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

Name

University of Idaho · Idaho Falls Center for Higher Education

Nuclear Engineering and Industrial Management Department

email

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Total - 450

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 $N = 10,\ 10^2.\ 10^3,\ 10^4,\ 10^5,\ 10^6$**.**

$$G = \int_0^1 g(x)dx \tag{1}$$

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

(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.

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

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

(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 of $1.1 \times 10^7\ n/s/g$ 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 $1 \mu Sv/h$ 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}Pu **and (2)** 80% ^{239}Pu**, where the rest is** ^{238}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}Pu of a bare cylinder?

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

(9) (30) Do the same for ^{235}U.

(10) (30) Do the same for ^{233}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** $2.71\ g/cm^3$ **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** $0.90\ g(^{235}U)/cm^3$ **with** $H :^{235} U = 309.$

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

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