MCNP Variance Reduction Examples

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Abstract

MCNP has a fairly rich set of variance reduction techniques. These variance reduction techniques exist in MCNP because they are applicable to a wide variety of common Monte Carlo calculations. The MCNP manual describes what the variance reduction methods do in a detailed sense, but many of these details only really start making sense when the Monte Carlo practitioner has seen a few examples using variance reduction methods. This report gives a number of examples of using variance reduction methods in MCNP.
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1 Introduction

Variance reduction techniques exist in MCNP[1], and many other Monte Carlo codes, because calculations cannot be done fast enough without these techniques. People tend to learn the variance reduction techniques as they need them and for their particular calculations at hand. The MCNP manual describes how the variance reduction techniques work in a detailed sense, but users often have trouble understanding if and/or how these techniques might be useful to their problem. The report “A Sample Problem for Variance Reduction in MCNP”[2] is often useful reading in this regard for MCNP users. In fact, the success of [2] gives some impetus for the current report because it indicates the value of teaching variance reduction, at least in part, by examples.

While it is hoped that the examples in this report will be useful to MCNP users, the examples constitute only part of what variance reduction is about. For some mathematically inclined users, standard books (e.g. [3], [4], and [5]) that discuss variance reduction theory mostly from an integral equation viewpoint that may be of considerable value. The reader of these books is cautioned that the variance reduction theory in these books is typically not directly applicable to most MCNP calculations that the author has seen[6]. Nonetheless, the books can impart some general understanding of variance reduction issues that may not be apparent from looking at examples.

Some of the examples that are given herein are in direct response to questions that users have raised either in MCNP courses or on the MCNP internet forum. Other examples are more in the style of [2].

2 The Weight Window Generator Output is All Zeroes

One of the most common frustrations of users results from using the weight window generator as a black box without really understanding how the generator works. The generator is a quite simple statistical estimation of the average score (importance) for particles in a given phase-space region. For those who are interested, the details are given on pages 43 and 44 of [2] For the present purpose, one should understand that the generator outputs the reciprocal of the average score generated by particles entering a given phase-space region. A zero is output when there has been no score generated by particles (or their progeny) entering a given phase-space region. There are two reasons that no score is generated from a region

1. No particles have entered the region, hence none can score.

2. Particles have entered the region, but none of those that entered ever scored.

For example, consider the input file:
200 cm concrete slab problem

1 1 -2.03 -2 1
2 1 -2.03 -3 2
3 1 -2.03 -4 3
4 1 -2.03 -5 4
5 1 -2.03 -6 5
6 1 -2.03 -7 6
7 1 -2.03 -8 7
8 1 -2.03 -9 8
9 1 -2.03 -10 9
10 1 -2.03 -11 10
11 1 -2.03 -12 11
12 1 -2.03 -13 12
13 1 -2.03 -14 13
14 1 -2.03 -15 14
15 1 -2.03 -16 15
16 1 -2.03 -17 16
17 1 -2.03 -18 17
18 1 -2.03 -19 18
19 1 -2.03 -20 19
20 1 -2.03 -21 20
21 0 -1
22 0 21

1 py 0
2 py 10
3 py 20
4 py 30
5 py 40
6 py 50
7 py 60
8 py 70
9 py 80
10 py 90
11 py 100
12 py 110
13 py 120
14 py 130
15 py 140
16 py 150
17 py 160
18 py 170
19 py 180
20 py 190
21 py 200
The following is Schaeffer Portland Concrete

\begin{verbatim}
1001.50c -.010  
8016.50c -.529  
11023.51c -.016  
12000.51c -.002  
13027.50c -.034  
14000.51c -.337  
19000.51c -.016  
20000.51c -.044  
26000.55c -.014  
6012.50c -.001
\end{verbatim}

c generate spatial windows

\begin{verbatim}
wwg 1 1 .5
f1:n 21
cut:n 1.e20 .01 0 0
tcte 5
nps 100000
prdmp j -60 j 2
print
\end{verbatim}

This input file was run for 100000 particles and the following weight window was generated (print table 200 in the output file).

\begin{verbatim}
wwp:n 5 3 5 0 0 0 0 0 0 0 0
wwe:n 1.0000E+02
wwn1:n 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
-1.0000E+00 -1.0000E+00
\end{verbatim}

This is not an unusual occurrence, especially for novice users. A look at the tracks entering from print table 200 shows what the trouble is.

<table>
<thead>
<tr>
<th>cell</th>
<th>tracks entering</th>
<th>population</th>
<th>collisions</th>
<th>collisions weight (per history)</th>
<th>number weighted energy</th>
<th>flux weighted energy</th>
<th>average track weight (relative)</th>
<th>average track mfp (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>110011</td>
<td>100581</td>
<td>169059</td>
<td>1.6906E+00</td>
<td>3.7101E+00</td>
<td>8.8634E+00</td>
<td>7.7535E+00</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>32444</td>
<td>23197</td>
<td>105918</td>
<td>1.0592E+00</td>
<td>1.5631E+00</td>
<td>5.3249E+00</td>
<td>6.5857E+00</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>17821</td>
<td>12562</td>
<td>60205</td>
<td>6.0205E-01</td>
<td>1.1263E+00</td>
<td>4.1721E+00</td>
<td>6.0576E+00</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>9466</td>
<td>6599</td>
<td>33094</td>
<td>3.3094E-01</td>
<td>9.7722E-01</td>
<td>3.6282E-01</td>
<td>5.8706E-01</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>4822</td>
<td>3408</td>
<td>16760</td>
<td>1.6760E-01</td>
<td>8.8063E-01</td>
<td>3.2999E-01</td>
<td>5.7257E-01</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>2378</td>
<td>1691</td>
<td>8240</td>
<td>8.2400E-02</td>
<td>8.9272E-01</td>
<td>3.2106E-01</td>
<td>5.7490E-01</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>1241</td>
<td>845</td>
<td>4564</td>
<td>4.5640E-02</td>
<td>8.4128E-01</td>
<td>3.0275E+00</td>
<td>1.0000E+00</td>
</tr>
</tbody>
</table>
8  8    612  419  1952  1.9520E-02  8.4466E-01  2.9016E+00  1.0000E+00  5.7729E+00
9  9    293  202  1084  1.0840E-02  8.5992E-01  2.7081E+00  1.0000E+00  5.7555E+00
10 10   142  100  451  4.5100E-03  8.9456E-01  2.8241E+00  1.0000E+00  5.6081E+00
11 11    61   48  203  2.0300E-03  7.1139E-01  2.4230E+00  1.0000E+00  5.3612E+00
12 12    34   23  125  1.2500E-03  5.2635E-01  2.0172E+00  1.0000E+00  5.0330E+00
13 13    19   13  86   8.6000E-04  5.7828E-01  2.1408E+00  1.0000E+00  5.0017E+00
14 14    9    5  30   3.0000E-04  5.6881E-01  1.7969E+00  1.0000E+00  4.2407E+00
15 15    4    3  14   1.4000E-04  9.2253E-01  3.0257E+00  1.0000E+00  6.7548E+00
16 16    3    1  8    8.0000E-05  1.2307E+00  2.2864E+00  1.0000E+00  7.3662E+00
17 17    2    1  8    8.0000E-05  1.7174E-01  3.0850E-01  1.0000E+00  3.1108E+00
18 18    1    1  2    2.0000E-05  9.2323E-02  9.2974E-02  1.0000E+00  2.9299E+00
19 19    0    0  0    0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
20 20    0    0  0    0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00

Note that no particles ever make it past cell 18, thus none cross tally surface 21 and none score.

There are several things that a user might try to solve the problem. There is the obvious solution of just running more particles. How many more? That is a bit difficult to say, but judging by track falloff rate in print table 126, a factor of 10 more particles would probably suffice. This judgment was incorrect when tried (slab1).

In addition to the brute force approach of running more particles, there are some other ways that the problem of zero weight windows sometimes can be successfully approached. Some approaches are:

1. Distribute the source all through the problem so that at least some cells get a good importance estimate. Then run another problem with these importance (weight window) estimates and get better estimates the next time.

   This approach makes use of the fact that an importance function is independent of the source; the importance depends on the tally, not the source.

2. Keep the true source, reduce the density so that some particles score. Then use this window, which should be better than no window, to run a problem at the true density. Sometimes one may have to take a couple of density steps from the low density runs to the true density runs.

3. Use exponential transform to decrease the effective cross section in a properly weighted way. Keep the true source.

4. Make an initial guess at weight windows or importance function by observing the behavior of the analog calculation. This is often the best way when the number of weight windows or cell importances is a small number. If there are 1000 cells in the problem, this can be quite tedious and time consuming.

5. Use another tally that is highly correlated with the ultimate tally desired, but easier to obtain. Use the generator to optimize the windows for the this other tally. The windows for this other tally, though not optimized for
the desired tally, will at least be better having no information at all. Using the windows for the other tally, it is often possible to generate windows for the desired tally.

