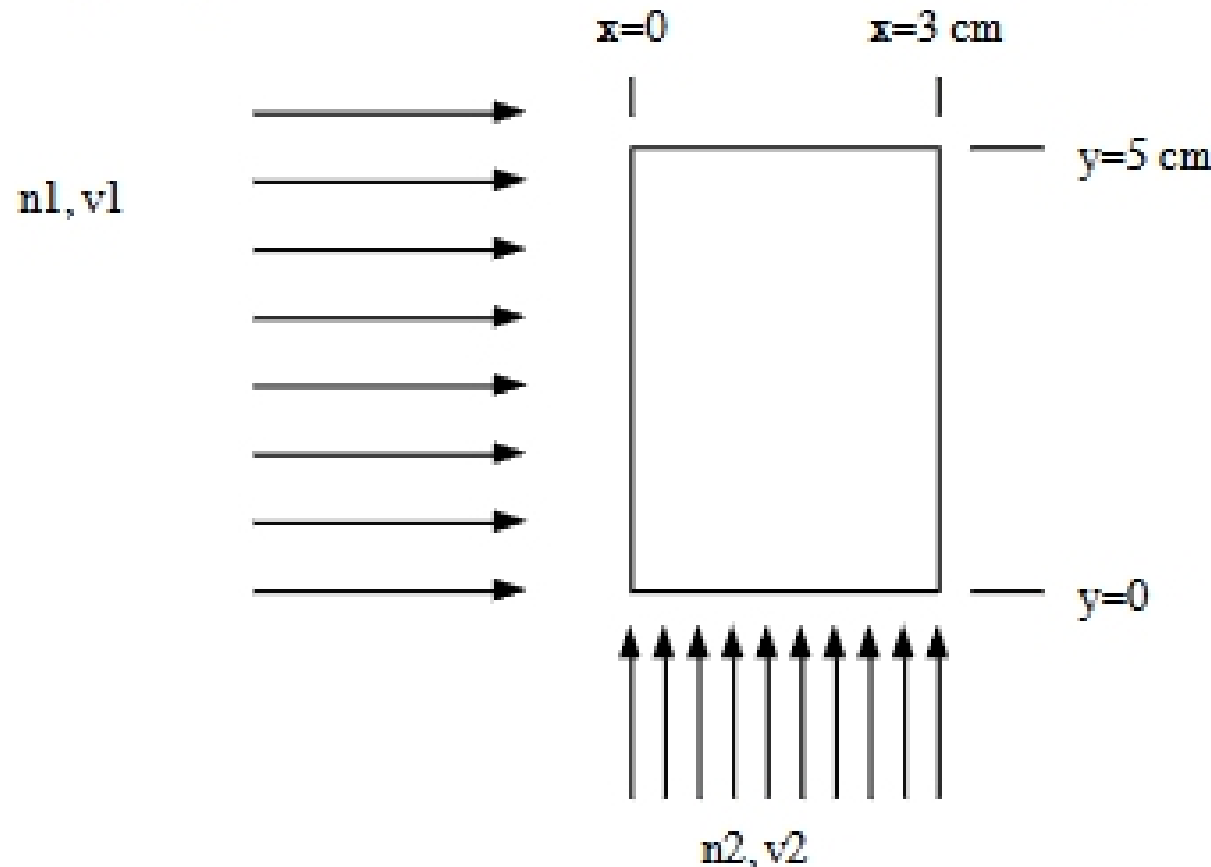


Nuke 301 Study Problems for Final Exam 2009

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 from the handouts I gave you and from info in the notes.)
 - 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/cm³-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.) 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.

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:

$\Sigma_t = 4 \text{ cm}^{-1}$ given a relative speed of 10^8 cm/s between neutron and nucleus;

$\Sigma_a = \Sigma_t$;

n_1 = neutron density in first beam = $2 \times 10^3 \text{ n/cm}^3$;

v_1 = neutron speed in first beam = 10^8 cm/s ;

n_2 = neutron density in second beam = 10^4 n/cm^3 ;

v_2 = neutron speed in second beam = 10^8 cm/s ;

the target is **cold**.

- What is $\phi(x,y,z)$, for $0 \leq x \leq 3 \text{ cm}$ and $0 \leq y \leq 5 \text{ cm}$ and $0 \leq z \leq 2 \text{ cm}$?
- What is $J(x,y,z)$, for $0 \leq x \leq 3 \text{ cm}$ and $0 \leq y \leq 5 \text{ cm}$ and $0 \leq z \leq 2 \text{ cm}$?

