OECD/NEA Source Convergence Benchmark 4: Array of interacting spheres
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Overview

In this benchmark a lattice of $5 \times 5 \times 1$ highly enriched uranium metal spheres separated by air is considered. The center-to-center distance between spheres is 80 cm. All the spheres have the same composition (see Table 1). The radius of the central sphere is 10 cm while the radius of the other spheres is 8.71 cm. Figure 1 describes the overall geometry. The benchmark is an adaptation from Kadotani et al. (Proc. ICNC'91, Oxford, 1991)

Specifications

Material data

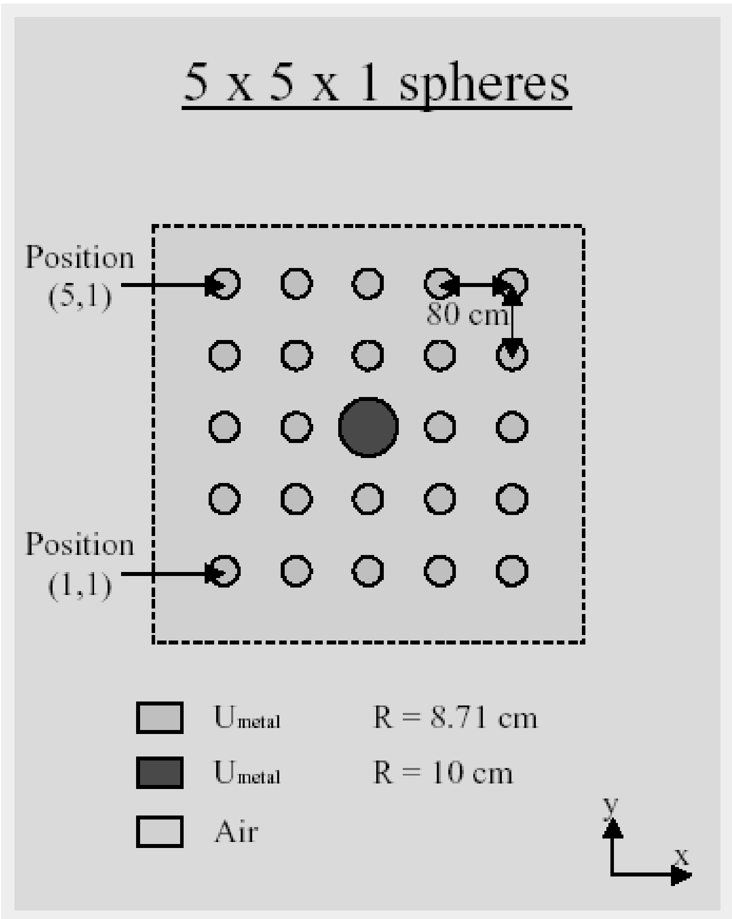
The fuel and air compositions are given in the following Table (in atoms/barn.cm):

High enriched uranium metal	
U235	4.549E-02
U238	2.560E-03
Air	
N	4.3250E-5
O	1.0810E-5

Table 1

Geometry data

The following figure describes the problem geometry. The spheres are numbered as in a conventional matrix, so that the lowest left-hand sphere in the figure below is in position (1,1) and the top right-hand sphere is in position (5,5).



Required calculations

Calculations are to be performed using the following parameters:

- **125** neutrons per generation
- **1000** active generations.

The source distribution of the **125** starting neutrons is the following:

- **101** neutrons in the **centre of the sphere (1,1)**,
- **1** neutron in the **centre of each of the other 24 spheres**.

Three different numbers of skipped generations (preceding the 1000 active generations) should be employed: **0**, **200** and **400**.

For each number of skipped generations, **100** replicas will be run, using different random number sequences.

300 calculations are therefore required as follows:

Case	Random number sequence	Skipped Generations
1	#1	0
2	#1	200
3	#1	400
4	#2	0
5	#2	200
6	#2	400
…	…	…
298	#100	0
299	#100	200
300	#100	400

Required information about the code

All these points are very important for a good analysis of the results and understanding of the differences between the codes. Please make your answers as precise as possible. If you think that other information is relevant to the understanding of the differences between the codes, do not hesitate to give it.

You can write this portion in a simple text file or in a MS Word or RTF document.

1) Identification of the code and of the cross-sections library

2) Identification of the strategy used by the code

Describe:

- the strategy used by the code (conventional, use of k matrix to renormalize source distribution, stratified sampling, superhistory powering...)
- the number of generations per stage (1 in general, greater than 1 if superhistory powering is used)

Whatever the number of generations per stage is, the number of active generations should be equal to 1000, and the number of passive generations should be equal to 0 or 200 or 400. For instance, if the number of generations per stage is equal to 20, the number of active stages is 50 and the number of passive stages is 0 or 10 or 20.

If you use the k matrix to renormalize the source distribution, describe:

- the frequency of renormalization (how many stages between two renormalizations?)
- if and how the spheres are grouped to compute the k matrix (is it a 25 × 25 matrix or a smallest one?)