The first approach (slab2) generated the window

\[
\begin{array}{cccccc}
\text{wwp:n} & 5 & 3 & 5 & 0 & 0 \\
\text{wwe:n} & 1.0000E+02 \\
\text{wwn1:n} & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 \\
& 0.0000E+00 & 0.0000E+00 & 7.2866E-04 & 3.6386E-04 & 1.8151E-04 \\
& 1.2053E-04 & 4.8785E-05 & 2.8172E-05 & 1.0236E-05 & 4.3976E-05 \\
& 2.0247E-06 & 9.3715E-07 & 4.5544E-07 & 2.1243E-07 & 1.0000E-07 \\
& -1.0000E+00 & -1.0000E+00 \\
\end{array}
\]

Note from the slab0 run that the particles easily got more than halfway through the slab, thus there should be no problem getting the particles from a source in cell 1 to cell 8 where the weight window information starts. The only other thing to keep in mind is that any particles reaching cell 8 are expected to have a weight of about 0.001 because the lower window bound is 7.2866E-04. Thus, in the slab3 run the weight window from slab2 is used and the source weight is set to 0.001.

Slab3 produces a window in every cell

\[
\begin{array}{cccccc}
\text{wwp:n} & 5 & 3 & 5 & 0 & 0 \\
\text{wwe:n} & 1.0000E+02 \\
\text{wwn1:n} & 5.0000E-01 & 1.1527E-01 & 6.2555E-02 & 3.2895E-02 & 1.7015E-02 \\
& 8.4250E-03 & 4.2100E-03 & 2.0900E-03 & 1.0050E-03 & 5.0000E-04 \\
& 2.4250E-04 & 1.1773E-04 & 5.2577E-05 & 2.1667E-05 & 9.5579E-06 \\
& 4.7931E-06 & 1.6319E-06 & 7.8125E-07 & 3.6458E-07 & 1.4757E-07 \\
& -1.0000E+00 & -1.0000E+00 \\
\end{array}
\]

It may help to insert this window into the input file and iterate once more time because print table 160 indicates that this window is based on only 6 scoring histories, but this demonstration ends because it suffices for the current purpose of showing approach 1 above.

For approach 2, note from slab0 that the particles got at least halfway through the slab. This suggests that if the density were reduced by a factor of 2 (slab4), that some particles would tally and a weight window would be produced. The weight window is not correct for the original density, but at least it is a better window for variance reduction at the true density than a window of all zeroes. Slab4 produces the window

\[
\begin{array}{cccccc}
\text{wwp:n} & 5 & 3 & 5 & 0 & 0 \\
\text{wwe:n} & 1.0000E+02 \\
\text{wwn1:n} & 5.0000E-01 & 1.5584E-01 & 1.1426E-01 & 8.4810E-02 & 6.1680E-02 \\
& 4.4995E-02 & 3.2525E-02 & 2.3585E-02 & 1.6785E-02 & 1.1930E-02 \\
& 8.4200E-03 & 5.8800E-03 & 4.0200E-03 & 2.7900E-03 & 1.9600E-03 \\
& 1.3950E-03 & 1.0200E-03 & 7.1000E-04 & 4.3000E-04 & 2.8000E-04 \\
& -1.0000E+00 & -1.0000E+00 \\
\end{array}
\]
The window produced from slab4 is then input into the problem with the original density (slab5) and then the following window is generated from the slab5 run.

\[
\text{wwp:n 5 3 5 0 0 0} \\
\text{wwe:n 1.0000E+02} \\
\text{wwn1:n 5.0000E-01 1.4238E-01 6.3158E-02 3.3215E-02 1.7151E-02} \\
\text{8.5582E-03 4.2231E-03 2.0497E-03 1.0004E-03 4.8758E-04} \\
\text{2.3900E-04 1.1243E-04 5.5200E-05 2.5313E-05 1.1929E-05} \\
\text{5.5469E-06 2.4414E-06 1.0547E-06 4.9222E-07 2.2461E-07} \\
\text{8.5562E-03 4.2231E-03 2.0497E-03 1.0004E-03 4.8758E-04} \\
\text{2.3900E-04 1.1243E-04 5.5200E-05 2.5313E-05 1.1929E-05} \\
\text{5.5469E-06 2.4414E-06 1.0547E-06 4.9222E-07 2.2461E-07} \\
\text{-1.0000E+00 -1.0000E+00}
\]

The window may improve with another iteration, but this demonstrates how to get started using approach 2.

Approach 3 uses the exponential transform to reduce the effective cross section in the forward direction. That is, particles preferentially take long jumps in the forward direction. Note that this is different from approach 2 because approach 2 used a fictitious density and approach 3 uses the true density and samples in a biased manner. The particles got at least halfway through in the unbiased problem (slab0), so that the exponential transform is set to reduce the effective cross section in the forward direction by a factor of 2 (slab6). Slab6 generates the warning message “warning, exponential transform usually needs weight window,” but this is not of concern until one needs reliable answers. For example, if the weight windows are unreliable by a factor of 2 from their correct values, it is not a serious problem. But if the final estimates are unreliable by a factor of 2, this is a serious problem. The warning message can be ignored while the user sets up the weight windows. Slab6 produces the window

\[
\text{wwp:n 5 3 5 0 0 0} \\
\text{wwe:n 1.0000E+02} \\
\text{wwn1:n 5.0000E-01 1.4238E-01 6.3158E-02 3.3215E-02 1.7151E-02} \\
\text{8.5582E-03 4.2231E-03 2.0497E-03 1.0004E-03 4.8758E-04} \\
\text{2.3900E-04 1.1243E-04 5.5200E-05 2.5313E-05 1.1929E-05} \\
\text{5.5469E-06 2.4414E-06 1.0547E-06 4.9222E-07 2.2461E-07} \\
\text{8.5562E-03 4.2231E-03 2.0497E-03 1.0004E-03 4.8758E-04} \\
\text{2.3900E-04 1.1243E-04 5.5200E-05 2.5313E-05 1.1929E-05} \\
\text{5.5469E-06 2.4414E-06 1.0547E-06 4.9222E-07 2.2461E-07} \\
\text{-1.0000E+00 -1.0000E+00}
\]

The window may improve with another iteration, but this demonstrates how to get started using approach 3.

Approach 4 starts by noting from the slab0 run that the tracks entering are decreasing by about a factor of 2 from cell to cell. This suggests that the tracks can be kept relatively constant throughout the problem if the window is set so that the weights in each cell drop by about a factor of two. Using this guess for the window (slab7), slab7 produces the window

\[
\text{wwp:n 5 3 5 0 0 0} \\
\text{wwe:n 1.0000E+02} \\
\text{wwn1:n 5.0000E-01 1.4238E-01 6.3158E-02 3.3215E-02 1.7151E-02} \\
\text{8.5582E-03 4.2231E-03 2.0497E-03 1.0004E-03 4.8758E-04} \\
\text{2.3900E-04 1.1243E-04 5.5200E-05 2.5313E-05 1.1929E-05} \\
\text{5.5469E-06 2.4414E-06 1.0547E-06 4.9222E-07 2.2461E-07} \\
\text{8.5562E-03 4.2231E-03 2.0497E-03 1.0004E-03 4.8758E-04} \\
\text{2.3900E-04 1.1243E-04 5.5200E-05 2.5313E-05 1.1929E-05} \\
\text{5.5469E-06 2.4414E-06 1.0547E-06 4.9222E-07 2.2461E-07} \\
\text{-1.0000E+00 -1.0000E+00}
\]
Note that a window can be generated even with guesses that are pretty fair off. For example, slab8 decreased the windows from cell to cell by a factor of 0.707 and produced the window

\[
\begin{align*}
\text{wwp:n} & \quad 5 & 3 & 5 & 0 & 0 & 0 \\
\text{wwe:n} & \quad 1.0000E+02 \\
\text{wwn1:n} & \quad 5.0000E-01 & 1.1593E-01 & 6.2942E-02 & 3.3075E-02 & 1.7017E-02 \\
& \quad 8.3292E-03 & 4.1146E-03 & 2.0437E-03 & 9.8542E-04 & 4.8021E-04 \\
& \quad 2.2500E-04 & 1.0990E-04 & 5.5715E-05 & 2.5781E-05 & 1.1198E-05 \\
& \quad 5.8594E-06 & 2.5391E-06 & 1.6276E-06 & 8.1380E-07 & 4.8828E-07 \\
& \quad -1.0000E+00 & -1.0000E+00 \\
\end{align*}
\]

whereas slab9 decreased the windows from cell to cell by a factor of 0.333 and produced the window

\[
\begin{align*}
\text{wwp:n} & \quad 5 & 3 & 5 & 0 & 0 & 0 \\
\text{wwe:n} & \quad 1.0000E+02 \\
\text{wwn1:n} & \quad 5.0000E-01 & 1.1800E-01 & 6.2000E-02 & 3.1500E-02 & 1.5000E-02 \\
& \quad 8.4722E-03 & 3.9969E-03 & 1.9918E-03 & 1.0394E-03 & 5.2995E-04 \\
& \quad 2.6478E-04 & 1.3001E-04 & 6.4132E-05 & 3.1505E-05 & 1.5440E-05 \\
& \quad 7.4715E-06 & 3.5575E-06 & 1.6693E-06 & 7.8905E-07 & 3.6547E-07 \\
& \quad -1.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 \\
& \quad 0.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 \\
& \quad 0.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 \\
& \quad -1.0000E+00 & -1.0000E+00 \\
\end{align*}
\]

The point here is that the user’s guess need not be a great guess in order to begin the process of obtaining a weight window from the generator.

