PHYS 4134, Fall 2016, Homework #10

Due Wednesday, November 23

1. Operating a Reactor

This problem is similar to the end-of-chapter problem 10-10. A thermal reactor uses 2.0% enriched uranium with a ratio of the fuel:moderator of 1:400. If the reactor is operating at a rating of 5 MW/metric ton of uranium, calculate: a) the number of atoms of ^{235}U per metric ton, the neutron flux Φ, and the thermal utilization factor *f*. [Hint: use equation 10.9 to calculate *f*.]

2. Operating a Nuclear (Fission) Reactor

We are going to calculate the power output, rating and fuel consumption for a thermal reactor containing 50 metric tons of "low enriched" uranium (4% ^{235}U). It may be helpful to review first the example on page 283 of your text. Because we are using enriched fuel, the physical dimensions of the reactor can be more compact, which will raise the neutron flux.

As basic data, you have a neutron flux of $\Phi = 10^{14}$ neutrons per square centimeter per second. Every fission of a ^{235}U nucleus releases 200 MeV of recoverable energy. The cross section (from your book) for fission is $\sigma_f\left(^{235}U\right) = 579$ b and the cross section for neutron capture is $\sigma_c\left(^{235}U\right) = 101$ b.

a) Calculate the number of ^{235}U atoms in the fuel.
b) Calculate the power output of the reactor.
c) The rating is the output power per ton of fuel. Calculate the rating.
d) What percentage of fuel is used up in one year of continuous running?
e) Assuming that 6% of the generated neutrons contribute to the flux given above, and if the effective area of fuel is about 10 m^2, how many neutrons are generated on average from each fission?

3. A 1.6% enriched Uranium, thermal fission reactor operates at a thermal power output level of 700 MW. Calculate the total rate of consumption of ^{235}U (in Kg) for a one-year period. You can use the energy release per fission of E=207 MeV.

4. The absorption mean free path for a neutron in naturally occurring Uranium was defined in Chapter 5 to be $\lambda = {}^{1}/_{N_{nat(U)}\sigma_{nat(U)}}$. Find the absorption mean free path for a) 2 MeV neutrons and b) thermal neutrons. [For thermal neutrons use the data in Table 10.2 and for 2 MeV neutrons take the cross sections to be $\sigma_a(235U) = 2.6\,b$, $\sigma_a(238U) = 0.6\,b$.