National Exams December 2008

98-Ind-A6, Systems Simulation

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a closed book exam. Candidates are permitted to use one of the two permitted calculators (Sharp or Casio models).

3. Candidates are permitted to have an aid sheet consisting of one 8.5" x 11.0" sheet of paper. Writing is permitted on both sides of the paper.

4. This exam consists of three sections (A, B, and C). Within each section, candidates will be given a choice of questions to answer. Please read the instructions for each section carefully. A breakdown of questions and marks is as follows:

Section A:	Do 2 of 3 Questions.	Total marks: 10
Section B:	Do 3 of 6 Questions.	Total marks: 15
Section C:	Do 2 of 3 Questions	Total marks: 10
Exam:	7 Questions.	Total marks: 35

4. The value of each question is listed in the exam. Remember to check the instructions for each section. DO NOT ATTEMPT TO DO ALL QUESTIONS.

5. Statistical tables are provided.

6. Good luck.

Introduction

Edward Shack is conducting a simulation of a serial production line for Lowliner Foods in St John's, NL. The line processes fresh fish into frozen fish fingers. The line operates on a three shift basis, 7.5 hours per shift, with a half-hour between shifts. Machines are idled between the shifts.

The questions below all deal with the methodology Mr. Shack should employ as he proceeds with his project.

Part A: Preliminaries

Complete **two** of the following **three** sets of questions. Do NOT attempt all questions. Please note that all questions have the same value.

1. Mr. Shack is very interested in determining the effect of unscheduled downtime of the flash freezing unit on shift output. Eddie has implemented a data collection procedure that will track the status of the machine over a fourteen day period. Ten instances of downtime are recorded during this data collection period. The time between failures is given below.

Downtime Instance	MTBF (Days)
1	2.33
2	1.58
3	4.65
4	9.18
5	2.61
6	1.24
7	0.36
8	2.41
9	0.45
10	1.37

Hypothesize a distribution for this dataset and identify the best fit parameter(s) for your hypothesized distribution. In your answer describe why you feel this selected distribution is appropriate.

5 Marks

2. After an extensive data collection process, Eddie has determined that the mean time to repair (MTTR) for the flash freezer follows a lognormal distribution. Mr. Shack's hypothesis is based on a data sample of 30 instances with a sample mean of 1.2 hours and a sample deviation of 0.35 hours. Assume that the simulation package that Mr. Shack uses produces the following random numbers: 0.23, 0.54, 0.81, 0.03, 0.91, 0.42. Determine the simulated length of time to repair the flash freezer in Mr. Shack's model for the first two instances of downtime.

5 Marks

3. After reviewing the random number stream from his simulation model, Mr. Shack is concerned about the suitability of the random number generator in his simulation environment. He decides to test his own linear congruential generator with parameters $x_0 = 15$, $m = 64$, $c = 23$, and $a = 5$. Generate the next two random numbers in this series and comment on the suitability of Eddie's generator. Indicate whether you think Eddie's generator is a good replacement for the simulation environment and *briefly* comment on two tests that Eddie could use to determine the suitability of an LCG.

5 Marks

Part B: Simulation Control Issues

Complete **three** of the following **six** sets of questions. Do NOT attempt all questions. Please note that all questions have the same value.

1. Define the terms "transient state" and "steady state" as they apply to a simulation model. Assume that Eddie has completed three replications of his model over a period of 180 minutes and has collected statistics on job time in system every 20 minutes. The results appear below:

Simulated Time	Replication	Time in Sys
20	1	1.76
20	2	2.31
20	3	1.58
40	1	3.87
40	2	4.31
40	3	2.16
60	1	3.94
60	2	5.99
60	3	7.40
80	1	3.76
80	2	7.04
80	3	2.82
100	1	3.77
100	2	7.73
100	3	2.91
120	1	4.32
120	2	2.94
120	3	3.11
140	1	5.38
140	2	7.70
140	3	3.27
160	1	5.67
160	2	7.52
160	3	4.06
180	1	5.40
180	2	5.20
180	3	3.20

Use Welch's technique with a window size (w=2) to estimate the transient condition.

5 Marks

2. Under what types of modelling conditions does it makes sense to identify and delete the transient model response? Under what modelling conditions does it not make sense to delete the transient? Comment on whether or not it is appropriate to delete the transient in Eddie's case.

5 Marks

3. Assume that Eddie has dealt with the transient condition appropriately. He now wishes to determine an appropriate run length and number of replications for his simulation model, under the assumption that he will execute the model under the batch means methodology. Define the terms "batch means" and "replication/deletion" and indicate how they apply to executing a simulation model. What are the advantages and disadvantages of each method?

5 Marks

4. Eddie, being a well trained industrial engineer, is aware of the issue of autocorrelation in simulation results. Describe what "autocorrelation of results" is and why it is an issue when conducting a simulation project. *Briefly* outline a procedure for estimating an appropriate run length when operating under the assumption of batch means.

5 Marks

5. Assume that Eddie has set a replication length of 1 month. Results from the 1st twelve replications of his model are given below. Determine if this replication length (1 month) is sufficiently long enough to eliminate autocorrelation within the results. If not, what should Mr. Shack do?