Approach 5 uses the fact that particles that get all the way from the source to the tally must first get part of the way from source to tally. In slab10, the generator is set to produce windows based on a surface tally (f11:n 11, i.e. an intermediate tally at 100cm) that is about midway between source and the tally that is ultimately desired. Note that a zero importance region has temporarily been set after surface 11; the reason for this will be demonstrated shortly.) Slab10 produces the window

\[
\begin{align*}
\text{wwp:n} & \quad 5 & 3 & 5 & 0 & 0 & 0 \\
\text{wwe:n} & \quad 1.0000E+02 \\
\text{wwn1:n} & \quad 5.0000E-01 & 1.1528E-01 & 6.2555E-02 & 3.2895E-02 & 1.7015E-02 \\
& \quad 8.4250E-03 & 4.2100E-03 & 2.0900E-03 & 1.0050E-03 & 5.0000E-04 \\
& \quad -1.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 \\
& \quad 0.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 \\
& \quad -1.0000E+00 & -1.0000E+00 \\
\end{align*}
\]

Now, change the -1.0 entry in cell 11 to 0.0 because one no longer wishes the particles to terminate in cell 11. That is,

\[
\begin{align*}
\text{wwp:n} & \quad 5 & 3 & 5 & 0 & 0 & 0 \\
\text{wwe:n} & \quad 1.0000E+02 \\
\end{align*}
\]
This window from slab10 is then inserted into slab11 and a new window is generated using the original tally (f1:n 21). Slab11 generates the window

\[
\text{wwp:n 5 3 5 0 0 0} \\
\text{wwe:n 1.0000E+02}
\]

\[
\text{wwn1:n 5.0000E-01 1.1528E-01 6.2555E-02 3.2895E-02 1.7015E-02} \\
8.4250E-03 4.2100E-03 2.0900E-03 1.0050E-03 5.0000E-04 \\
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 \\
-1.0000E+00 -1.0000E+00
\]

This window from slab10 is then inserted into slab11 and a new window is generated using the original tally (f1:n 21). Slab11 generates the window

\[
\text{wwp:n 5 3 5 0 0 0} \\
\text{wwe:n 1.0000E+02}
\]

\[
\text{wwn1:n 5.0000E-01 1.1621E-01 6.3145E-02 3.3654E-02 1.7062E-02} \\
8.5618E-03 4.3042E-03 2.1257E-03 1.0423E-03 5.0584E-04 \\
2.4569E-04 1.1841E-04 5.5736E-05 2.5203E-05 1.2232E-05 \\
5.7225E-06 3.0158E-06 1.3830E-06 5.6641E-07 2.3438E-07 \\
-1.0000E+00 -1.0000E+00
\]

Note that through cell 10 the windows generated by slab10 and slab11 are very similar. Because of the very high degree of correlation, the intermediate tally (f11:n 11) in slab10 is acting as a standin for the desired tally (f1:n 21).

Slab12 returns to the question of why slab10 used a zero importance in cell 11. Specifically, slab12 is the same as slab10 except that cell 11 has unit importance. Slab12 generates the window

\[
\text{wwp:n 5 3 5 0 0 0} \\
\text{wwe:n 1.0000E+02}
\]

\[
\text{wwn1:n 5.0000E-01 1.1621E-01 6.3145E-02 3.3654E-02 1.7062E-02} \\
8.5618E-03 4.3042E-03 2.1257E-03 1.0423E-03 5.0584E-04 \\
2.4569E-04 1.1841E-04 5.5736E-05 2.5203E-05 1.2232E-05 \\
5.7225E-06 3.0158E-06 1.3830E-06 5.6641E-07 2.3438E-07 \\
-1.0000E+00 -1.0000E+00
\]

Note that the windows in cells beyond cell 10 are higher than in cell 10. That is, if this window were used as input instead of (slab11’s window) then the particles would actually be rouletted as they tried to get from surface 11 (intermediate tally) to surface 21 (desired tally). This is understandable because the generator results for the intermediate tally will naturally have windows that increase as the particles get farther and farther away, in either direction, from surface 11.

### 3 Zeroes in an Energy-Dependent Weight Window

Although it is often the case that a spatial window can be produced fairly easily, a space and energy dependent window is usually substantially harder. Starting with the spatial window generated by slab11, slab20 generates the energy dependent window
Note that the high energy windows are filled in whereas the low energy windows have lots of zeroes. This is not a surprise because low energy neutrons are much
less likely to score using the same energy independent window as the high energy 
neutrons. Unfortunately, filling in these energy dependent weight windows is 
more difficult than filling in the zeroes in a spatial window. The goals of this 
section are to give:

1. An explanation of why it is dangerous to leave zeroes in the windows.
2. An explanation of how to fill in the zeroes.
3. Comments on possible better solutions to this problem in the future.

To see why it is dangerous to leave the zeroes in the weight window, slab21 
was run using the energy dependent window from slab20. Here is the fom (figure 
of merit) table

<table>
<thead>
<tr>
<th>tally 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>nps</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>4000</td>
</tr>
<tr>
<td>8000</td>
</tr>
<tr>
<td>12000</td>
</tr>
<tr>
<td>16000</td>
</tr>
<tr>
<td>20000</td>
</tr>
<tr>
<td>24000</td>
</tr>
<tr>
<td>28000</td>
</tr>
<tr>
<td>32000</td>
</tr>
<tr>
<td>36000</td>
</tr>
<tr>
<td>40000</td>
</tr>
<tr>
<td>44000</td>
</tr>
<tr>
<td>48000</td>
</tr>
<tr>
<td>50000</td>
</tr>
</tbody>
</table>

Note that had the user stopped at 40000 particles, everything in the figure of 
merit chart would have looked fine. Indeed, it is not shown here, but if one 
stops at 40000 particles, then the tally passes all ten MCNP statistical checks. 
(Note that there is some legerdemain in slab21. Specifically, the starting random 
number was changed so that the fom table would show the problem. Sometimes, 
the problem never becomes apparent to the user; for example, had the present 
calculation been stopped at 40000 particles.)

When one sees such strange statistical behavior, it is advisable to get an 
event log for the particle that gave the largest score, because there will typically 
be something quite special about that particle. (If there were nothing special 
about the particle, then it is unlikely that the fom table would look so strange.) 
At this point, one looks at the output file (slab21.o here) and finds the line 
(print table 160)

```
history number of largest tally = 42000
largest unnormalized history tally = 5.11163E-04
```

To reproduce this particle history, one would normally use the MCNP input card

12
but because slab21 started with

slab22 uses the following rand and ddbc cards

### history

<table>
<thead>
<tr>
<th>Tally History</th>
<th>Largest Unnormalized History Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.11163E-04</td>
</tr>
</tbody>
</table>

for a check that the particle history is being reproduced.

Now look at the tracks that tally in the event log. Note that the tracks that tally (for this problem) all have “escape” on the event line print and all have 2.000+02 (the y coordinate upon tallying) in columns 21 to 29. When the text editor is instructed to find every line that has “escape” in it and has 2.000+02 in columns 21 to 29 the result is

```plaintext
*dp*/escape/tp,,21,29/2.000+02
```

