Semester thesis/ midterm presentation
FYS4580 Fall 2019

Overall goal:
Establish a fission reactor model and investigate and specify relevant aspects for energy generation, safety or security (proliferation), such as flux levels, reactivity, depletion/ fuel consumption/ breeding, waste properties and material attractiveness (fuel cycle analysis).

Before the midterm exam:
You should have completed the exercises marked “before midterm”. In addition, you will be given a topic from the course to present as your midterm exam. Your presentation should be 8-10 minutes. Relate the topic you have been given to the basics of the course - think of it as a refresher of what we have been going through in class. Run extra OpenMC simulations related to this topic, and show the results in your presentation. Also, take a look in literature related to your topic (articles, books etc), and include what you find in your presentation (“something fun”).

The final report (due on Nov 7th):
Your report should be self-supporting, so that all topics are introduced and discussed. Include an brief introduction to your topic, include relevant theory, present results and discuss them, and end with an conclusion.

Answer and discuss all the exercises, both marked “Before midterm” (using the simple pincell), and “after midterm” (where you have modified you reactor). Include results from the OpenMC calculations. The final report should describe in detail your reactor design (see the keywords), and why you have chosen this setup. (It better be able to go critical…!)

The final exam will start with a question concerning your report.

Before midterm

Use the script “PinCellNotebook” from “https://github.com/sindrehk/FYS4580" as a basis, and modify it.

1. **A pin cell** (also known as: heterogeneous infinite reactor lattice with reflecting boundary conditions (covered in sections 1-4).

    a. Change H2O with D2O, what happens to k (effective multiplication constant)? Change percentage of U-235 to U-238 (enrichment), what happens? Plot the energy distribution of the neutron flux. in pin cell for H2O and D2O. Decrease the pin size, and try with H2O and D2O again. Explain.
    b. Why does the neutron flux distribution not look like the prompt fission neutron spectrum?
    c. Tune the parameters of the “reactor” to make it go critical. Which variables in the four factor formula did you change?
    d. Increase temperature or void in the moderator. What happens?
    e. Calculate the thermal utilisation factor of the reactor.

After midterm

Choose one of the following topics:

1. **Thorium reactor** – establish a reactor concept with enough fissionable material with adequate enrichment for sustainable reactor operation and specify the main advantages and disadvantages compared with Generation II/ III-facilities.

   Keywords: thermal, epithermal, fast spectrum/ resonance peaks/ core, moderator, control rods, coolant/ effect of delayed neutrons – reactor control/ fuel enrichment, changes in fuel composition over time/ breeding/ waste specifications/ positive/ negative reactivity feedback

2. **Advanced reactors** - (Generation IV-reactors) – select another advanced reactor concept and specify the main advantages and disadvantages compared with Generation II/ III-facilities.

   Keywords: thermal, epithermal, fast spectrum**/** slowing down processes/ resonance peaks/ core, moderator, control rods, coolant/ effect of delayed neutrons – reactor control/ fuel enrichment, changes in fuel composition over time/ breeding/ waste specifications/ positive/negative reactivity feedback/ heat-transfer capabilities

3. **Military reactors/Fast reactor** – establish a reactor concept with the sole purpose on optimizing operation time (submarine/ space purposes) and specific important safety and security issues related to your design.

   Keywords: Core, moderator, control rods, coolant/ changes in reactivity/ fuel enrichment, changes in fuel composition over time/ reactivity/ material attractiveness/ heat-transfer capabilities

4. **Research reactors** – establish a reactor concept with the sole purpose on optimizing operation time (submarine/ space purposes) and specific important safety and security issues related to your design.

   Keywords: D20 vs H20 as moderator/core, moderator, control rods, coolant/ diffusion length, neutron spectrum

The Interesting reactor (also known as: heterogeneous finite reactor). Change your previous set-up to one of the reactors above: (Thorium reactor, advanced, military/fast, research). Remember, now it should be finite. You can base your reactor geometry on the OpenMC python script or any other script you can find. (If you are particularly elegant you could make the pin cell model in the previous exercise resemble your finite reactor in the largest extent possible, i.e. same moderator, enrichment, temperatures etc. and compare the spatial flux distribution).

2. **For the reactor type you have chosen, discuss the following exercises:**

   a. Tune the parameters of the reactor to make it go critical. Discuss your choices. Calculate the neutron flux energy distribution.

   b. Investigate the reactivity coefficients reactor model in a small parameter range (near criticality)(void, temperature, D2O/H2O-concentration).

c. Plot the neutron and gamma flux energy distributions in the reactor and fit suitable probability distributions to the calculated distribution.

d. Calculate the thermal utilisation factor of the reactor.

e. Outline and discuss the advantages and disadvantages of your reactor design.

f. Run a depletion calculation and calculate the fission yield products of the reactor.

g. Discuss (with the support of OpenMC simulations) the relevant keywords for your reactor type, as listed above.

3. **In addition, choose <u>one</u> of the following exercises,** and discuss it:

   a. **Accident scenario (Chernobyl):** Implement inhomogeneities in xenon-concentration in the reactor. Change your reactor-parameters in order to observe the spatial oscillations of xenon-poisoning and the subsequent excess reactivity in local regions of the reactor.

   b. **Thorium breeder reactor:** Define a depletion chain of a manageable number of isotopes and implement the decay chain in an OpenMC simulation. Choose your depletion algorithm of choice carefully. What is the flux requirement in a Th-breeder reactor (breeding gain)?

   c. **Nuclear waste:** Run depletion calculations on your reactor and investigate the long lived isotopes which are produced in the reactor. Make a thorium breeder reactor and compare the waste products from these two fuel cycles.

   d. **Fast vs thermal reactor:** Construct a fast/thermal reactor (depending on what you did in section 2), and compare key properties: safety, reactivity control, fuel, waste… Discuss.