NPRE412 Spring 2025
HW 12 Due 2025.04.22

- 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.

---

1. An 1150-MW(e) LWR that operated for a year with the power history shown in the book. Assume a thermal efficiency of 32%. (Tsoulfanidis, Question 9.9).

   (a) (15 points) Calculate the decay power 1s after shutdown **using Eq. 9.5**.

   Solution: One second after shutdown, the predicted decay power was 205.559 MW. First start by converting the electric power to thermal power.

   $$P_{0,th} = P_{0,e}/\eta \tag{1}$$

   Then, use equation 9.5 for each interval of the reactor operation.

   $$P(t, T, P_0) = P_0 \cdot \left(5.92e - 2 * \left[t^{-0.2} - (t+T)^{-0.2}\right]\right) \tag{2}$$

   The first interval is where $P_{0,1}$ is equal to $0.4 \cdot P_{0,th}$, t_1 is 1 second plus 7 months, and T_1 is 5 months.

   $$P(t_1, T_1, P_{0,1}) = 0.306 MW_{th} \tag{3}$$

   The second interval is where $P_{0,2}$ is equal to $P_{0,th}$, t_2 is 1 second, and T_2 is 7 months.

   $$P(t_2, T_2, P_{0,2}) = 205.252 MW_{th} \tag{4}$$

   Then, add the contributions together.

   $$P_t = P_1 + P_2 = 205.559 MW_{th} \tag{5}$$

   (b) (15 points) Calculate the decay power 1s after shutdown **using the ANS-5.1 equations.**

   Solution: One second after shutdown, the predicted decay power was 215.898 MW. Like the previous problem, find the decay heat from each of the intervals, but using Eq. 9.8 this time.

   $$P(t, T, P_0) = \frac{P_0}{Q} F(t, T) \tag{6}$$

The first interval is where $P_{0,1}$ is equal to $0.4 \cdot P_{0,th}$, t_1 is 1 second plus 7 months, and T_1 is 5 months.

$$P(t_1, T_1, P_{0,1}) = 0.243 MW_{th} \tag{7}$$

The second interval is where $P_{0,2}$ is equal to $\cdot P_{0,th}$, t_2 is 1 second, and T_2 is 7 months.

$$P(t_2, T_2, P_{0,2}) = 215.655 MW_{th} \tag{8}$$

Then, add the two contributions together.

$$P_t = P_1 + P_2 = 215.989 MW_{th} \tag{9}$$

(c) (10 points) Compare the results.

Solution: The simplified equation from part a under-predicts the true power. I am assuming the equation from part a is more accurate. The ANS equation predicts a decay power 10.34 MW_th higher than the simplified equation. This is 1.23% of the total decay power. If the approximation over-predicted the decay power, it would be fine to use as it would be a conservative estimation. However, calamity may befall the earth if we use approximations that under-predict decay power in nuclear engineering.

2. (30 points) In High-Level Waste geologic repository concepts, should we be more concerned about high or low sorption elements? Why?

Solution: We are more concerned about low sorption elements because low sorption elements are not contained by the rock as they diffuse away from the waste storage. As these elements are not absorbed by the surrounding rock very well, their concentrations are "geometrically attenuated" by the host media very little.

3. (30 points) In High-Level Waste geologic repository concepts, should we be more concerned about high or low solubility elements? Why?

Solution: We are more concerned about high solubility elements because high solubility elements have an easier time shedding the confines we imposed upon them. These elements do not like being contained, and, as free-spirited elements, high solubility elements are more likely to leave containment.