Rep	Time in System (Minutes)
1	5.16
2	3.06
3	2.97
4	4.05
5	2.62
6	2.62
7	2.42
8	2.33
9	2.58
10	2.46
11	2.42
12	2.72

5 Marks

6. Assuming that the replication length in (5) is sufficient to eliminate autocorrelation, determine the number of runs necessary so the resulting confidence interval for time in system is no more that +/- 0.20 of a minute 19 times out of 20.

5 Marks

Part C: Output Analysis

Complete **two** of the following **three** sets of questions. Do NOT attempt all questions. Please note that all questions have the same value.

1. Assume that Eddie has completed 10 runs of his simulation and he wishes to compare this to data he has from the function of the current processing line (i.e. the real system). Using an alpha value of 0.05, determine if Eddie has sufficient reason to believe that the two systems are the same or not. State any assumptions you make when answering this question. For the purpose of answering this question, you may assume that 10 replications are sufficient to provide a desired level of accuracy.

Month	Simulation Result	Actual Data
1	5.66	2.18
2	2.82	2.37
3	2.65	1.94
4	4.50	2.18
5	3.05	2.04
6	4.28	2.49
7	2.73	2.08
8	2.35	1.70
9	2.74	1.85
10	2.53	1.88

5 Marks

2. Eddie wishes to evaluate more fully the effect of a preventative maintenance on fish finger throughput. He sets up a series of production runs to evaluate the effect of different PM cycles on throughput. Eddie decides to implement antithetic random variates (ARVs) within the production runs. Define the concept of "antithetic random variates" as applied to a simulation model and identify, using an example, how antithetic random variates work. Is it possible for ARVs to "backfire" and if so, how? What should Eddie do to ensure that his antithetic variates technique does not backfire? Finally, comment on whether other techniques, methods, or approaches, could be used to gain the same benefit as ARVs.

5 Marks

3. An important aspect of optimizing the fish finger production line is developing an inventory policy for raw materials used in the production process (oil, breadcrumbs, boxes, etc). Lowliner foods is considering three new policies inventories (EOQ, S-s, and S-R) and has Eddie to modify his simulation model to evaluate them. Eddie executes ten replications of his model under each inventory scenario and records the average daily inventory cost (in $Can). Results from the three models appear below:

	Policy		
Run	EOQ	S-s	S-R
1	107.5	102.7	110.6
2	111.9	92.7	117.4
3	102.7	99.5	114.5
4	112.4	93.1	113.6
5	115.2	89.3	111.8
6	114.6	96.2	113.1
7	112.6	89.7	112.0
8	105.7	93.8	107.4
9	108.5	101.4	113.4
10	110.1	86.0	111.3
Mean	110.1	94.4	112.5
Variance	16.0	30.1	6.8

Assume that Eddie wishes to identify the best possible policy (where lower cost is considered better). Moreover, assume that Lowerliner wants to be 90% certain (i.e. $\alpha = 0.10$) that the selected policy is the best. Using this information, can any of the three policies be identified as "best"?

5 Marks

Critical points $\chi^2_{\nu,\gamma}$ for the chi-square distributions with ν df

$\gamma = P\left(Y_\nu \le \chi^2_{\nu,\gamma}\right)$ where Y_ν has a chi-square distribution with ν df.

ν	γ = 0.250	0.500	0.750	0.900	0.950	0.975	0.990
1	0.102	0.455	1.323	2.706	3.841	5.024	6.635
2	0.575	1.386	2.773	4.605	5.991	7.378	9.210
3	1.213	2.366	4.108	6.251	7.815	9.348	11.345
4	1.923	3.357	5.385	7.779	9.488	11.143	13.277
5	2.675	4.351	6.626	9.236	11.070	12.832	15.086
6	3.455	5.348	7.841	10.645	12.592	14.449	16.812
7	4.255	6.346	9.037	12.017	14.067	16.013	18.475
8	5.071	7.344	10.219	13.362	15.507	17.535	20.090
9	5.899	8.343	11.389	14.684	16.919	19.023	21.666
10	6.737	9.342	12.549	15.987	18.307	20.483	23.209
11	7.584	10.341	13.701	17.275	19.675	21.920	24.725
12	8.438	11.340	14.845	18.549	21.026	23.337	26.217
13	9.299	12.340	15.984	19.812	22.362	24.736	27.688
14	10.165	13.339	17.117	21.064	23.685	26.119	29.141
15	11.037	14.339	18.245	22.307	24.996	27.488	30.578
16	11.912	15.338	19.369	23.542	26.296	28.845	32.000
17	12.792	16.338	20.489	24.769	27.587	30.191	33.409
18	13.675	17.338	21.605	25.989	28.869	31.526	34.805
19	14.562	18.338	22.718	27.204	30.144	32.852	36.191
20	15.452	19.337	23.828	28.412	31.410	34.170	37.566
21	16.344	20.337	24.935	29.615	32.671	35.479	38.932
22	17.240	21.337	26.039	30.813	33.924	36.781	40.289
23	18.137	22.337	27.141	32.007	35.172	38.076	41.638
24	19.037	23.337	28.241	33.196	36.415	39.364	42.980
25	19.939	24.337	29.339	34.382	37.652	40.646	44.314
26	20.843	25.336	30.435	35.563	38.885	41.923	45.642
27	21.749	26.336	31.528	36.741	40.113	43.195	46.963
28	22.657	27.336	32.620	37.916	41.337	44.461	48.278
29	23.567	28.336	33.711	39.087	42.557	45.722	49.588
30	24.478	29.336	34.800	40.256	43.773	46.979	50.892
40	33.660	39.335	45.616	51.805	55.758	59.342	63.691
50	42.942	49.335	56.334	63.167	67.505	71.420	76.154
75	66.417	74.334	82.858	91.061	96.217	100.839	106.393
100	90.133	99.334	109.141	118.498	124.342	129.561	135.807