<table>
<thead>
<tr>
<th>Event</th>
<th>y</th>
<th>x</th>
<th>z</th>
<th>Energy</th>
<th>Track</th>
<th>Escape</th>
</tr>
</thead>
<tbody>
<tr>
<td>1317</td>
<td>2.000+02</td>
<td>1.871+01</td>
<td>5.539-02</td>
<td>7.926-01</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>1376</td>
<td>2.000+02</td>
<td>3.571+01</td>
<td>9.005-01</td>
<td>1.187+00</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>2173</td>
<td>2.000+02</td>
<td>3.638+00</td>
<td>7.292-01</td>
<td>2.448-01</td>
<td>1.088+00</td>
<td>escape</td>
</tr>
<tr>
<td>2178</td>
<td>2.000+02</td>
<td>1.113+01</td>
<td>8.175-01</td>
<td>4.962-01</td>
<td>1.309+00</td>
<td>escape</td>
</tr>
<tr>
<td>2219</td>
<td>2.000+02</td>
<td>1.309+01</td>
<td>8.003-01</td>
<td>1.652-01</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>2262</td>
<td>2.000+02</td>
<td>2.079+01</td>
<td>9.865-01</td>
<td>4.616-02</td>
<td>2.354+00</td>
<td>escape</td>
</tr>
<tr>
<td>2276</td>
<td>2.000+02</td>
<td>1.953+01</td>
<td>7.460-01</td>
<td>1.162+00</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>2280</td>
<td>2.000+02</td>
<td>2.079+01</td>
<td>9.865-01</td>
<td>4.616-02</td>
<td>2.354+00</td>
<td>escape</td>
</tr>
<tr>
<td>2515</td>
<td>2.000+02</td>
<td>1.321+01</td>
<td>6.020-01</td>
<td>1.162+00</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>2531</td>
<td>2.000+02</td>
<td>3.495+01</td>
<td>9.644-01</td>
<td>2.134+00</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>2696</td>
<td>2.000+02</td>
<td>1.254+01</td>
<td>8.442-01</td>
<td>1.422+00</td>
<td>2.662-06</td>
<td>escape</td>
</tr>
<tr>
<td>2848</td>
<td>2.000+02</td>
<td>4.835+01</td>
<td>7.012-01</td>
<td>9.702-01</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>2857</td>
<td>2.000+02</td>
<td>5.473+01</td>
<td>7.853-01</td>
<td>1.408+00</td>
<td>2.662-06</td>
<td>escape</td>
</tr>
<tr>
<td>2865</td>
<td>2.000+02</td>
<td>5.263+01</td>
<td>9.644-01</td>
<td>2.134+00</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
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<td>4.874+01</td>
<td>9.702-01</td>
<td>1.422+00</td>
<td>2.662-06</td>
<td>escape</td>
</tr>
<tr>
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<td>6.673+01</td>
<td>9.413-01</td>
<td>1.127+00</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>2908</td>
<td>2.000+02</td>
<td>5.213+01</td>
<td>9.702-01</td>
<td>1.127+00</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>3870</td>
<td>2.000+02</td>
<td>5.082+01</td>
<td>7.519-01</td>
<td>5.837-01</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>3978</td>
<td>2.000+02</td>
<td>2.854+01</td>
<td>9.964-01</td>
<td>2.364+00</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>3999</td>
<td>2.000+02</td>
<td>1.796+01</td>
<td>6.693-01</td>
<td>2.364+00</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>4007</td>
<td>2.000+02</td>
<td>7.401+00</td>
<td>7.889-01</td>
<td>6.730-01</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>4024</td>
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<td>6.823+00</td>
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<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>4243</td>
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<td>2.941+01</td>
<td>9.532-01</td>
<td>2.179+00</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>4249</td>
<td>2.000+02</td>
<td>4.945+01</td>
<td>8.587-01</td>
<td>4.921-01</td>
<td>5.176-01</td>
<td>1.286-06</td>
</tr>
<tr>
<td>4258</td>
<td>2.000+02</td>
<td>5.943+01</td>
<td>8.932-01</td>
<td>7.999-01</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
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<td>4.391+01</td>
<td>9.964-01</td>
<td>2.364+00</td>
<td>1.286-06</td>
<td>escape</td>
</tr>
<tr>
<td>4361</td>
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<td>4.279+01</td>
<td>8.866-01</td>
<td>9.776+02</td>
<td>2.353+00</td>
<td>1.286-06</td>
</tr>
<tr>
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<td>4.279+01</td>
<td>8.866-01</td>
<td>9.776+02</td>
<td>2.353+00</td>
<td>1.286-06</td>
</tr>
<tr>
<td>4375</td>
<td>2.000+02</td>
<td>3.911+01</td>
<td>6.576-01</td>
<td>6.246+02</td>
<td>2.349+00</td>
<td>1.286-06</td>
</tr>
<tr>
<td>4380</td>
<td>2.000+02</td>
<td>3.726+01</td>
<td>8.549-01</td>
<td>3.247+00</td>
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<td>escape</td>
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<td>4386</td>
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<td>8.767-01</td>
<td>6.426+02</td>
<td>2.349+00</td>
<td>1.286-06</td>
</tr>
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<td>4836</td>
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<td>2.430+01</td>
<td>9.949-01</td>
<td>3.314+00</td>
<td>2.138+00</td>
<td>1.286-06</td>
</tr>
</tbody>
</table>

Table 160 for slab22 then gives
Note that some energies (columns 71-80) occur frequently among scoring particles. Note further that almost all of the repeating energies are less than 3 MeV. A glance at the weight window (print table 20 below) shows that above 3 MeV all the space energy regions have nonzero windows.

et cetera
Looking at the first few lines of the event log, one sees that there is a lot of splitting going on (npa=4 indicating a 5:1 split with four tracks banked) at random number indices 157 to 160 as the tracks enter cells 7-9.

<table>
<thead>
<tr>
<th>cell</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>u</th>
<th>v</th>
<th>w</th>
<th>erg</th>
<th>wgt</th>
<th>nch</th>
<th>tch</th>
<th>nrn</th>
</tr>
</thead>
<tbody>
<tr>
<td>src</td>
<td>1.000+00</td>
<td>0.000+00</td>
<td>-7.072-01</td>
<td>5.246-01</td>
<td>-4.740-01</td>
<td>1.400+01</td>
<td>1.000+00</td>
<td>particle=neutron</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>1</td>
<td>-1.047+01</td>
<td>7.765+00</td>
<td>-7.017+00</td>
<td>-6.643-01</td>
<td>6.961-01</td>
<td>-2.724-01</td>
<td>1.396+01</td>
<td>1.000+00</td>
<td>14000.51c r=</td>
<td>2</td>
</tr>
<tr>
<td>s</td>
<td>2</td>
<td>-1.260+01</td>
<td>1.000+01</td>
<td>-7.891+00</td>
<td>-6.643-01</td>
<td>6.961-01</td>
<td>-2.724-01</td>
<td>1.396+01</td>
<td>1.000+00</td>
<td>3.333-01</td>
<td>surf=</td>
</tr>
<tr>
<td>c</td>
<td>2</td>
<td>-1.821+01</td>
<td>1.587+01</td>
<td>-1.019+01</td>
<td>-7.211-01</td>
<td>6.895-01</td>
<td>2.747+00</td>
<td>1.400+01</td>
<td>1.000+00</td>
<td>3.333-01</td>
<td>surf=</td>
</tr>
<tr>
<td>s</td>
<td>3</td>
<td>-1.611+01</td>
<td>2.099+01</td>
<td>1.029+01</td>
<td>-7.461-01</td>
<td>6.961-01</td>
<td>2.747+00</td>
<td>1.400+1</td>
<td>19000.51c r=</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>c</td>
<td>3</td>
<td>-1.636+01</td>
<td>2.000+01</td>
<td>9.497+00</td>
<td>-7.461-01</td>
<td>6.961-01</td>
<td>2.747+00</td>
<td>1.400+01</td>
<td>19000.51c r=</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Why is there so much splitting occurring? Note from the weight window, that the tracks being split have not had their weight checked from the time the progenitor track was in cell 1 (random number index 105; the 'nrn' column) until the progenitor track enters cell 7 because cells 1 to 6 have zeroes for the weight window in the 2 to 3 MeV range. The progenitor track enters cell 7 with weight 8.333 whereas the window in cell 7 is between .0272 and 5.0272. That is, the progenitor’s weight is 61 times the upper bound in the cell 7 and energy range 2 to 3 MeV. With a text editor one finds out that the energy “2.375+00” occurs in columns 71 to 80 of the event log 556 times. It is likely that almost all of these tracks result from the single progenitor track at random number index 105. This should not be occurring. The whole idea of splitting is that the split tracks tend to do different things. Here, there are large numbers of tracks with exactly the same energy.
Note that despite the fact that higher energy particles penetrate the concrete better, one does not see the variance problem in the higher energy ranges. One sees the variance problem in the highest energy range where the weight windows are not controlling the weights. The solution is to fill in the weight window zeroes with some “reasonable values.”

So what is a “reasonable” value or, perhaps more appropriately, what is an “unreasonable” value? To answer this question, it helps to understand why the weight window generator produced a zero window in the first place. Note that a zero window means that no tracks ever scored from the phase-space region. This is either because 1) no tracks ever entered the region or because 2) no entering tracks ever scored. In both cases, the space energy region tends to be relatively unimportant to the desired tally. Because of this, one can pick almost any value that is not outrageous. Examples will follow soon.

Before trying some actual weight window numbers, perhaps the essence of the term “reasonable values” can be illustrated by a simple example with binary distributions. Suppose the sampling space is partitioned into two regions $R_1$ and $R_2$. Suppose that $R_i$ is chosen with probability $c_i$. Once in region $i$, the particle scores $s_i$ with probability $p_i$ and scores 0 with probability $1 - p_i$. The mean for this problem is

$$M_1 = c_1 p_1 s_1 + c_1 (1 - p_1)0 + c_2 p_2 s_2 + c_2 (1 - p_2)0 = c_1 p_1 s_1 + c_2 p_2 s_2$$

The second moment is

$$M_2 = c_1 p_1 s_1^2 + c_1 (1 - p_1)0^2 + c_2 p_2 s_2^2 + c_2 (1 - p_2)0^2 = c_1 p_1 s_1^2 + c_2 p_2 s_2^2$$

hence the variance is

$$V = M_2 - M_1^2 = c_1 p_1 s_1^2 + c_2 p_2 s_2^2 - (c_1 p_1 s_1 + c_2 p_2 s_2)^2$$

Suppose, similar to the MCNP example, that most samples of $R_2$ result in no scoring particle, but that an occasional sample of $R_2$ results in a large score $s_2$. This is a high variance situation. Let’s put in some numbers now. Let

1. $c_1 = 0.7$
2. $p_1 = 0.01$
3. $s_1 = 1$
4. $c_2 = 0.3$
5. $p_2 = 1.e - 7$
6. $s_2 = 1000$

The mean and variance for this case are $M_1 = 0.00703$ and $V = 0.0369506$. Note that until a particle scores $s_2 = 1000$ from $R_2$, the sample mean and
variance, \( \hat{M}_1 \) and \( \hat{V} \), will be missing any terms involving \( s_2 \) and will therefore be approximately

\[
\hat{M}_1 \approx c_1 p_1 s_1 = 0.007
\]

\[
\hat{V} \approx c_1 p_1 s_1^2 - (c_1 p_1 s_1)^2 = 0.006951
\]

Note that the mean is pretty close to the true mean, but the variance estimate will be about a factor of 5 low (.0369506/.006951) until one of the large \( s_2 = 1000 \) scores occurs. Suppose that a variance reduction attack is mounted to increase the probability that a particle in \( R_2 \) scores, and correspondingly decrease the magnitude of the score when the particle does score. Assume that the variance reduction method applied preserves the binomial distribution of scores from \( R_2 \), but changes the binomial \( p_2 \). Note that \( M_1 \) will be preserved as long as the product \( p_2 s_2 \) is preserved. For the specific case under consideration then

\[
p_2 s_2 = 1 \times 10^{-7} \times 1000 = 1 \times 10^{-4}
\]

Thus, \( p_2 \) can be adjusted to anything and \( M_1 \) will be preserved, if \( s_2 \) is correspondingly adjusted to \( s_2 = .0001/p_2 \). Some possible adjustments of \( p_2 \) and \( s_2 \) are shown in the following table.

