UNIVERSITY OF REDDIT

Nuclear Reactor Physics : Neutronics

Homework 1: Useful definitions

The number of stars gives the estimated difficulty of an exercise, though I must say they are not a very trustworthy notation system since I do not really know what you will find challenging or not.

You can either write your answer through :

- Google Docs document (insert > Equation... > type your question using LateX-like directives or select manually the formulas you want to introduce).
- Any word processor that supports equations (Word, LibreOffice,...)
- Good ol' paper and pencil, then scan your solutions.
- Virtually any other method you can think of, as long as I can read it

You can then send that to me by :

- Email at NuclearEngineer@ureddit.com (unavailable for now !)
- Dropbox/Google docs link
- Use of the "send your answer" form (select the homework/quiz you are answering to, write your Ureddit username, upload your document and submit !)
- Virtually any other method you can think of, as long as I can receive it

I will acknowledge receipt of your email/message within two days or so, so that you don't worry that it did not reach me.

Please let me know at the end of your homework if you want a partial correction (i.e. hints toward the good answer if your answer is not correct, so that you can try it again if you want), or a total correction (complete solution to the problems).

Once again, I remind you about the discussion platform, if you have any trouble with the math or if you're thinking "how the hell do I answer that ? I'm stuck !"

Question n°1 : ✪

Please demonstrate why $Q(x) = e^{-\Sigma x}$. (§1.1.3)

Question n°2 : ✪✪✪

Please demonstrate why $\lambda = \frac{1}{\Sigma}$. *(Hint : $\lambda = < x >$, "the average value of the distance x at which the first collision occurs")*

Question n°3 : ✪✪

Please demonstrate why $J_+(\vec{r}, E, t) \ = J_-(\vec{r}, E, t) = \frac{\phi(\vec{r},E,t)}{4}$ in the case of an isotropic flux.

Question n°4 : ✪✪✪

1) Let us consider monokinetic neutrons (they all have the same speed) emitted in an infinite and homogeneous medium characterized by the macroscopic cross-sections Σ_t,Σ_s and Σ_a.
Calculate the expressions of :

- The mean number of elementary paths between emission and absorption, i.e. the average number of time a neutron can "bounce" (scatter) before being absorbed. Let us call this mean number $\bar{n}$.
- The absorption mean free path, i.e. the total mean path between emission and absorption

2) Take the case of three common moderators used in nuclear reactors :

1. light water
2. heavy water
3. graphite

We consider monokinetic $2200\ m.s^{-1}$neutrons.
Please calculate the macroscopic cross-section (aborption and scattering), the mean absorption path (refer to the previous question), and the mean duration of the migration.

Data :

Nuclide	Atomic mass (u)	Absorption microscopic cross-section (b)	Scattering microscopic cross-section (b)
Hydrogen	1.00794	0.322	30.3
Oxygen	15.9994	0.000191	3.76
Carbon	12.0107	0.00337	4.94
Deuterium	2.01410	0.00051	4.25

Densities ($kg.m^{-3}$):
Light water : 998
Heavy water : 1105
Graphite : 1700

$1\,u = 1.660538921.10^{-27}\,kg$

What is a moderator ?

A moderator is a material that does not absorb the neutrons, but can slow them down (by scattering, i.e. lots of collisions). Water is used in PWR (Pressurized Water Reactors) and BWR (Boiling Water Reactors) for example, but it can also be heavy water, graphite, sodium, etc. Basically, we want a material that is good at scattering the neutrons and that does not absorb them before they have time to slow down.
Why do we need to slow down neutrons ? Well, it is then more likely for the U_{235} to absorb them and to undergo fission.
That is what allows you to have a chain reaction in a classical nuclear reactor. Indeed, the fissions will produce fast neutrons (1-2 MeV [a million electronVolt, that's an energy]), but will be provoked mainly by thermal neutrons (around 0,025 eV, quite the difference, isn't it ?).

I will talk about that in much greater details later on, do not worry.