# NE-150 - Introduction to Nuclear Reactor Theory

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**Homework 5**

Due April 5, 2018

Textbook (E. E. Lewis, "Fundamentals of Nuclear Reactor Physics"), Chapters 6 and 7

1. Use the input for the MCNP/SERPENT analysis of a PWR single pin from Problem 4.3. Keep the fuel rod outer diameter constant, and increase pitch (in cm), as follows: 1.10; 1.26; 1.40; 1.60; 1.80; and 2.00. Plot the infinite multiplication factor as a function of the moderator-to-fuel volume ratio and explain the obtained results by using the four-factor formula consideration.

2. Demonstrate that for small reactivity insertion and for
$$(\beta - \rho_0 + \lambda\Lambda)^2 >> 4\lambda\Lambda\rho_0$$
the reactor power is given by the approximate form.
$$P(t) \cong P_0 \left[ \frac{\beta}{\beta - \rho_0} e^{\left(\frac{\lambda\rho_0}{\beta - \rho_0}\right)t} - \frac{\rho_0}{\beta - \rho_0} e^{-\left(\frac{\beta - \rho_0}{\Lambda}\right)t} \right]$$

3. Show that P(t) given in Problem 2 is independent of $\Lambda$ after long enough time if, $0 < \rho_0 < \beta$.

4. Delayed neutron data for thermal fissions in U-235 and Pu-239 are listed below:

| | $\beta$ | $\sum_{i=1}^{6} \beta_i / \lambda_i$ |
|---|---|---|
| U-235 | 0.0065 | 0.084 s |
| Pu-239 | 0.0021 | 0.033 s |

A critical reactor with a thermal neutron lifetime $\ell = \Lambda k\beta = 10^{-4}\, s$ may be fueled with either U-235 or Pu-239.

(a) What are the stable periods for the two fuels if all control and safety absorbers are removed so that $k_{eff}$ = 1.005?

(b) What are the stable periods for the two fuels if all control and safety absorbers are inserted so that $k_{eff}$ is far less tan unity?

5. An infinite planar source, emitting *S* neutrons/cm$^2$-s is placed at x = 0 in an infinite moderator with known properties (D, L).

(a) Calculate the flux and current as a function of a distance from the source.
(b) Assume now that the moderator is finite, with thickness 2a, with the same source in the center. Calculate the flux and current as a function of a distance from the source, with the zero flux at the extrapolated distance as boundary condition.
(c) Compare two solutions at x = a.
(d) Calculate the rate at which neutrons leak from the slab moderator in (b).

6. A homogeneous one-speed bare reactor has a cylindrical configuration. Determine:
(a) Flux distribution in the reactor.
(b) The radius and length of the reactor as functions of the buckling so that the volume of the critical reactor is a minimum;
(c) The minimum volume as a function of buckling.