NE-150 - Introduction to Nuclear Reactor Theory

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Homework 4

Due March 20, 2018

Textbook (E. E. Lewis, "Fundamentals of Nuclear Reactor Physics"), Chapters 3 and 4

1. A rector is to be built with fuel rods of 1.2 cm in diameter and a liquid moderator with 2:1 volume ration of moderator to fuel. What will be the distance between nearest fuel centerlines be:
    a. For a square lattice?
    b. For a hexagonal lattice?
    (E.E. Lewis, Problem 4.1)

2. Consider an infinitely large homogeneous mixture of ^{235}U and a moderating material. Determine the ratio of fuel-to-moderator density that will render this system critical for the following moderators:
    (a) graphite;
    (b) water;
    (c) heavy water;
    Use thermal cross section data.

3. In a certain thermal reactor, fueled with partially enriched uranium, 13% of the fission neutrons are absorbed in resonances of ^{238}U and 3% leak out of the reactor, both while these neutrons are slowing down; 5% of the neutrons that slow down in the reactor subsequently leak out; of those slow neutrons that do not leak out, 82% are absorbed in fuel, 74% of these in ^{235}U. What is the multiplication factor of this reactor? What is the conversion ratio?

4. The following MCNP input describes a bare uranium sphere (enrichment 93.71 at% ^{235}U; density 18.74 g/cm^3; radius 8.74 cm). What is the k_{eff} of this system obtained from MCNP? Modify the input to represent:
    (a) a bare sphere of uranium 50 at% ^{235}U enriched, 18.74 g/cm^3 density;
    (b) a sphere of uranium 50 at% ^{235}U enriched, 18.74 g/cm^3 density surrounded by a 10 cm thick spherical shell of lead (natural composition – 82000 – 11.3 g/cm^3 density);
    Run these new inputs to determine the mass of uranium required to reach criticality (first decimal digit accuracy – 1.0) in both cases. E-mail the inputs.

```
Lady Godiva
1   1   -18.74   -1   imp:n=1  $ U sphere
2   0             1   imp:n=0  $ external

1   so   8.74   $ sphere radius

m1  92235 0.9371  92238 0.0629
kcode 3000 1. 100 300
```

```
ksrc  0. 0. 0.
mode n
print
```

5. Write a MCNP/SERPENT input for a PWR single pin with the following characteristics: fuel rod outer diameter 0.96 cm; clad thickness 0.6 mm; gap 0.1 mm; square pitch 1.26 cm; total active length 400 cm. The fuel is UO_2 5 wt% enriched and density 10.41 g/cm^3; the clad is in Zircaloy-4 (assume 100 Zr at natural composition, 6.56 g/cm^3); the gap is void; water density is 0.7 g/cm^3. Use reflective boundary conditions.
   Determine:
   (a) k_{inf}
   (b) Average total flux value in the fuel, clad and moderator regions.
   (c) Average thermal and fast flux in fuel, clad and moderator regions.
   (d) Plot the average total, thermal and fast flux in fuel, clad and moderator regions on one plot and discus the flux shapes.
   (e) Total fission and capture rates in the fuel region.
   Turn in your input! Note: For average total flux, the code will integrate the angular energy and space dependent flux over all angles, over all energies, and over each region (subdivided by the region volume). Assume that the upper energy boundary of the thermal flux is 0.1 eV, and the upper energy boundary of the fast flux is 10 MeV. *For average thermal flux, the code will integrate the angular energy and space dependent flux over all angles, over all energies from 0 to 0.1 eV, and over each region (subdivided by the region volume). For average fast flux, the code will integrate the angular energy and space dependent flux over all angles, over all energies from 0.1 eV to 10 MeV, and over each region (subdivided by the region volume)*

6. Using the data from problem 5, modify your MCNP/SERPENT input in the following way:
   (a) Subdivide the fuel region into 5 concentric regions of equal volume.
   (b) Determine the average total, thermal, and fast flux values in each concentric region in the fuel.
   (c) Plot these flux distributions and compare with your result for problem 5. (d). What can you conclude?
   (d) Determine the fine energy distribution for the flux averaged over the fuel region. Add 10 energy sub-regions from 0 to 0.1 eV, and 10 energy sub-regions from 0.1 eV to 10 MeV. Plot this fine energy distribution.
   Turn in your input!