Final Project Proposal: Neutron Diffusion

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Background

Diffusion is a process in which something moves from an area of high density to an area of lower density. It can be described in physical systems by *Fick's equation* [1].

$$J = -D\frac{\partial n}{\partial x}$$

Where D is the diffusion coefficient, J is the diffusion flux (The amount of material moving away from the region of higher concentration per unit area per unit time). n is the concentration of the material and x is its position. This project will involve the study of diffusion in neutrons, particularly in its use inside of nuclear reactor cores and atomic weapons to produce high energy output. The study of neutron diffusion was a key point of interest at Los Alamos during the Manhatten Project during the second world war [2]. In this project I will study different configurations for stable neutron diffusion and chain reaction neutron diffusion in fissile materials in order to determine maximum energy output.

Key Questions

1. How do the different types of boundary condition approximations affect the energy output of the system? (Dirichlet Boundary Condition vs Neumann Boundary Condition)

2. What is the critical mass of a fissile material? In other words at what point in these reactions does the process grow exponentially?

3. How does the choice of material change the energy output of the diffusion? Which materials are the best?

4. What is the minimum size the material such that neutron diffusion is still possible [3]?

5. How does the shape of the fuel rods impact the output of energy?

Objectives

1. Understand the theory of diffusion in atomic systems and how it can be used to produce energy.

2. Write code to simulate the neutron diffusion process for different boundary conditions on the materials being used. I will start with a simple cube and then move to more complicated shapes.

3. Determine which materials are most optimal for the diffusion process

4. Determine what the maximum quantity for optimal energy output is for different fissile materials. More specifically finding the exact point when the process becomes exponential.

5. Determine the minimum quantity for a positive energy output in different fissile materials.

6. Relate these results to that of current nuclear power plants to compare.

7. Test different boundary conditions and thier energy output to the energy output of other power producing methods.

Methods and Benchmarks

1. Implement Fick's Equation with Neumann Boundary Conditions using the Crank - Nicolson method for stable solutions

2. Implement Fick's Equation with Dirchlet Boundary Conditions using the Crank - Nicolson method for stable solutions

3. Use a mixture of methods developed in class such as RK4, Verlet Integration, ODE solvers, and PDE solvers to model the ideal shape and material for a high energy output via neutron diffusion. I will mainly focus on the Crank - Nicolson methods for stable PDE solutions.

4. Benchmark the solution via simulating analytic solutions for simple shapes such as a sphere or cyclinder. Compare these results to that of our numerically solved shape.

5. Benchmark the solution by comparing to the energy output of the Demon Core.

References

[1] "Neutron diffusion theory," Oct 2021.

[2] G. W. Griffiths, "Neutron diffusion," Jan 2020.

[3] R. Serber and R. Rhodes, *The Los Alamos Primer the first lectures on how to build an atomic bomb Robert Serber ; annotated by Robert Serber ; updated with a new introduction by Richard Rhodes.* University of California Press, 2020.