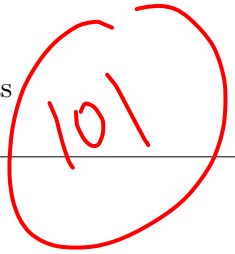
NPRE 560 Oleksandr Yardas Fall 2024
HW 5 Due 2024.12.09



- Show your work.
- This work must be submitted online as a `.pdf` through Canvas.
- Work completed with LaTeX or Jupyter earns 1 extra point. Submit source file (e.g. `.tex` or `.ipynb`) along with the `.pdf` file.
- If this work is completed with the aid of a numerical program (such as Python, Wolfram Alpha, or MATLAB) all scripts and data must be submitted in addition to the `.pdf`.
- If you work with anyone else, document what you worked on together.

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1. (20 points) Give two reasons that make space-energy dependent dynamics necessary.

   Solution:

   1. From a physics perspective, point kinetics cannot account for localized effects in a reactor core, which leads to under-prediction of positive reactivity insertions and over-prediction of negative reactivity insertions. To model localized effects accurately, we needs space-energy dynamics. accurately, we need space-energy dependence.
   2. From a safety perspective, as the assumptions of point kinetics give inaccurate results on whole cores, particular thermal reactor cores, they are insufficient for safety studies. To model transients accurately to determine reactor safety, we needs space-energy dependence.

2. (10 points) Give an example of a scenario in which energy dependent dynamics is necessary for reactor analysis.

   Solution: Consider a transient in a fast reactor. Fast reactors generally have a wider neutron spectrum for fissioning neutrons and are more sensitive to doppler broadening. To account for the doppler feedback and neutron spectrum during a transient in a fast reactor, energy dependence is needed.

3. (10 points) Give an example of a scenario in which space dependent dynamics is necessary for reactor analysis.

   Solution: Consider a transient in a thermal reactor. Thermal reactor cores are very large, and thus have have highly localized effects, particularly during a transient. Space dependence is needed to capture these localized effects.

4. Describe and discuss the advantages and disadvantages of the following four approaches to space-energy dependent dynamics:
   (a) (10 points) the finite difference solution approach

   Solution:

   - Advantages: Simple mathematics; straightforward to implement; accurate for sufficiently small timesteps
   - Disadvantages: Memory intensive; not fast.

   (b) (10 points) the nodal approach

   Solution:

   - Advantages: ?
   - Disadvantages: Expensive for complicated geometries

   (c) (10 points) the modal approach

   Solution:

   - Advantages: Modes only need to be calculated once for a given problem, typically using a lower-dimensional static problem
   - Disadvantages: Savings over finite differences only achieved with a small number of modes

   (d) (10 points) the quasistatic approach

   Solution:

   - Advantages: Relatively fast; Flux factorization into shape and amplitude functions assumes shape changes slowly with respect to time, so the shape function is not recalculated at every timestep as the amplitude function.
   - Disadvantages: Inaccuracies when simulating initial fast reactivity changes

5. Discuss the relation of the quasistatic and the adiabatic methods.
   (a) (10 points) Which approximation is common to both?

   Solution: Both methods assume the flux $\phi(\mathbf{r}, E, t)$ is factored into a shape function, $\psi(\mathbf{r}, E, t)$, and an amplitude function $p(t)$.

   (b) (10 points) What are the key differences?

Solution: The quasistatic method neglects the shape function time derivative (in the improved quasistatic method, a finite difference approximates the shape function time derivative). In the adiabatic method, the $\frac{\alpha}{v}$ term is neglected and the delayed neutron source is approximated as a fraction of the prompt neutron source. This leads to the adiabatic method eliminating kinetic features in the shape function