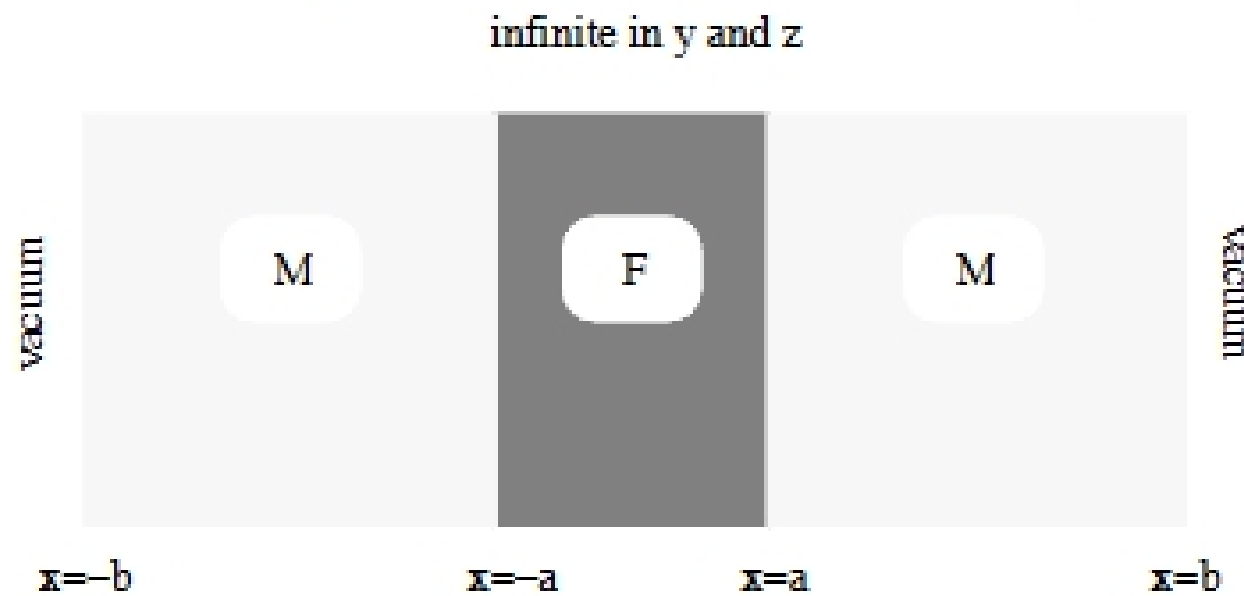
Compute:

- Probability that a neutron in the first beam penetrates past $x=2 \text{ cm}$,
- Inleakage rate [n/s] into the block,
- Absorption rate [n/s] in the block,
- Rate [n/s] at which neutrons cross the plane at $y=2 \text{ cm}$.

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 all macroscopic thermal cross sections are known and properly averaged over all neutron and nucleus velocities, and further assume that $[P_{FNL} \epsilon p]$ is known. In terms of the given data and these perfectly averaged cross sections and $[P_{FNL} \epsilon p]$:

- What is the scalar flux at the center of the reactor (i.e., at $x=y=z=0$)?
- At what rate [n/s] are neutrons leaving the reactor through the right face (i.e., at $x=a/2$)?

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.)



Suppose there is a spatially-uniform source emitting S_0 n/cm³-s in the “M” regions. Suppose further that all neutrons move with the **same speed** and that the problem is **steady-state**.

- Write (don’t solve) the diffusion equation(s) for the scalar flux in this problem.
- Write all boundary and other conditions required to fully specify the problem.

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

- 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 ²³⁵U and heavy water (D₂O) with the following parameters:

$$\begin{aligned}
 N_O &= 3 \times 10^{22} \text{ atoms/cm}^3 ; \\
 N_{235} &= N_O / 2000 , \\
 T_n &= \text{“neutron temperature”} = 200 \text{ }^\circ\text{C} , \\
 T_{\text{mix}} &= \text{mixture temperature} = 100 \text{ }^\circ\text{C} , \\
 n &= \text{thermal-neutron density} = 10^5 \text{ n/cm}^3 ,
 \end{aligned}$$

- At what rate per cm³ are thermal neutrons being absorbed in the mixture?
- At what rate per cm³ are thermal neutrons causing fission in the mixture?

11. A **cubical** container holds a uniform mixture of heavy water (D₂O) and ²³⁵U. The interaction of the container walls with neutrons is negligible. The container is surrounded by vacuum. The width of the container is **three meters**. There is **one** atom of ²³⁵U per **500** molecules of D₂O. There is approximately 1.1 gram of D₂O per cm³ of mixture. The mixture is at 200°C, and the neutron temperature is 400°C.

Estimate the multiplication factor.