

NE450 - Principles of nuclear engineering  
Project 5 - Monte Carlo methods and MCNP

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For problems 1 - 3 use Monte Carlo techniques to obtain the solutions.

- (1) (30) Solve for G using Monte Carlo techniques. Solve the integral analytically and graph g(x). Also plot G v N for  $N = 10, 10^2, 10^3, 10^4, 10^5, 10^6$ .**

$$G = \int_0^1 g(x) dx \quad (1)$$

$$g(x) = 1 - e^{-x} \quad (2)$$

- (2) (30) Do the same for the following function. This  $g(x)$  does not have an analytical solution. However, you can use another numerical solver to compare the Monte Carlo result.**

$$\int_0^{\frac{\pi}{2}} \sin(x^2) dx \quad (3)$$

**(3) (30) Approximate  $\sqrt{2}$  in a similar manner to the way we approximated  $\pi$ .**

**(4) (50) Conduct a short modeling study of the metal fuel alloy for the hot cell facility using -**

- 4\_ff.alloy.inp (flux)
- 4d\_ff.alloy.inp (dose)

See also the related paper in piazza for more information.

Apply the following procedure -

- Look at the original geometry in the plotter/VisEd.
- Modify the facility to only include the SE and SW cells.
- Use MCNP to compute the volume averaged (F4) flux tallies for the SE cell and SW cell.
- Use a neutron emission rate of  $1.1 \times 10^7 \text{ n/s/g}$  for 24 grams of material.
- Increase NPS from the original files to reduce standard error.
- Start with a wall thickness of 15 cm using the material already included in the deck. It is a form of borated concrete that is common to these kinds of facilities. Increase the wall thickness until the dose rate falls below  $1\mu\text{Sv/h}$  and the relative flux falls below 0.01.
- Plot dose rate v wall thickness and the relative flux v wall thickness.

Is this wall thickness reasonable? As in, could a facility be practically built like this using current engineering design techniques?

Include the MCNP file at the end in an appendix.

For the criticality models -

- Include a screenshot of the model from the VisEd/plotter.
- Use finite geometries.
- Design geometries that will minimize leakage. Show (as part of making the mcnp file and results; not calculating by hand) that leakage has been minimized.
- For criticality, try to get to 4 9s or 0s (.9999x, 1.0000x) for the mean, and 68% confidence; 3 9s or 0s for each remaining confidence interval.
- Report output in a table - k, standard deviation, 68% confidence, 95% confidence, and 99% confidence.
- Include the input deck in the appendix.

**PROTIP** - k can vary weird when your trying to get the critical radius to 4 or 5 decimal places. Study the KCODE parameters. You could also add more particles on KSRC, but be careful where you place them.

- (5) (20) What is the critical mass of a bare sphere of plutonium containing (1) 95.5%  $^{239}\text{Pu}$  and (2) 80%  $^{239}\text{Pu}$ , where the rest is  $^{238}\text{Pu}$ ?**

**(6) (20) What is the critical mass for the above, but with a thin nickel shell of 0.10 cm?**



**(7) (20) What is the critical mass of pure  $^{239}\text{Pu}$  of a bare cylinder?**

- (8) (30) Taking the bare sphere  $^{239}\text{Pu}$  model, what is the optimal reflector that minimizes the critical mass?**

**(9) (30) Do the same for  $^{235}\text{U}$ .**

**(10) (30) Do the same for  $^{233}\text{U}$ .**

**(11) (20) Which material is minimal and why, neutronically speaking?**

- (12) (50) Three unreflected aluminum cylinders contain  $U(93.2)O_2F_2$  water solutions. The inside cylinder diameter and critical height measured 20.3 cm and 41.4 cm. The aluminum container had a density of  $2.71 \text{ g/cm}^3$  and was 0.15 cm thick. The three cylinders were set in an equilateral configuration with a surface separation of 0.38 cm. The solution concentration parameters were  $0.90 \text{ g}(^{235}\text{U})/\text{cm}^3$  with  $H : ^{235}\text{U} = 309$ .

It was estimated that the solution density was approximately  $1.131 \text{ g/cm}^3$  and consisted of  $0.0021345 \text{ }^{235}\text{U}$ ,  $0.00015382 \text{ }^{238}\text{U}$ ,  $0.33383 \text{ O}$ ,  $0.65930 \text{ H}$ ,  $0.0045756 \text{ F atoms/b - cm}$ .

MCNP gives  $k = 0.9991 \pm 0.0011$ .

Reproduce the model to get the result. See the MCNP benchmark document in the OER for guidance.

**(13) (20) Find the critical mass for a bare cylinder of 10.9% enriched U with a density of 18.63 g/cc.**

- (14) (20) Find the minimum critical mass for an infinite graphite reflected 93.5% enriched U sphere. Use 18.8 g/cc for the U density and just use carbon for the graphite.**



- (15) (20) Find the critical mass of 97.67% enriched U cube in an infinite water reflector. Use a density of 18.794 g/cc.**

## **Hot cell MCNP input decks**

## Criticality MCNP input decks