<table>
<thead>
<tr>
<th>( p_2 )</th>
<th>( s_2 )</th>
<th>variance</th>
</tr>
</thead>
<tbody>
<tr>
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<td>100000</td>
<td>3.00695</td>
</tr>
<tr>
<td>1.e-8</td>
<td>10000</td>
<td>.306951</td>
</tr>
<tr>
<td>1.e-7</td>
<td>1000</td>
<td>.0369506</td>
</tr>
<tr>
<td>1.e-6</td>
<td>100</td>
<td>.00995058</td>
</tr>
<tr>
<td>1.e-5</td>
<td>10</td>
<td>.00725058</td>
</tr>
<tr>
<td>1.e-4</td>
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<td>.01</td>
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<td>.00695061</td>
</tr>
<tr>
<td>1.e+0</td>
<td>.0001</td>
<td>.00695058</td>
</tr>
</tbody>
</table>

Note that the last entry, with \( p_2 = 1 \), is absolutely the best that can be done for particles entering \( R_2 \) since every particle arriving in \( R_2 \) scores exactly \( .0001 \); that is, a zero variance sampling of the problem occurs after arriving in \( R_2 \). Note however, that any \( .00001 \leq p_2 \leq 1 \) gives approximately the same value for the variance. Thus, there is a very broad range of reasonable values for \( p_2 \) that remove the variance problem initially encountered. For this reason, the user should not fret unduly about using a “good” choice of variance reduction parameters; he merely has to avoid “bad” choices.

Returning to the actual weight window at hand, one can note the general behavior in the weight window. For the highest energy window, the windows are increasing by something like a factor of 2 for each cell moving away from the tally region. For the lowest energy window he windows are increasing by something like a factor of 10 for each cell moving away from the tally region. Note that having high weight windows saves time relative to lower weight windows because their is less splitting and/or more roulette. Conversely, having high windows tends to increase the history variance compared with having low windows. Thus, from a conservative point of view, one is much less likely to get into variance problems by using a factor of 2 rule to extend the window into regions where
the generator supplied a zero. (It is convenient to figure what the window value in cell 1 is and then use a 0.5m multiplier entry to multiply each subsequent entry by 0.5. Note for MCNP code developers: it might be nice to allow a divide option as well as a multiply option.)

wwp:n 5 3 5 0 0
wwe:n 1.0000E-01 3.0000E-01 1.0000E+00 2.0000E+00 3.0000E+00 5.0000E+00 8.0000E+00 1.6000E+01

wn1:n 23.4789 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 1.7913E-04 1.8089E-05 1.3290E-06
wwn1:n 23.4789 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 1.7913E-04 1.8089E-05 1.3290E-06

wn2:n 37.4197 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 5.7098E-04 5.5807E-05 5.0814E-06
wwn2:n 37.4197 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 5.7098E-04 5.5807E-05 5.0814E-06

wn3:n 6.79739 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 1.0372E-04 1.4200E-05 2.4648E-06
wwn3:n 6.79739 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 1.0372E-04 1.4200E-05 2.4648E-06

wn4:n 37.5874 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 1.0000E-01 1.0000E-01
wwn4:n 37.5874 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 1.0000E-01 1.0000E-01

wn5:n 1.74093 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 1.0141E-05 4.1023E-06 6.9490E-07
wwn5:n 1.74093 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 0.5m 1.0141E-05 4.1023E-06 6.9490E-07


wn7:n 2.4824E+00 1.7749E-01 1.2103E-01 5.5439E-02 1.7977E-02
wwn7:n 2.4824E+00 1.7749E-01 1.2103E-01 5.5439E-02 1.7977E-02

wn8:n 5.0000E-01 6.7056E-02 3.0592E-02 1.3709E-02 6.9265E-03 3.5548E-03 1.6576E-03 7.8467E-04 4.2039E-04 1.6068E-04
wwn8:n 5.0000E-01 6.7056E-02 3.0592E-02 1.3709E-02 6.9265E-03 3.5548E-03 1.6576E-03 7.8467E-04 4.2039E-04 1.6068E-04

Or, from Table 20 of the output file (slab23.o)

weight-window lower bounds

energy: 1.0000E-01 3.0000E-01 1.0000E+00 2.0000E+00 3.0000E+00 5.0000E+00 8.0000E+00 1.0000E+036

cell
1 2.348E-01 3.742E-01 6.797E-00 3.759E+00 1.741E+00 3.333E+00 2.482E+00 5.000E-01
2 1.174E-01 1.871E-01 3.399E-00 1.879E+00 8.706E+00 5.675E-01 1.775E-01 6.706E-02
3 5.870E+00 9.355E+00 1.699E+00 9.397E-00 4.352E+00 2.752E+00 1.210E+01 3.059E-02
4 2.935E+00 4.677E+00 8.497E-01 4.698E+00 2.176E+01 1.334E-01 5.549E-02 1.371E-02
5 1.467E+00 2.339E+00 4.248E+00 2.349E+00 1.088E+01 8.078E-02 1.798E-02 6.927E-03
6 7.339E-01 1.169E+00 2.124E-01 1.175E+00 5.440E-02 2.399E+00 1.715E-03 8.670E-04
7 3.669E+00 5.847E+00 1.062E+01 5.873E+00 2.720E+02 2.164E+02 3.829E+03 1.658E+03
8 1.834E-01 1.027E-01 2.926E-01 1.027E-01 2.926E-01 1.027E-01 2.926E-01 1.027E-01
9 9.171E-02 1.462E-01 2.658E-02 1.462E-01 2.658E-02 1.462E-01 2.658E-02 1.462E-01
14 2.866E-03 4.568E-03 8.298E-04 4.298E-03 5.435E-05 2.988E-05 1.060E-05 1.093E-05
15 1.433E-03 2.284E-03 4.149E-04 2.920E-04 2.482E-05 1.587E-05 6.778E-06 5.668E-06
16 7.165E-04 1.142E-03 2.074E-04 5.904E-05 1.014E-05 7.993E-06 2.983E-06 2.103E-06
17 3.583E-04 5.710E-04 1.037E-04 1.447E-05 4.102E-06 4.287E-06 1.439E-06 1.340E-06
21 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00
22 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00

Using this filled in window, the calculation now appears well behaved at 500,000 particles as indicated by MCNP's ten statistical checks and the tally fluctuation chart below.

<table>
<thead>
<tr>
<th>tally fluctuation charts</th>
</tr>
</thead>
<tbody>
<tr>
<td>tally 1</td>
</tr>
<tr>
<td>nps mean error vov slope fom</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>32000 2.4724E-07 0.0496 0.0104 5.1 293</td>
</tr>
<tr>
<td>64000 2.5002E-07 0.0364 0.0055 5.0 274</td>
</tr>
<tr>
<td>96000 2.5163E-07 0.0297 0.0037 10.0 272</td>
</tr>
<tr>
<td>128000 2.5832E-07 0.0261 0.0042 6.0 261</td>
</tr>
<tr>
<td>160000 2.5450E-07 0.0236 0.0035 5.6 259</td>
</tr>
<tr>
<td>192000 2.5251E-07 0.0216 0.0037 10.0 272</td>
</tr>
<tr>
<td>224000 2.5510E-07 0.0198 0.0023 7.6 261</td>
</tr>
<tr>
<td>256000 2.5781E-07 0.0186 0.0022 8.5 258</td>
</tr>
<tr>
<td>288000 2.5777E-07 0.0176 0.0019 10.0 258</td>
</tr>
<tr>
<td>320000 2.5721E-07 0.0168 0.0021 6.6 254</td>
</tr>
<tr>
<td>352000 2.5921E-07 0.0153 0.0017 5.0 256</td>
</tr>
<tr>
<td>384000 2.5817E-07 0.0146 0.0015 5.5 257</td>
</tr>
<tr>
<td>416000 2.5792E-07 0.0141 0.0014 6.3 258</td>
</tr>
<tr>
<td>448000 2.5838E-07 0.0135 0.0013 5.7 260</td>
</tr>
<tr>
<td>480000 2.5849E-07 0.0133 0.0012 6.2 260</td>
</tr>
</tbody>
</table>

To see that there is nothing magic about the choice of a factor of 2, let's use a factor of 3 between windows in adjacent cells instead. This results in the window

**dump no. 2 on file slab23.r nps = 500000 coll = 8020654 ctm = 21.86 nrn = 84378048**
Table 20 in the output file for slab24 (24.o) gives the explicit window
weight-window lower bounds

After 20 minutes, this calculation also passes the ten statistical checks. Here is the tally fluctuation chart.

