ENGY.4340 Nuclear Reactor Theory

Fall 2016

HW #4: Data for Design Calculations

Problem 1 Reactor Core Data for a Fast Reactor (10 points)

Consider an oxide fueled fast reactor core consisting of 50% sodium, 30% fuel, and 20% stainless steel by volume. The fuel material consists of 15% PuO_2 and 85% UO_2 by volume. The spectrum-averaged 1-group microscopic cross sections (in units of barns) are tabulated below:

isotope	average neutrons per fission, ν	fission cross section σ_f	absorption cross section σ_a	transport cross section σ_{tr}
U238	2.6	0.05	0.404	8.2
Pu239	3.0	1.95	2.4	8.6
Na	--	--	0.0018	3.7
Fe	--	--	0.0087	3.6

Assuming that all the plutonium in the PuO_2 is Pu239, the uranium in UO_2 is U238, the stainless steel is predominantly iron, and the cross sections for oxygen are negligible, compute the following core-averaged macroscopic cross sections and the extrapolation distance: $\nu\Sigma_f$, Σ_f, Σ_a, D and d = 2.13D.

The required material density information is as follows:

$UO_2 \rightarrow 10.4\ g/cm^3$ $PuO_2 \rightarrow 10.9\ g/cm^3$ $Na \rightarrow 0.87\ g/cm^3$ $Fe \rightarrow 7.80\ g/cm^3$

Problem 2 Reflector Data for a Fast Reactor (5 points)

The core region described in the previous problem is surrounded by a reflector composed of 30% stainless steel and 70% liquid sodium by volume. Using the data given above, compute the macroscopic cross sections for a homogeneous mixture of this material. What is the diffusion length for this region?

Problem 3 Additional Core Material Data for a Fast Reactor (5 points)

For the core material described in the above problem, compute the following quantities:

a. The fuel utilization, f, which is the ratio of absorptions in the fuel to total absorptions in the core.

b. The value of η, which is the average number of neutrons emitted per absorption in the fuel.

c. The infinite multiplication factor, k_∞, for the core material.

Problem 4 Preliminary Design Data for Water for a PWR at 300 C (10 points)

Calculate the thermal diffusion coefficient, the thermal diffusion length, and the thermal neutron age for water near the outlet of a PWR -- that is, at about T = 300 C and a density of 0.68 g/cm^3.

Problem 5 The Diffusion Length of Water vs. Boric Acid Concentration (10 points)

This problem addresses how the thermal diffusion length of water changes with various concentrations of boric acid. In particular, you are asked to calculate the thermal diffusion length at room temperature of boric acid (H_3BO_3) solutions in water with concentrations of

a. 10 g/liter   b. 1 g/liter   c. 0.1 g/liter

Hint: Note that, because of the small concentration of boric acid, the diffusion coefficient for the mixture is essentially the same as that of pure water. However, this is NOT true for the absorption cross section of the mixture...

Problem 6 Neutron Activation of Gold at Thermal Energies (10 points)

The thermal (0.0253 eV) capture cross section for Au-197 is about 98.7 b. If a thin 0.12 g gold foil is placed in a thermal system where the temperature is about 150 ^{o}C and the thermal flux is $\phi_T = 2.0\times10^{13}$ neutrons/cm^2-sec, compute the following quantities:

a. the thermal absorption rate in Au-197

b. the activity of Au-198 after a 3-hour irradiation

Note that Au-197 has an isotopic abundance of 100 a/o and that Au-198 has a 2.7 day half-life and a negligible thermal absorption cross section. Explain the solution logic and clearly state any assumptions needed to solve this problem.

Note: Gold actually has fairly significant resonance cross sections so, if we only use the thermal reaction rate, the above Au-198 activity computations will be under-predicted. However, here we will ignore the production of Au-198 by capture in Au-197 in the epithermal and fast energy ranges by arguing that the flux above about 1 eV is low compared to the thermal flux. Thus, here we are assuming that the total capture rate per second in Au-197 can be computed by considering only thermal neutrons below about 1 eV.