Date: 20 November 2018

To: Prof. Scott Palmtag, NE301 Instructor

From: Charles Goodman

Re: Numerical Point Kinetics

Project 2: Numerical Solution to the Point Kinetics Equations

Introduction:

The goal of the project to to create a program that simulates neutron populations over time associated with reactivity changes. The program is written to limit error and allow flexible inputs, rather than being limited to U-235. The program could be used to verify reactor response to reactivity changes over short time scales, as fission product poissons are not accounted for.

Background:

The Matlab program accepts a file input for each case including the number of precursor groups, the half-lives and fission yield of each precursor group, the prompt neutron lifetime, the reactivity insertion, the duration, and the initial number of time steps. The program outputs a comma-separated-values file that contains the time, the neutron population, and the precursor group concentration for each time step. The program checks the error of the code and increases resolution, until the absolute error is sufficiently small.

Results:

Part 1: Verification

Test Conditions:

- Prompt neutron lifetime = 5e-5 seconds
- Six group delayed neutron data for U-235
- Reactivity change = +/- $.08
- Transient simulated for 120 seconds

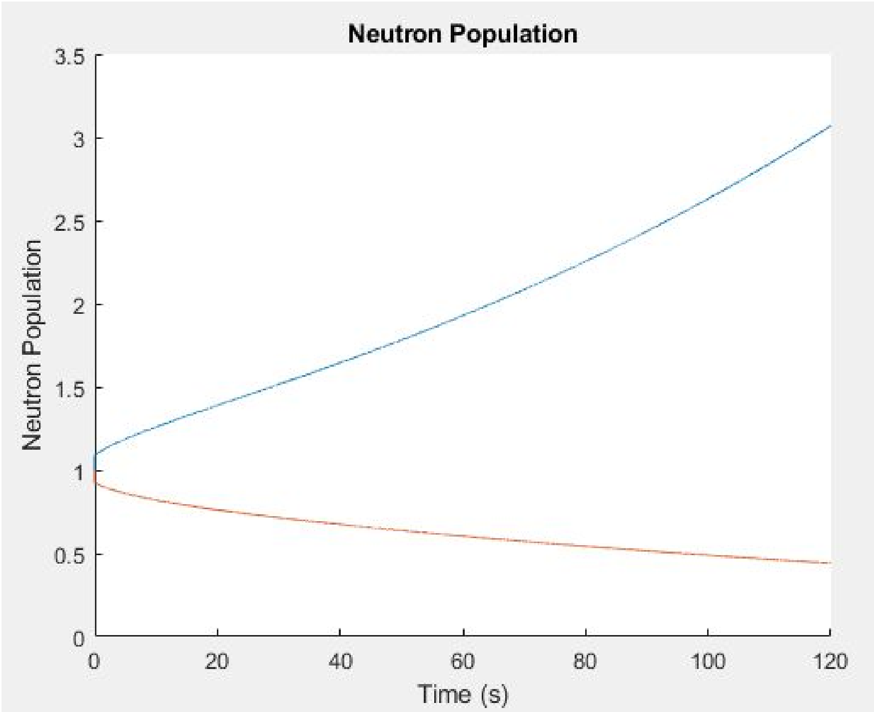

Figure 1: The above figure shows the neutron population associated with a positive of negative reactivity insertion of $.08. This resembles Figure 5.2 from Fundamentals of Nuclear Reactor Physics by Elmer E. Lewis.

The neutron population at 120 seconds from the positive and negative reactivity insertions are 3.0699 and .44125 of the original respectively.

In order to minimize error, the code is written to increase resolution until the error between consecutive trials is less than .0001. Since the total error in Euler's method is proportional to the time step, a series of consecutive errors is geometric in nature, so the total error would be 1/9000, well below the limit of .001 absolute error the project imposed.

The used time step was 750 microseconds. I had started the trials at 16000 time steps, which may have already been sufficient, but to determine error, another trial had to be run, leading to 160000 time steps being used.

Part 2: Neutron Lifetime

Test Conditions:

- Same as part 1 except
- Prompt neutron lifetime is double (1e-4 seconds)
- Same time step of 750 microseconds