Itally fluctuation charts

energy: 1.000E+01 3.000E+01 1.000E+00 2.000E+00 3.000E+00 5.000E+00 8.000E+00 1.000E+36

cell

1. 2.313E+04 7.362E+04 4.465E+03 4.877E+03 1.983E+01 3.333E+00 2.482E+00 5.000E-01
2. 7.710E+03 2.454E+04 1.488E+03 1.626E+03 6.610E+00 1.334E-01 5.549E-02 1.371E-02
3. 2.570E+03 8.180E+03 4.961E+02 5.419E+02 2.203E+00 1.210E-01 5.549E-02 1.371E-02
4. 8.566E+02 2.727E+03 1.664E+02 1.806E+02 7.346E-01 6.021E-02 1.798E-02 6.927E-03
5. 2.855E+02 9.089E+02 5.121E+01 6.021E+00 2.448E-01 1.093E-02 4.032E-03 1.153E-02
6. 9.518E+01 3.030E+02 1.837E+01 2.077E+01 6.927E-01 2.399E-02 8.935E-03 2.865E-03
7. 3.173E+01 1.010E+02 6.125E+00 6.690E+00 2.164E-02 8.935E-03 2.865E-03 1.263E-02
8. 1.058E+01 3.366E+01 2.042E+00 2.230E+00 1.435E+02 8.935E-03 2.865E-03 1.263E-02
9. 3.525E+00 1.122E+01 6.805E+00 7.433E+00 4.253E+00 4.574E-03 7.700E+00 4.204E-04
10. 1.175E+00 3.740E+00 2.268E+00 2.478E+00 1.684E+00 1.607E+00 1.153E+00 1.607E+00
11. 3.976E+00 1.274E+00 7.561E+00 6.258E+00 3.988E-02 1.263E-02 4.253E-03 1.263E-02
12. 3.060E+00 1.456E+00 2.520E-01 2.563E-02 4.096E-04 4.265E-04 8.935E-05 4.032E-05
13. 4.352E-02 1.385E+00 9.401E-03 9.177E-03 1.844E-04 9.086E-05 2.082E-05 2.067E-05
14. 1.451E-02 4.618E-02 2.800E-03 2.898E-03 5.435E-05 1.060E-05 1.093E-05 1.093E-05
15. 4.836E-03 1.539E-02 9.336E-04 2.920E-04 2.482E-05 1.587E-05 6.778E-06 5.668E-06
16. 1.612E-03 5.131E-03 3.112E-04 5.904E-05 1.014E-05 7.993E-06 2.983E-06 2.103E-06
17. 5.373E-04 5.710E-04 1.037E-04 1.447E-05 4.102E-06 4.287E-06 1.439E-06 1.346E-06
21. -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00
22. -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00 -1.000E+00

Table 20 in the output file for slab24 (24.o) gives the explicit window

After 20 minutes, this calculation also passes the ten statistical checks. Here is the tally fluctuation chart.

Itally fluctuation charts
<table>
<thead>
<tr>
<th>Value</th>
<th>2.6241E-07</th>
<th>0.0169</th>
<th>0.0026</th>
<th>4.5</th>
<th>272</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>2.6166E-07</td>
<td>0.0161</td>
<td>0.0023</td>
<td>4.8</td>
<td>272</td>
</tr>
<tr>
<td>Value</td>
<td>2.5933E-07</td>
<td>0.0154</td>
<td>0.0021</td>
<td>5.1</td>
<td>275</td>
</tr>
<tr>
<td>Value</td>
<td>2.5896E-07</td>
<td>0.0148</td>
<td>0.0020</td>
<td>5.1</td>
<td>272</td>
</tr>
<tr>
<td>Value</td>
<td>2.5884E-07</td>
<td>0.0142</td>
<td>0.0018</td>
<td>5.2</td>
<td>274</td>
</tr>
<tr>
<td>Value</td>
<td>2.5900E-07</td>
<td>0.0137</td>
<td>0.0017</td>
<td>4.9</td>
<td>275</td>
</tr>
<tr>
<td>Value</td>
<td>2.5983E-07</td>
<td>0.0134</td>
<td>0.0016</td>
<td>4.8</td>
<td>276</td>
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</tbody>
</table>

One final note before leaving this topic. Russian roulette games typically increase the history variance and decrease the computer time per history. A roulette game with a survival probability of 0.1 can often save about 90% of the time that would otherwise be spent processing the particle. Changing this roulette game to have a survival probability of 0.01 can often save about 99% of the processing time. Note that the extra time saved by using 0.01 rather than 0.1 is only 9%. Meanwhile, the weight of the particle has been increased by a factor of 10 and so any scores that the particle does make will have an impact 10² times as great as with the milder roulette game. Thus, the calculation in slab23 is to be preferred over the calculation in slab24. Usually, there is little point in having weight windows that are more than 100 times the source weight. The extra time saved is very small and the possible bad effects of increased weight grow as the windows get larger.

References
slab0:  200 cm concrete slab problem
1  1 -2.03  -2  1
2  1 -2.03  -3  2
3  1 -2.03  -4  3
4  1 -2.03  -5  4
5  1 -2.03  -6  5
6  1 -2.03  -7  6
7  1 -2.03  -8  7
8  1 -2.03  -9  8
9  1 -2.03 -10  9
10  1 -2.03 -11 10
11  1 -2.03 -12 11
12  1 -2.03 -13 12
13  1 -2.03 -14 13
14  1 -2.03 -15 14
15  1 -2.03 -16 15
16  1 -2.03 -17 16
17  1 -2.03 -18 17
18  1 -2.03 -19 18
19  1 -2.03 -20 19
20  1 -2.03 -21 20
21  0  -1
22  0  21

1 py  0
2 py  10
3 py  20
4 py  30
5 py  40
6 py  50
7 py  60
8 py  70
9 py  80
10 py  90
11 py  100
12 py  110
13 py  120
14 py  130
15 py  140
16 py  150
17 py  160
18 py  170
19 py  180
20 py  190
21 py  200

mode  n
imp:n  1 19r 0 0
c the following is schaeffer portland concrete
ml
  1001.50c  -.010
  8016.50c  -.529
 11023.51c  -.016
 12000.51c  -.002
 13027.50c  -.034
 14000.51c  -.337
 19000.51c  -.013
20000.51c  -.044
26000.55c  -.014
6012.50c  -.001
sdef   x=0 y=1.e-6 z=0 cel=1 wgt=1  erg=14
c generate spatial windows
wwg   1 1 .5
f1:n   21
cut:n 1.e20 .01 0 0
crme   5
nps   100000
prdmp   j -60 j 2
print
slab1:  cm concrete slab problem, increase particle by ten times

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
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<td>1</td>
<td>-2.03</td>
<td>-2</td>
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</tr>
<tr>
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<td>-2.03</td>
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<td>2</td>
</tr>
<tr>
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</tr>
<tr>
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<td>-2.03</td>
<td>-5</td>
<td>4</td>
</tr>
<tr>
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<td>1</td>
<td>-2.03</td>
<td>-6</td>
<td>5</td>
</tr>
<tr>
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<td>-2.03</td>
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<td>-2.03</td>
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<td>8</td>
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<td>-2.03</td>
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<td>18</td>
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<td>-2.03</td>
<td>-21</td>
<td>20</td>
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</tbody>
</table>

1 py 0
2 py 10
3 py 20
4 py 30
5 py 40
6 py 50
7 py 60
8 py 70
9 py 80
10 py 90
11 py 100
12 py 110
13 py 120
14 py 130
15 py 140
16 py 150
17 py 160
18 py 170
19 py 180
20 py 190
21 py 200

mode n
imp:n 1 19r 0 0
c the following is schaeffer portland concrete
ml

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1001.50c</td>
<td>-.010</td>
<td></td>
</tr>
<tr>
<td>8016.50c</td>
<td>-.529</td>
<td></td>
</tr>
<tr>
<td>11023.51c</td>
<td>-.016</td>
<td></td>
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<tr>
<td>12000.51c</td>
<td>-.002</td>
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<td>13027.50c</td>
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<td></td>
</tr>
<tr>
<td>14000.51c</td>
<td>-.337</td>
<td></td>
</tr>
<tr>
<td>19000.51c</td>
<td>-.013</td>
<td></td>
</tr>
</tbody>
</table>
sdef x=0 y=1.e-6 z=0 cel=1 wgt=1 erg=14
c generate spatial windows
wwg 1 1 .5
f1:n 21
cut:n 1.e20 .01 0 0
cutm 50
nps 1000000
prdmp j -60 j 2
print
slab2: cm concrete slab problem, fictitious source to start

```
1 1 -2.03 -2 1
2 1 -2.03 -3 2
3 1 -2.03 -4 3
4 1 -2.03 -5 4
5 1 -2.03 -6 5
6 1 -2.03 -7 6
7 1 -2.03 -8 7
8 1 -2.03 -9 8
9 1 -2.03 -10 9
10 1 -2.03 -11 10
11 1 -2.03 -12 11
12 1 -2.03 -13 12
13 1 -2.03 -14 13
14 1 -2.03 -15 14
15 1 -2.03 -16 15
16 1 -2.03 -17 16
17 1 -2.03 -18 17
18 1 -2.03 -19 18
19 1 -2.03 -20 19
20 1 -2.03 -21 20
21 0 -1
22 0 21
```

