ENGY 3310 Fundamentals of Nuclear Science and Engineering

Spring 2016

HW #4: Basic Notation and Material Atom Densities

Problem 1 (15 points)

Do Problems 1.8, 1.13, and 1.20 in Shultis and Faw 2nd Ed. These problems deal with some basic notation from nuclear and atomic physics and the computation of atom densities for various materials.

Problem 2 (10 points)

Compute the atom densities of U235, U238, and C within uranium carbide (UC) fuel with a U235 enrichment of 25 w/o and a UC density of 13.6 g/cm^3.

Problem 3 (10 points)

The fuel for a certain breeder reactor consists of pellets composed of mixed oxides, UO_2 and PuO_2, with the PuO_2 comprising approximately 30 w/o of the mixture. The uranium is essentially all U238, whereas the plutonium contains the following isotopes: Pu239 (70.5 w/o), Pu240 (21.3 w/o), Pu241 (5.5 w/o), and Pu242 (2.7 w/o). Calculate the number of atoms of each of the six isotopes per gram of fuel.

Note: Here you are asked to compute the number of atoms per gram of fuel. With this quantity and the physical density of the fuel in g/cm^3, you could easily compute the usual atom density, N_i, of each of the components in atoms/cm^3 or atoms/b-cm. However, you are not given the fuel density as part of this particular problem, so the desired units here should be atoms/gram of fuel.

Problem 4 (20 points)

During the summer of 2011, UMass-Lowell obtained several essentially fresh fuel assemblies from the recently decommissioned WPI reactor (the fuel was only very slightly used). The existing UMLRR fuel elements and the WPI fuel assemblies are quite similar in overall size and shape, but there are enough key differences so that a formal comparison and safety evaluation for their combined use is required. In particular, Table 1 highlights many of these similarities and differences. For example, both assemblies have 18 plates within the two side plates -- but the WPI element has 18 fuel plates, whereas the UMLRR element has 16 fuel plates and two aluminum end plates for a total of 18 plates. The fuel meat for the WPI plate is UAl_x-Al with a U235 loading of about 9.3 g, whereas the UMLRR full fuel plate contains U_3Si_2-Al fuel with 12.5 g of U235 per plate. In addition, although the nominal cladding thicknesses are essentially identical, the WPI fuel meat is slightly thicker than the UMLRR fuel -- thus, the overall fuel plate thickness is a little larger, with a slightly decreased channel thickness for the WPI element.

Before any physics analysis can be performed for the WPI assembly, one first must determine the region and assembly-averaged material compositions associated with this fuel element -- and this will be the goal of this HW Problem. In particular, based on the UMLRR example done in class, the general geometry layout given in the Lecture Notes, and the specific WPI design data highlighted in Table 1, your goal is to compute assembly-averaged densities for all five isotopes that make up the WPI fuel element (U235, U238, Al, H, and O). All the needed information for the fuel region is given in Table 1 and you can assume nominal densities for the pure aluminum and water regions (2.7 g/cm^3 and 1.0 g/cm^3, respectively, at room temperature). Note that the assembly basis in the axial direction should only include the active fuel region (i.e. the fuel meat height) -- and, since all the structures have the same height, the volume fraction calculations can really be done using area fractions (as done in the class examples).

Note that this problem requires a number of computations -- so be sure to organize your work so that a reviewer can easily follow your assumptions/analyses. Also clearly tabulate appropriate intermediate results (such as the region densities and volume fractions), so that it is easy to see how the final assembly-homogenized densities are developed. Thus, at a minimum, you should have three summary tables of results -- one for the fuel meat, structure, and water region densities, one for the fuel meat, structure, and water volume fractions, and a final table of densities averaged over the entire fuel assembly. It is this final table that contains the desired homogenized densities for the WPI fuel assembly…

Good luck -- and be sure to do your work neatly and to clearly explain your overall solution logic!

Table 1 Nominal physical data for the UMLRR and WPI standard fuel elements.

Parameter	UMLRR Full Fuel Element	WPI Fuel Element
Plate Data:		
fuel type	U_3Si_2-Al	UAl_x-Al
enrichment (w/o)	19.75	19.75
U_3Si_2 or U fraction in fuel meat (w/o)	67.54	45.0
U235 loading (g/plate)	12.5	9.28
plate width (cm)	7.140	7.049
meat width (cm)	6.085	6.085
plate thickness (cm)	0.1270	0.1524
meat thickness (cm)	0.0510	0.0762
clad thickness (cm)	0.0380	0.0381
plate height (cm)	63.50	62.55
meat height (cm)	59.69	59.69
Assembly Data:		
fuel plates/element	16	18
aluminum plates/element	2	0
U235 loading (g/element)	200.0	167.0
side plate thickness (cm)	0.5080	0.4572
channel thickness (cm)	0.2963	0.2709
assembly dimension (cm × cm)	7.620 × 7.620	7.620 × 7.620
assy. dim. with gap (cm × cm)	7.7724 × 7.7724	7.7724 × 7.7724