ENGY.4340 Nuclear Reactor Theory

Fall 2016

HW #6: Modified 1-Group Theory for Bare and Reflected Cores: Critical Size and Composition Calculations

Problem #1 Critical Composition in a 1-D Bare Slab Reactor (10 points)

Consider a critical bare slab reactor 200 cm thick consisting of a homogeneous mixture of U235 and graphite. The maximum thermal flux is 5×10^{12} neutrons/cm^2-sec. Using modified 1-group theory, compute the following quantities:

a. The atom density of U235 needed for critical operation.

b. The value of k_∞.

c. The thermal power generated per unit area of the slab.

Problem #2 Critical Size in a Bare Cubical Reactor (10 points)

A bare cubical thermal reactor consists of a homogeneous mixture of U235 and graphite. The ratio of atom densities is $N_F/N_M = 1.0\times10^{-5}$ and the operating temperature is about 250 ^{o}C. Using modified 1-group theory, compute the following quantities:

a. The critical dimensions of the reactor.

b. The critical mass of U235.

c. The maximum thermal flux if the reactor power is 100 kW.

Note: For a bare rectangular parallelepiped system, with extrapolated side lengths of a, b, and c (i.e. $a = a_o + 2d$ with a_o as the physical dimension), the appropriate B^2 is given by

$$B^2 = \left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{b}\right)^2 + \left(\frac{\pi}{c}\right)^2$$

and the flux is given as

$$\phi(x,y,z) = A\cos\left(\frac{\pi x}{a}\right)\cos\left(\frac{\pi y}{b}\right)\cos\left(\frac{\pi z}{c}\right)$$

where the flux normalization (assuming a small extrapolation distance) is given by

$$A = \frac{3.87P}{V\kappa\overline{\Sigma}_f}$$

As a final note, make sure you treat the temperature dependence properly in this problem!!!

Problem #3 Criticality Calculations for Bare & Reflected 1-D Slab Systems (10 points)

Consider a slab reactor geometry that consists of a solution of Pu239 and water, with a plutonium concentration of 8.5 g/liter of solution.

a. Using modified 1-group theory, estimate the critical size (i.e. thickness a_o) and critical Pu239 mass (in g/cm^2) of a bare critical slab of this material.

b. Again using modified 1-group theory, estimate the critical size and critical Pu239 mass (in g/cm^2) of the Pu-water solution if it has an infinite water reflector on both sides of the slab configuration.

   Hint: For Part b, use the expression (from the Lecture Notes)

   $$\delta \approx 7.2 + 0.10\left(M_T^2 - 40.0\right) \qquad \text{(for water moderated and reflected systems)}$$

   to estimate the reflector savings, and then compute the new critical thickness, a_o, of the Pu-water solution that is required for a just-critical core-reflector system.

c. How do the critical sizes and critical masses for the reflected and bare cores compare? Is this consistent with your expectations? Discuss your results briefly…

Problem #4 Use of the *diluteh* GUI to Analyze Bare and Reflected Systems (20 points)

Several years ago, a relatively simple Matlab code, called ***diluteh.m***, was written to solve critical size and composition problems for dilute homogeneous systems using modified 1-group theory. Recently a graphical user interface (GUI) was added to make the code even easier to use. The code simply implements modified 1-group theory as discussed in the Lecture Notes (using the Lamarsh formulation), along with the basic nuclear data contained in various tables, figures, and analytical relationships directly from Lamarsh. The GUI is quite intuitive and quite easy to use.

In particular, the code requires the following information about the system of interest:

Reactor Type:	Bare or Reflected
Fuel Material:	U233, U235/U238, or Pu239
Fuel Density (g/cm^3 in mix):	
Moderator Material:	H_2O, D_2O, Be, or C-12
Moderator Density (g/cm^3 in mix):	
Temperature (^{o}C) of Core Mixture:	
Reflector Material:	H_2O, D_2O, Be, or C-12
Reflector Density (g/cm^3 in mix):	
Temperature (^{o}C) of Reflector:	
Geometry Information:	

With this information, the ***diluteh_gui*** code will compute the appropriate cross sections required for the problem, it will determine the parameters needed within the 4-factor and 6-factor formulas (with $p\varepsilon \approx 1$ for a dilute homogeneous system), and it will calculate k_∞, the reflector savings, the geometric buckling, and k_{eff} for the system. A plot that shows how k_{eff} varies with size for the specified material composition is also given. It is very easy to use and, by manually changing a key parameter of interest, it is easy to determine the effect of that particular parameter on the overall multiplication factor. Note also that the GUI has a Save Data/Results button that will save the results for a particular case in a data file -- and this file can be printed as full documentation for a particular system of interest.

With this background, your job is to re-solve Problems #1 - #3 using the ***diluteh_gui*** code. Discuss the method/approach for each calculation (you will need to prepare the required data for each case and vary one or more parameters, as needed), and compare the code results to your hand calculations. Discuss your comparisons and be sure to resolve any large differences that are observed. Do this separately for each problem and be sure to ***include a printout of the Data/Results file for each case of interest*** as part of your overall documentation for this assignment. Note that Prob. #3 includes both a bare and reflected core design, so two ***diluteh*** runs are needed here for comparison to the hand calculations for Prob. #3 -- giving a total of **four (4) unique applications** of the ***diluteh_gui*** software.