1 py 0
2 py 10
3 py 20
4 py 30
5 py 40
6 py 50
7 py 60
8 py 70
9 py 80
10 py 90
11 py 100
12 py 110
13 py 120
14 py 130
15 py 140
16 py 150
17 py 160
18 py 170
19 py 180
20 py 190
21 py 200

mode n
imp:n 1 19r 0 0
c the following is schaeffer portland concrete
ml

```
1001.50c -.010
8016.50c -.529
11023.51c -.016
12000.51c -.002
13027.50c -.034
14000.51c -.337
19000.51c -.013
```
c sdef x=0 y=1.e-6 z=0 cel=1 wgt=1 erg=14
replace real source above with fictitious source below
sdef x=0 y=d1 z=0 wgt=1 erg=14
si1 0 200
sp1 0 1
generate spatial windows
wwg 1 1.5
Because 10**6 particles did not score, assume importance on the order of
10**(-7)
wwg 1 20 1.e-7
fl:n 21
cut:n 1.e20 .01 0 0
crne 5
nps 100000
prdmp j -60 j 2
print
slab3: use window from slab 2 and adjust source weight

1 1 -2.03 -2 1
2 1 -2.03 -3 2
3 1 -2.03 -4 3
4 1 -2.03 -5 4
5 1 -2.03 -6 5
6 1 -2.03 -7 6
7 1 -2.03 -8 7
8 1 -2.03 -9 8
9 1 -2.03 -10 9
10 1 -2.03 -11 10
11 1 -2.03 -12 11
12 1 -2.03 -13 12
13 1 -2.03 -14 13
14 1 -2.03 -15 14
15 1 -2.03 -16 15
16 1 -2.03 -17 16
17 1 -2.03 -18 17
18 1 -2.03 -19 18
19 1 -2.03 -20 19
20 1 -2.03 -21 20
21 0 -1
22 0 21

1 py 0
2 py 10
3 py 20
4 py 30
5 py 40
6 py 50
7 py 60
8 py 70
9 py 80
10 py 90
11 py 100
12 py 110
13 py 120
14 py 130
15 py 140
16 py 150
17 py 160
18 py 170
19 py 180
20 py 190
21 py 200

mode n
imp:n 1 19r 0 0
c the following is schaeffer portland concrete
ml
1001.50c -.010
8016.50c -.529
11023.51c -.016
12000.51c -.002
13027.50c -.034
14000.51c -.337
19000.51c -.013
20000.51c  -.044
26000.55c  -.014
6012.50c  -.001

c sdef x=0 y=1.e-6 z=0 cel=1 wgt=1 erg=14
c drop source weight to 0.001 because scoring particles will enter cell 8
c and should have weights somewhat commensurate with the window in cell 8
c generate spatial windows
sdef x=0 y=1.e-6 z=0 cel=1 wgt=0.001 erg=14
wwg 1 1 .5
wwp:n 5 3 5 0 0 0
wwe:n 1.0000E+02
wwn1:n
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
0.0000E+00 0.0000E+00 7.2866E-04 3.6386E-04 1.8151E-04
1.2053E-04 4.8785E-05 2.8172E-05 1.0236E-05 4.3976E-06
2.0247E-06 9.3715E-07 4.5544E-07 2.1243E-07 1.0000E-07
-1.0000E+00 -1.0000E+00

f1:n 21
cut:n 1.e20 .01 0 0
crne 5
nps 100000
prdmp j -60 j 2
print
slab4: use reduced density and true source

1 1 -1.03 -2 1
2 1 -1.03 -3 2
3 1 -1.03 -4 3
4 1 -1.03 -5 4
5 1 -1.03 -6 5
6 1 -1.03 -7 6
7 1 -1.03 -8 7
8 1 -1.03 -9 8
9 1 -1.03 -10 9
10 1 -1.03 -11 10
11 1 -1.03 -12 11
12 1 -1.03 -13 12
13 1 -1.03 -14 13
14 1 -1.03 -15 14
15 1 -1.03 -16 15
16 1 -1.03 -17 16
17 1 -1.03 -18 17
18 1 -1.03 -19 18
19 1 -1.03 -20 19
20 1 -1.03 -21 20
21 0 -1
22 0 21

1 py 0
2 py 10
3 py 20
4 py 30
5 py 40
6 py 50
7 py 60
8 py 70
9 py 80
10 py 90
11 py 100
12 py 110
13 py 120
14 py 130
15 py 140
16 py 150
17 py 160
18 py 170
19 py 180
20 py 190
21 py 200

mode n
imp:n 1 19r 0 0
c the following is schaeffer portland concrete
ml
1001.50c -.010
8016.50c -.529
11023.51c -.016
12000.51c -.002
13027.50c -.034
14000.51c -.337
19000.51c -.013
sdef x=0 y=1.e-6 z=0 cel=1 wgt=1 erg=14

generate spatial windows

wwg 1 1 .5
f1:n 21
cut:n 1.e20 .01 0 0
cutm 5
nps 100000
prdmp j -60 j 2
print
slab5: use window from slab4 with original density restored (approach 2)

1 1 -2.03 -2 1
2 1 -2.03 -3 2
3 1 -2.03 -4 3
4 1 -2.03 -5 4
5 1 -2.03 -6 5
6 1 -2.03 -7 6
7 1 -2.03 -8 7
8 1 -2.03 -9 8
9 1 -2.03 -10 9
10 1 -2.03 -11 10
11 1 -2.03 -12 11
12 1 -2.03 -13 12
13 1 -2.03 -14 13
14 1 -2.03 -15 14
15 1 -2.03 -16 15
16 1 -2.03 -17 16
17 1 -2.03 -18 17
18 1 -2.03 -19 18
19 1 -2.03 -20 19
20 1 -2.03 -21 20
21 0 -1
22 0 21

1 py 0
2 py 10
3 py 20
4 py 30
5 py 40
6 py 50
7 py 60
8 py 70
9 py 80
10 py 90
11 py 100
12 py 110
13 py 120
14 py 130
15 py 140
16 py 150
17 py 160
18 py 170
19 py 180
20 py 190
21 py 200

mode n
imp:n 1 19r 0 0
c           the following is schaeffer portland concrete
ml

1001.50c -.010
8016.50c -.529
11023.51c -.016
12000.51c -.002
13027.50c -.034
14000.51c -.337
19000.51c -.013
sdef x=0 y=1.e-6 z=0 cel=1 wgt=1 erg=14
c generate spatial windows
wwg 1 1 .5
wwp:n 5 3 5 0 0 0
wwe:n 1.0000E+02
wwn1:n 5.0000E-01 1.5584E-01 1.1426E-01 8.4810E-02 6.1680E-02
  4.4995E-02 3.2525E-02 2.3585E-02 1.6785E-02 1.1930E-02
  8.4200E-03 5.8800E-03 4.0200E-03 2.7900E-03 1.9600E-03
  1.3950E-03 1.0200E-03 7.1000E-04 4.3000E-04 2.8000E-04
    -1.0000E+00 -1.0000E+00
f1:n 21
cut:n 1.e20 .01 0 0
cHEME 5
nps 100000
prdmp j -60 j 2
print
slab6: use exponential transform to help generate window (approach 3)

1  1 -2.03 -2   1
2  1 -2.03 -3   2
3  1 -2.03 -4   3
4  1 -2.03 -5   4
5  1 -2.03 -6   5
6  1 -2.03 -7   6
7  1 -2.03 -8   7
8  1 -2.03 -9   8
9  1 -2.03 -10  9
10 1 -2.03 -11  10
11 1 -2.03 -12  11
12 1 -2.03 -13  12
13 1 -2.03 -14  13
14 1 -2.03 -15  14
15 1 -2.03 -16  15
16 1 -2.03 -17  16
17 1 -2.03 -18  17
18 1 -2.03 -19  18
19 1 -2.03 -20  19
20 1 -2.03 -21  20
21 0 -1
22 0 21

1 py  0
2 py  10
3 py  20
4 py  30
5 py  40
6 py  50
7 py  60
8 py  70
9 py  80
10 py 90
11 py 100
12 py 110
13 py 120
14 py 130
15 py 140
16 py 150
17 py 160
18 py 170
19 py 180
20 py 190
21 py 200

mode   n
imp:n  1 19r 0 0
c the following is schaeffer portland concrete
ml
1001.50c -.010
8016.50c -.529
11023.51c -.016
12000.51c -.002
13027.50c -.034
14000.51c -.337
19000.51c -.013
sdef x=0 y=1.e-6 z=0 cel=1 wgt=1 erg=14

c  generate spatial windows

wwg 1 1 .5

c  set transform parameter to 0.5 because particles make it at least halfway thru

ext:n .5 19r 0 0

f1:n 21

cut:n 1.e20 .01 0 0

c tme 5

nps 100000

prdmp j -60 j 2

print
slab7: guess windows decrease by a factor of 2 from cell to cell

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mode n
imp:n 1 19r 0 0
c the following is schaeffer portland concrete
ml