3) Neutron tracking

Do neutrons survive absorption?
If this is the case, describe the algorithm to kill neutrons?

4) Source distribution estimation

Describe how the number of starters in a new stage is determined.

- constant (equal to the initial number of sources)
- other (describe)

Describe how the source fraction of each fissile volume is computed.

- equal to the fission fractions at previous stage? (which estimator of the fission fraction is used: collision, track-length, absorption?)
- determined by the eigenvector of k matrix? (which estimator of the kij is used: collision, track-length, absorption? Is it an average over previous stages? How many stages?)
- other (describe)

Describe the nature of the starters of a new generation.

- sampling of collision sites of previous generation
- sampling of absorption sites of previous generation
- other (describe)

5) Identification of the k-eff estimator of a single stage

Describe the definition of k-eff used to estimate the k-eff of a single stage.

- productions / sources
- productions / (absorptions + leakage - excess)

Describe the estimator of reaction rates used to estimate the k-eff of a single stage.

- collision
- track-length
- absorption

6) Identification of the final k-eff estimator

Describe the definition of k-eff used to estimate the final k-eff.

- average of k-eff estimates at each stage
- average of productions / average of sources
- average of productions / average of (absorptions + leakage - excess)
- combination of several estimators: which ones?

Whatever the definition is, describe the estimator(s) of reaction rates used.

- collision
- track-length
- absorption

7) Identification of the final fission fractions estimator

Describe the estimator(s) of reaction rates used to estimate fission fractions.

- collision
- track-length
- absorption
- a combined estimator (describe)

8) Standard deviation computation

Describe how the code computes the standard deviation of the final k-eff value?

- the code assumes no correlation between the estimates at each stage
- the code uses a batching method (precise the size of the batches)
- the code uses another method (describe)

Describe how the code computes the standard deviation of the final fission fractions?

- the code assumes no correlation between the estimates at each stage
- the code uses a batching method (precise the size of the batches)
- the code uses another method (describe)

9) Convergence tests
If the code performs some convergence tests, give a brief description of each of these tests, and a literature reference.

10) Sample input file of the code
Could you give the input file of case 1, 2 or 3 for instance.

Required output

For each of the 300 cases

- the final k-eff estimate (cumulative over the active stages, i.e. 1000 active generations) and its standard deviation

- the k-eff estimate of each single stage (as much values as the number of stages: 1000 values if the number of generation per stage is equal to 1, and less if the number of generation per stage is greater than 1)

- the final fission fractions (cumulative over the active stages, i.e. 1000 active generations), and their standard deviation, of only 3 spheres:
  - sphere (1,1): where the majority of neutrons are emitted at first generation
  - sphere (3,3): the central sphere
  - sphere (5,5): to compare with the fission fraction of sphere (1,1)

- the results of the convergence tests performed by the code

Please use the proposed submission format (at the end of the document) for these data, intended to make the analysis phase easier.

Reference calculation

If possible, provide a reference calculation with adequate source convergence and precision and give:

- the description of the calculation (strategy used, number of passive stages, number of active stages, number of generations per stage, number of neutrons per generation...)

- the final k-eff estimate and its standard deviation

- the final fission fractions (with their standard deviation) of the 3 spheres: (1,1), (3,3) and (5,5).

- the results of the convergence tests performed by the code

Add the above information from the reference calculation to the document containing the required information about the code.

Submission format

For each of the 300 cases, the information is required in a simple text file.
The 300 files can be concatenated in one file.

Numerical results should be given with a minimum of 5 decimal places. Numerical data separator should be "," without blanks and the word NODATA is to be inserted if a field is empty.

Line Number	Required information
1:	Date
2:	Institution
3:	Contact Person
4:	e-mail address
5:	Voice phone number
6:	FAX Phone Number
7:	Problem name, e.g., "Benchmark 4: Array of interacting spheres"
8:	Case name, e.g., 1
9:	Code name
10:	Code type, e.g., Monte Carlo, SN
11:	Cross section library source, e.g., JEF-2.2
12:	Starting source
13:	nskip = number of stages skipped before beginning tallies
14:	nstage = number of stages tallied
15:	nhist = number of histories per generation
16:	ngenst = number of generations per stage
17:	final k-eff estimate
18:	final k-eff estimate uncertainty (one standard deviation)
19:	individual k-eff estimate at first stage
20:	individual k-eff estimate at second stage (not cumulative)
...	
18+nstage:	individual k-eff estimate at last stage (not cumulative)
18+nstage+1:	final fission fraction of sphere (1,1)
18+nstage+2:	standard deviation of final fission fraction of sphere (1,1)
18+nstage+3:	final fission fraction of sphere (3,3)
18+nstage+4:	standard deviation of final fission fraction of sphere (3,3)
18+nstage+5:	final fission fraction of sphere (5,5)
18+nstage+6:	standard deviation of final fission fraction of sphere (5,5)
18+nstage+7:	results of convergence tests (as many lines as necessary)
...	