60 minutes.
Closed book. One page of hand-written notes, front and back.
SimLib code. Clean and Patch example.
For all true/false questions, three points if correct;
if you wish, write an explanation of your thinking.

Score ___________________________
1. Event graphs

(a) T  F Event graphs can be used to show the structure of a next-event simulation model.

(b) T  F There is one event-graph node for each type of event.

(c) T  F An event graph cannot have a cycle. (That is, no path of arcs from a node can lead back to the same node.)

2. SimLib

(a) T  F The average list size is a time-based statistic.

(b) (four points) Explain how possibly the average list size is zero, but the maximum list size is 1.

(c) (four points) To insert a record into the middle (that is, not at an end) of a list, how many double-linked list pointers are updated? Which ones? (You do not need to use SimLib’s variable names.)

(d) T  F To create a next-event simulation experiment using SimLib, the user must write the main program and each event’s logic.

(e) T  F Future events are stored in a list, sorted by the first attribute, which is the time that the event is scheduled to occur.
3. Suppose that we simulate two systems, $A$ and $B$, and obtain point estimators $\hat{\theta}_A$ and $\hat{\theta}_B$, each based on simulating 1000 hours. Consider modifying the experiment by using common random numbers to induce correlation between $\hat{\theta}_A$ and $\hat{\theta}_B$.

(a) T  F Ideally, the induced correlation is close to one.

(b) T  F Ideally, common random numbers reduces both $V(\hat{\theta}_A)$ and $V(\hat{\theta}_B)$.

(c) T  F The purpose of using multiple random number streams is to ensure independence between $\hat{\theta}_A$ and $\hat{\theta}_B$. Therefore, a single stream of random numbers is best for implementing common random numbers.

4. Suppose that we simulate a system to estimate $\theta$, an unknown performance measure. Consider the sequence of point estimators, with $\hat{\theta}_n$ based on output data $Y_1, Y_2, \ldots, Y_n$. In this class, we assume that both point estimator bias and point estimator variance are $O(1/n)$.

(a) T  F $\text{MSE}(\hat{\theta}_n, \theta) = O(1/n^2)$ since one component of MSE is the squared bias.

(b) T  F If the point estimator $\hat{\theta}_n$ is biased, then the micro/macro standard-error estimator of $\text{ste}(\hat{\theta}_n)$ automatically ignores the bias.

(c) T  F $\text{ste}(\hat{\theta}_n) = O(1/\sqrt{n})$.

(d) T  F Increasing the sample size $n$ by a factor of ten yields two additional meaningful point-estimator digits.

5.
7. Recall: Stochastic simulation experiments, as studied in this class, are used to analyze a given probability model. In particular, a performance measure $\theta$ is estimated by generating random variates $X$ from a known input model, transforming them to output data $Y$ using a known logic model, and from $Y$ computing a point estimator $\hat{\theta}$. The standard error of the point estimator depends upon how long the model is simulated.

Consider the output report, from the clean-and-patch model, on Page 5. The standard errors are estimated using $k = 20$ independent replications of $m = 1,000$ minutes each. No initial data were deleted.

(a) If antithetic variates were used (successfully) to reduce variance in the clean-and-patch example, which column(s) (of 1, 2, 3, and 4) would have smaller expected values?

1 2 3 4

(b) yes  no  Under "Number at the cleaner", the third column says that "macro stdev" is 0.9920. Is this a "time-based" statistic?

(c) T  F  If the experiment were changed only by setting the number of replications to $k = 5$, then the "macro stdev" values would (approximately) increase by a factor of two.

(d) T  F  If the experiment is changed to run $k = 10$ replications of $m = 2,000$ minutes each, so that the total time simulated remains at 20,000 minutes, the standard errors would all remain about the same.
8. Let $Y_{ij}$ denote the time in the system for the $i$th job during macro-replication $j$. Consider the second-to-last line the clean-and-patch output report on Page 5. (This line contains the values 4.7573, 0.3006, 3.7580, and 0.34882.)

(a) (Five points) Write the formula to compute the "macro average" (4.7573).

(b) (Five points) Write the formula to compute the standard deviation "macro stdev" (3.7580).

(c) (Five points) Write the formula to compute the "standard error" (0.3488) for the "macro stdev".

Clean-and-patch model using simlib
Purdue University, IE581, HW5
Schmeiser, April 2004

Model parameters...
- Mean interarrival time = 1.000 minutes
- Mean cleaning time = 0.700 minutes
- Mean patching time = 0.800 minutes
- Max jobs waiting to clean = 3 jobs
- Corr(clean time, patch time) = 0.000

Experiment parameters...
- Simulation end time = 1000.000 minutes
- Number of macro reps = 20 replications
- Initial Seed, Stream 1 = 1973272912
- Initial Seed, Stream 2 = 281629770
- Initial Seed, Stream 3 = 20006270

Arrival overflows:
<table>
<thead>
<tr>
<th>macro</th>
<th>standard</th>
<th>macro</th>
<th>standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0267</td>
<td>0.0018</td>
<td>0.1596</td>
<td>0.0052</td>
</tr>
</tbody>
</table>

Time at the cleaning operation, in minutes:
<table>
<thead>
<tr>
<th>macro</th>
<th>standard</th>
<th>macro</th>
<th>standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6909</td>
<td>0.0071</td>
<td>0.6801</td>
<td>0.0111</td>
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</tbody>
</table>

Time at the patching operation, in minutes:
<table>
<thead>
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<th>macro</th>
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<th>macro</th>
<th>standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0661</td>
<td>0.3011</td>
<td>3.7716</td>
<td>0.3505</td>
</tr>
</tbody>
</table>

Time in the system, in minutes:
<table>
<thead>
<tr>
<th>macro</th>
<th>standard</th>
<th>macro</th>
<th>standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.7573</td>
<td>0.3006</td>
<td>3.7580</td>
<td>0.3488</td>
</tr>
</tbody>
</table>

Number at the cleaner:
<table>
<thead>
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<th>standard</th>
<th>macro</th>
<th>standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6778</td>
<td>0.0075</td>
<td>0.9920</td>
<td>0.0081</td>
</tr>
</tbody>
</table>

Number at the patcher:
<table>
<thead>
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<th>standard</th>
<th>macro</th>
<th>standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0119</td>
<td>0.3222</td>
<td>4.2281</td>
<td>0.3829</td>
</tr>
</tbody>
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