- 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. (Ott Review 6.20) Describe in words, with graphs, and with formulas the transient following a step change in reactivity or source:

   (a) (5 points) Without delayed neutrons.

   Solution: With no delayed neutrons, we drop delayed neutrons from the kinetics equation:

   $$\dot{p} = \frac{\rho(t)}{\Lambda} p(t) \tag{1}$$

   Following a step reactivity insertion, the slope of the power will constantly increase at a rate of $\frac{\rho}{\Lambda}\rho$, that is, without any delayed neutrons the power blows up. We can also see this if we solve the equation analytically, assuming the reactivity stays constant, as $p(t) = p_0 e^{\frac{\rho}{\Lambda}t}$. Figure **??** shows a plot of the power over time using $p_0 = 1.0$, $\Lambda = 2 \cdot 10^{-5}$.

   (b) (5 points) With constant delayed neutron source.

   Solution: With a constant delayed source, we approximate the delayed neutron source as constant, that is $S_d(t) = S_d = \beta p_0$. Assumuing no external source, the kinetics equation becomes

   $$\dot{p} = \frac{\rho(t) - \beta}{\Lambda} p(t) + \frac{\beta p_0}{\Lambda} \tag{2}$$

   The transient following a step reactivity insertion depends on the value of β. If $\beta \gg \rho$, we will have an inital jump in reactivity that quickly stabilizes. As $\beta > \rho$, the transient takes longer to stabilize. If $\beta = \rho$, the $p(t)$ term dissappaer and we have linear transient. As β becomes less than ρ, the transient blows up more quickly.

   (c) (5 points) With no approximations (no formula required).

   Solution: solution here

2. (Ott Review 6.34) Estimate the time it takes to establish the stable asymptotic transient for $\rho_1 < \beta$ in an initially critical reactor.

Solution: solution here

3. (10 points) (Ott Review 6.35) Explain in terms of roots of the characteristic equation:
   (a) (5 points) the prompt jump phenomenon

   Solution: solution here.

   (b) (5 points) the delayed neutron induced transition

   Solution: solution here.

   (c) (5 points) the stable period

   Solution: solution here.

4. (30 points) (Ott Problem 8.1) Find the numerical value of p^{00}, the flux after a prompt jump for which the increase due to delayed neutrons is just compensated by Doppler feedback, for an LWR from the typical λ and γ/β values given in the text. Discuss why p^{00} may vary between reactors (e.g. the SEFOR reactor discussed in the text).

Solution: solution here.

5. (15 points) (Ott Review 8.1) Define each term, give an example of the physical phenomena involved, and an example of a transient for each:
   (a) (5 points) Energy coefficient.
   (b) (5 points) Temperature coefficient. of reactvity.
   (c) (5 points) Power coeffciient.

Solution: solution here.