1001.50c -.010
8016.50c -.529
11023.51c -.016
12000.51c -.002
13027.50c -.034
14000.51c -.337
19000.51c -.013
sdef x=0 y=1.e-6 z=0 cel=1 wgt=1 erg=14
c generate spatial windows
wwg 1 1 .5
c guess windows decrease by factor of 2 from cell to cell
wwn1:n .5 .5m .5m .5m .5m .5m .5m .5m .5m .5m .5m .5m .5m .5m .5m .5m .5m .5m -1 -1
f1:n 21
cut:n 1.e20 .01 0 0
cctm 5
nps 60000
prdmp j -60 j 2
print
slab8:  guess windows decrease by a factor of 1.414 from cell to cell
   1  1 -2.03 -2  1
   2  1 -2.03 -3  2
   3  1 -2.03 -4  3
   4  1 -2.03 -5  4
   5  1 -2.03 -6  5
   6  1 -2.03 -7  6
   7  1 -2.03 -8  7
   8  1 -2.03 -9  8
   9  1 -2.03 -10  9
  10  1 -2.03 -11 10
  11  1 -2.03 -12 11
  12  1 -2.03 -13 12
  13  1 -2.03 -14 13
  14  1 -2.03 -15 14
  15  1 -2.03 -16 15
  16  1 -2.03 -17 16
  17  1 -2.03 -18 17
  18  1 -2.03 -19 18
  19  1 -2.03 -20 19
  20  1 -2.03 -21 20
  21  0 -1
  22  0 21

   1 py  0
   2 py  10
   3 py  20
   4 py  30
   5 py  40
   6 py  50
   7 py  60
   8 py  70
   9 py  80
  10 py  90
  11 py 100
  12 py 110
  13 py 120
  14 py 130
  15 py 140
  16 py 150
  17 py 160
  18 py 170
  19 py 180
  20 py 190
  21 py 200

mode   n
imp:n  1 19r 0 0
  c        the following is schaeffer portland concrete
   ml
     1001.50c -.010
     8016.50c -.529
    11023.51c -.016
    12000.51c -.002
    13027.50c -.034
    14000.51c -.337
    19000.51c -.013
20000.51c  -.044
26000.55c  -.014
6012.50c  -.001
sdef   x=0 y=1.e-6 z=0 cel=1 wgt=1 erg=14
c  generate spatial windows
wwg   1 1 .5
c  guess windows decrease by factor of 2 from cell to cell
wwn1:n .5 .707m .707m .707m .707m .707m .707m .707m .707m .707m .707m .707m
    .707m .707m .707m .707m .707m .707m .707m .707m .707m .707m .707m .707m
    -1 -1
f1:n  21
cut:n 1.e20 .01 0 0
c tme  5
nps  60000
prdmp  j -60 j 2
print
slab9:  guess windows decrease by a factor of 3 from cell to cell

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1 py 0
2 py 10
3 py 20
4 py 30
5 py 40
6 py 50
7 py 60
8 py 70
9 py 80
10 py 90
11 py 100
12 py 110
13 py 120
14 py 130
15 py 140
16 py 150
17 py 160
18 py 170
19 py 180
20 py 190
21 py 200

mode n
imp:n 1 19r 0 0
c       the following is schaeffer portland concrete
ml
1001.50c -.010
8016.50c -.529
11023.51c -.016
12000.51c -.002
13027.50c -.034
14000.51c -.337
19000.51c -.013
sdef x=0 y=1.e-6 z=0 cel=1 wgt=1 erg=14
c generate spatial windows
wwg 1 1 .5
c guess windows decrease by factor of 2 from cell to cell
wwn1:n .5 .333m .333m .333m .333m .333m .333m .333m .333m .333m
   .333m .333m .333m .333m .333m .333m .333m .333m .333m
   .333m .333m .333m .333m .333m .333m .333m .333m .333m
   -1 -1
f1:n 21
cut:n 1.e20 .01 0 0
cume 50
nps 250
prdmp j -60 j 2
print
slab10: generate windows using intermediate tally

1 1 -2.03 -2 1
2 1 -2.03 -3 2
3 1 -2.03 -4 3
4 1 -2.03 -5 4
5 1 -2.03 -6 5
6 1 -2.03 -7 6
7 1 -2.03 -8 7
8 1 -2.03 -9 8
9 1 -2.03 -10 9
10 1 -2.03 -11 10
11 1 -2.03 -12 11
12 1 -2.03 -13 12
13 1 -2.03 -14 13
14 1 -2.03 -15 14
15 1 -2.03 -16 15
16 1 -2.03 -17 16
17 1 -2.03 -18 17
18 1 -2.03 -19 18
19 1 -2.03 -20 19
20 1 -2.03 -21 20
21 0 -1
22 0 21

1 py 0
2 py 10
3 py 20
4 py 30
5 py 40
6 py 50
7 py 60
8 py 70
9 py 80
10 py 90
11 py 100
12 py 110
13 py 120
14 py 130
15 py 140
16 py 150
17 py 160
18 py 170
19 py 180
20 py 190
21 py 200

mode n
c set cell importance past intermediate surface to zero
imp:n 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0

c the following is schaeffer portland concrete
ml
1001.50c -.010
8016.50c -.529
11023.51c -.016
12000.51c -.002
13027.50c -.034
14000.51c -.337
sdef x=0 y=1.e-6 z=0 cel=1 wgt=1 erg=14
c generate spatial windows
c wwg 1  1 .5

c use intermediate tally f11:n for window generator
wwg 11 1 .5
f1:n 21
f11:n 11
cut:n 1.e20 .01 0 0
cctme 5
nps 100000
prdmp j -60 j 2
print
slab11: use windows from slab10 run to generate final windows

1  1  -2.03  -2  1
2  1  -2.03  -3  2
3  1  -2.03  -4  3
4  1  -2.03  -5  4
5  1  -2.03  -6  5
6  1  -2.03  -7  6
7  1  -2.03  -8  7
8  1  -2.03  -9  8
9  1  -2.03  -10 9
10  1  -2.03  -11 10
11  1  -2.03  -12 11
12  1  -2.03  -13 12
13  1  -2.03  -14 13
14  1  -2.03  -15 14
15  1  -2.03  -16 15
16  1  -2.03  -17 16
17  1  -2.03  -18 17
18  1  -2.03  -19 18
19  1  -2.03  -20 19
20  1  -2.03  -21 20
21  0  -1
22  0  21

1 py  0
2 py  10
3 py  20
4 py  30
5 py  40
6 py  50
7 py  60
8 py  70
9 py  80
10 py  90
11 py  100
12 py  110
13 py  120
14 py  130
15 py  140
16 py  150
17 py  160
18 py  170
19 py  180
20 py  190
21 py  200

mode   n
imp:n  1  19r  0  0
c  the following is schaeffer portland concrete
ml
1001.50c  -.010
8016.50c  -.529
11023.51c  -.016
12000.51c  -.002
13027.50c  -.034
14000.51c  -.337
19000.51c  -.013
20000.51c -.044
26000.55c -.014
6012.50c -.001
sdef x=0 y=1.e-6 z=0 cel=1 wgt=1 erg=14
c generate spatial windows
wwg 1 1 .5
wwp:n 5 3 5 0 0 0
wwe:n 1.0000E+02
wwn1:n 5.0000E-01 1.1528E-01 6.2555E-02 3.2895E-02 1.7015E-02
  8.4250E-03 4.2100E-03 2.0900E-03 1.0050E-03 5.0000E-04
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  -1.0000E+00 -1.0000E+00
f1:n 21
cut:n 1.e20 .01 0 0
cutme 5
nps 50000
prdmp j -60 j 2
print
slab12: generate windows using intermediate tally (imp=1 in cell 11)

1  1 -2.03 -2   1
2  1 -2.03 -3   2
3  1 -2.03 -4   3
4  1 -2.03 -5   4
5  1 -2.03 -6   5
6  1 -2.03 -7   6
7  1 -2.03 -8   7
8  1 -2.03 -9   8
9  1 -2.03 -10  9
10 1 -2.03 -11 10
11 1 -2.03 -12 11
12 1 -2.03 -13 12
13 1 -2.03 -14 13
14 1 -2.03 -15 14
15 1 -2.03 -16 15
16 1 -2.03 -17 16
17 1 -2.03 -18 17
18 1 -2.03 -19 18
19 1 -2.03 -20 19
20 1 -2.03 -21 20
21 0 -1
22 0 21

1 py 0
2 py 10
3 py 20
4 py 30
5 py 40
6 py 50
7 py 60
8 py 70
9 py 80
10 py 90
11 py 100
12 py 110
13 py 120
14 py 130
15 py 140
16 py 150
17 py 160
18 py 170
19 py 180
20 py 190
21 py 200

mode n

set cell importance past intermediate surface to 1
imp:n 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0

the following is schaeffer portland concrete

ml
1001.50c -.010
8016.50c -.529
11023.51c -.016
12000.51c -.002
13027.50c -.034
14000.51c -.337
sdef  x=0  y=1.e-6  z=0  cel=1  wgt=1  erg=14

C  generate spatial windows
C  wwg   1 1 .5
C  use intermediate tally f11:n for window generator
wwg   11 1 .5
f1:n  21
f11:n  11
cut:n 1.e20 .01 0 0
c tme   5
nps   100000
prdmp  j -60 j 2
print