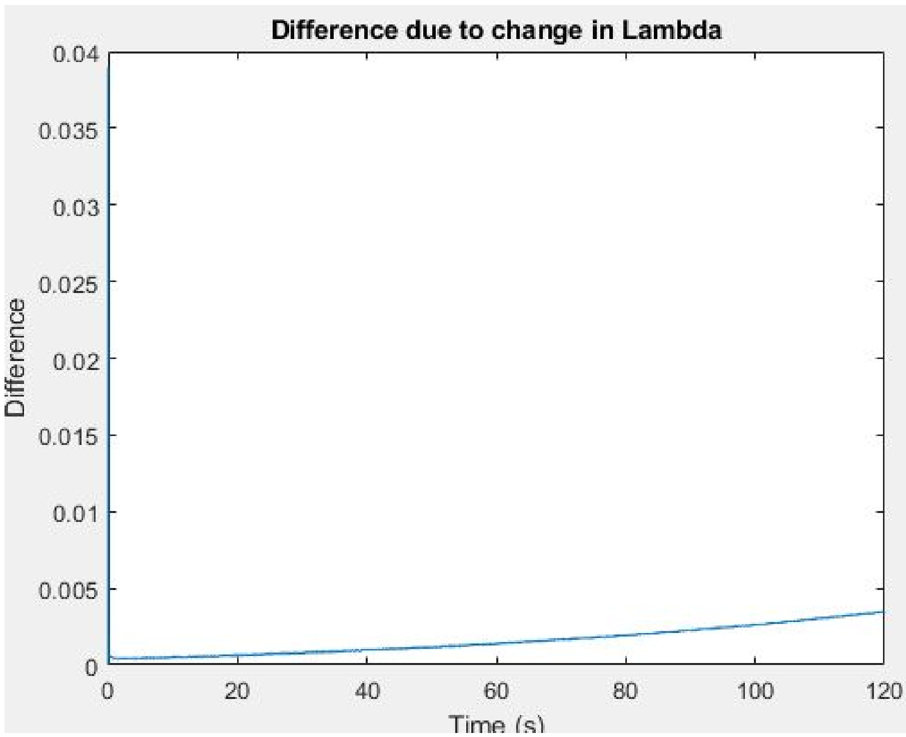

Figure 2: The above figure shows the absolute difference in neutron populations over time resulting from the prompt neutron lifetime being doubled from 5e-5 seconds to 1e-4 seconds for a reactivity insertion of $.08.

The difference in the neutron populations at 120 seconds associated with doubling the prompt neutron lifetime are .0035 and .00019 for the positive and negative reactivity insertions of $.08 respectively. The difference is large during the prompt jump, as the shorter prompt neutron lifetime allows the prompt jump to occur faster. After the prompt jump, the difference increases exponentially; however, at the end of 120 seconds, the difference is still practically negligible.

Part 3: Prompt Jump

Test Conditions:

- Prompt Neutron lifetime of 5e-5 s
- Reactivity changes of +/-$.05 and +/-$.10
- Six group delayed neutron data for U-235
- Simulated for 3 seconds to emphasize prompt jump
- Time step of 187.5 microseconds

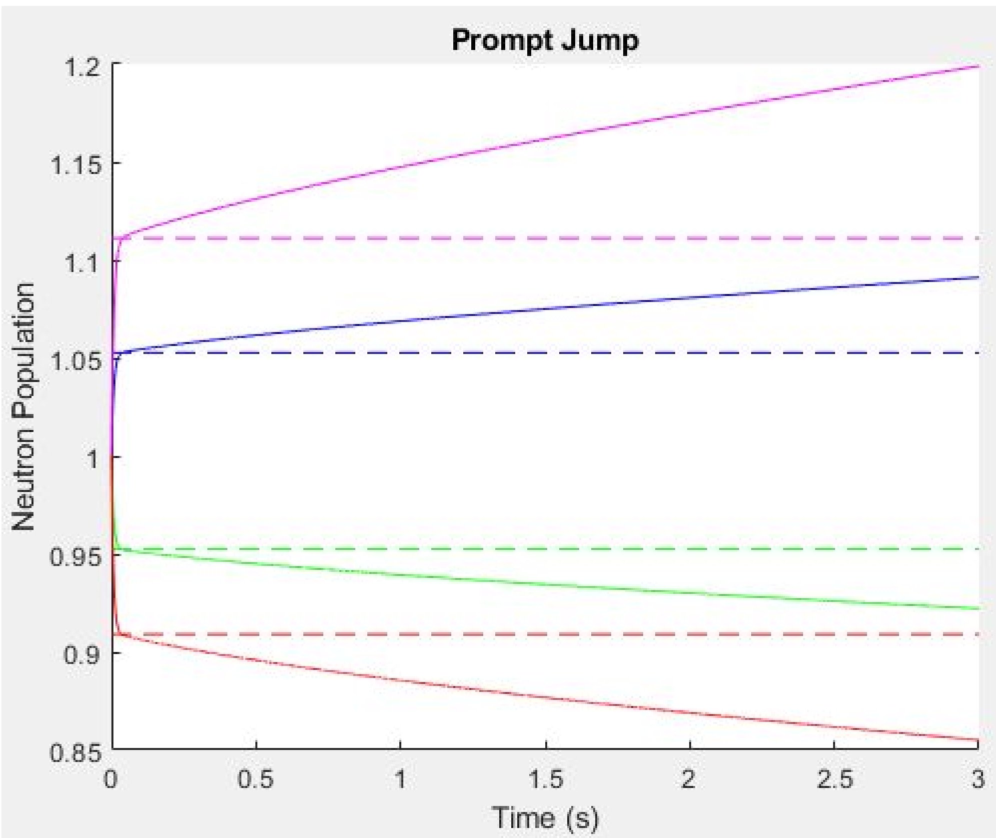

Figure 3: The neutron population simulation matches the predicted magnitude of the prompt jump. The above simulations are for $.10, $.05,-$.05, and -$.10 from top to bottom respectively. The dotted horizontal line represent the predicted prompt jump magnitudes for each reactivity change.

The neutron populations are 1.1990, 1.0911, .92218, and .85503 at the end of the 3 second transient for the $.10, $.05, -$.05, and -$.10 reactivity changes respectively.

The ratio by which neutron population changes after the prompt jump is $\frac{1}{1-\rho/\beta}$. Using the prompt jump approximation formula for the reactivity changes associated in this experiment results in predicted neutron populations of 1.111, 1.0526, .95238, and .90909.

Summary:

The program creates valid numerical solutions to solve the point kinetics equations given a finite number of precursor groups. The prompt neutron lifetime was found to have minimal effect on the neutron populations. The program automatically scales the time step to ensure that the absolute error in neutron population is below one thousandth. This allows a user to accurately know the neutron population and precursor group concentrations at any given time for a reactivity change.