ENGY.4340 Nuclear Reactor Theory

Fall 2016

HW #8: Reactor Kinetics

Problem #1 The Lifetime Formulation of Point Kinetics (15 points)

Starting with the Point Kinetics form of the 1-speed diffusion equation,

$$\frac{1}{v}\langle\psi_o\rangle\frac{dT}{dt}=\left[(1-\beta)\langle\nu\Sigma_f\psi_o\rangle T+\sum_i\lambda_i\langle C_i\rangle+\langle Q\rangle\right]-\left[\langle-\vec{\nabla}\bullet D\vec{\nabla}\psi_o\rangle+\langle\Sigma_a\psi_o\rangle\right]T$$

$$\frac{d}{dt}\langle C_i\rangle=\beta_i\langle\nu\Sigma_f\psi_o\rangle T-\lambda_i\langle C_i\rangle \qquad \text{for } i=1,2,\cdots 6$$

and the definition of the prompt neutron lifetime, l_p, as

$$\text{lifetime}=\frac{\text{neutron population}}{\text{loss rate}}$$

formally derive the standard the **Lifetime Formulation** of the point kinetics equations.

Problem #2 Interpretation of the Reactivity Equation (15 points)

The solution of the **Lifetime Formulation** of the point kinetics equation with no reactivity feedback and no external source for a **step change** in external reactivity (step change in k) is typically given in terms of the so-called **reactivity equation**. For six delayed neutron groups using the **lifetime formulation**, the reactivity equation can be written as

$$\rho=\frac{\omega\ell_p}{1+\omega\ell_p}+\frac{\omega}{1+\omega\ell_p}\sum_i\frac{\beta_i}{\omega+\lambda_i}$$

Now, your job for this problem is to explain, in detail, your understanding of point kinetics via a thorough discussion of this particular form of the **reactivity equation**. In your discussion you should address such things as:

What does this expression mean and where does this come from? Note that a formal derivation is not required here -- but a good explanation of the general process should be given to make sure the reader understands the origin of this expression…

Discuss its interpretation in terms of the actual time dependent behavior of the amplitude of the neutron population for both positive and negative reactivity insertions.

How many roots are there? What is the sign of the roots for both positive and negative reactivity? What is the significance of the dominant root? How about the most negative root?

Be sure to introduce the concepts of reactor period and prompt jump/drop in your discussions and also use appropriate sketches, as needed, to show typical behavior for a step change in k…

Problem #3 - #6 Application Problems (5 points each for 20 total points)

With the insight and basic concepts gained from the above theory-related discussion, now do the following quantitative problems. These problems illustrate various uses of the reactivity equation and the prompt jump/drop approximation. They represent typical examples where the terminology and application of the point kinetics equation are needed.

Note that the **kinetics_gui** code may be a useful resource for some of the problems given here -- especially the plot of reactor period vs. reactivity (i.e. **τ vs. ρ**)!!! However, in each case, be sure to explain the overall logic and assumptions used in your analysis and show your numerical calculations, as appropriate.

Problem #3: Express the following reactivities in %Δk/k for both Pu239 and U235. Also compute k_{eff} for these reactivities and summarize everything in a short table:

a. 0.001 b. 2 dollars c. −50 cents

Note: For U335 thermal fission, $\beta \approx 0.0065$ and for Pu239, $\beta \approx 0.0021$ for thermal fission.

Problem #4: A U235 fueled thermal reactor has an initial power of 10 MW and it is put on a reactor period of about 5 minutes. Neglecting feedback effects, estimate how long it takes to increase the reactor power by a factor of 50.

Problem #5: A U235 fueled reactor is scrammed by the instantaneous insertion of 5 dollars of negative reactivity after having operated at a constant power of 1 megawatt for several hours. Ignoring all fission product effects (decay heat and xenon reactivity effects), estimate how long it takes for the fission power to drop to 1 milliwatt.

Problem #6: During test-out procedures, a Pu239 fueled thermal reactor is operated for a time at a power of 1 megawatt. The power is then to be increased to 100 megawatts in 8 hours. Ignoring any temperature effects,

a. What stable period is needed to achieve this power increase in the time given?

b. What reactivity insertion is required here?

Explain the logic used in your analysis…

Note: $\beta = 0.0021$ for Pu239 and the mean lifetime of the delayed neutrons in Pu239-fueled systems is about 15.4 seconds.