Critical points $t_{\nu,\gamma}$ for the *t* distribution with with ν df.

$\gamma = P\left(T_\nu \le t_{\nu,\gamma}\right)$, where T_ν is a random variable having the t distribution with ν df.

ν	γ: 0.6000	0.7000	0.8000	0.9333	0.9500	0.9600	0.9667	0.9750	0.9800	0.9875	0.9000	0.9950
1	0.325	0.727	1.376	4.702	6.314	7.916	9.524	12.706	15.894	25.452	3.078	63.656
2	0.289	0.617	1.061	2.456	2.920	3.320	3.679	4.303	4.849	6.205	1.886	9.925
3	0.277	0.584	0.978	2.045	2.353	2.605	2.823	3.182	3.482	4.177	1.638	5.841
4	0.271	0.569	0.941	1.879	2.132	2.333	2.502	2.776	2.999	3.495	1.533	4.604
5	0.267	0.559	0.920	1.790	2.015	2.191	2.337	2.571	2.757	3.163	1.476	4.032
6	0.265	0.553	0.906	1.735	1.943	2.104	2.237	2.447	2.612	2.969	1.440	3.707
7	0.263	0.549	0.896	1.698	1.895	2.046	2.170	2.365	2.517	2.841	1.415	3.499
8	0.262	0.546	0.889	1.670	1.860	2.004	2.122	2.306	2.449	2.752	1.397	3.355
9	0.261	0.543	0.883	1.650	1.833	1.973	2.086	2.262	2.398	2.685	1.383	3.250
10	0.260	0.542	0.879	1.634	1.812	1.948	2.058	2.228	2.359	2.634	1.372	3.169
11	0.260	0.540	0.876	1.621	1.796	1.928	2.036	2.201	2.328	2.593	1.363	3.106
12	0.259	0.539	0.873	1.610	1.782	1.912	2.017	2.179	2.303	2.560	1.356	3.055
13	0.259	0.538	0.870	1.601	1.771	1.899	2.002	2.160	2.282	2.533	1.350	3.012
14	0.258	0.537	0.868	1.593	1.761	1.887	1.989	2.145	2.264	2.510	1.345	2.977
15	0.258	0.536	0.866	1.587	1.753	1.878	1.978	2.131	2.249	2.490	1.341	2.947
16	0.258	0.535	0.865	1.581	1.746	1.869	1.968	2.120	2.235	2.473	1.337	2.921
17	0.257	0.534	0.863	1.576	1.740	1.862	1.960	2.110	2.224	2.458	1.333	2.898
18	0.257	0.534	0.862	1.572	1.734	1.855	1.953	2.101	2.214	2.445	1.330	2.878
19	0.257	0.533	0.861	1.568	1.729	1.850	1.946	2.093	2.205	2.433	1.328	2.861
20	0.257	0.533	0.860	1.564	1.725	1.844	1.940	2.086	2.197	2.423	1.325	2.845
21	0.257	0.532	0.859	1.561	1.721	1.840	1.935	2.080	2.189	2.414	1.323	2.831
22	0.256	0.532	0.858	1.558	1.717	1.835	1.930	2.074	2.183	2.405	1.321	2.819
23	0.256	0.532	0.858	1.556	1.714	1.832	1.926	2.069	2.177	2.398	1.319	2.807
24	0.256	0.531	0.857	1.553	1.711	1.828	1.922	2.064	2.172	2.391	1.318	2.797
25	0.256	0.531	0.856	1.551	1.708	1.825	1.918	2.060	2.167	2.385	1.316	2.787
26	0.256	0.531	0.856	1.549	1.706	1.822	1.915	2.056	2.162	2.379	1.315	2.779
27	0.256	0.531	0.855	1.547	1.703	1.819	1.912	2.052	2.158	2.373	1.314	2.771
28	0.256	0.530	0.855	1.546	1.701	1.817	1.909	2.048	2.154	2.368	1.313	2.763
29	0.256	0.530	0.854	1.544	1.699	1.814	1.906	2.045	2.150	2.364	1.311	2.756
30	0.256	0.530	0.854	1.543	1.697	1.812	1.904	2.042	2.147	2.360	1.310	2.750
40	0.255	0.529	0.851	1.532	1.684	1.796	1.886	2.021	2.123	2.329	1.303	2.704
50	0.255	0.528	0.849	1.526	1.676	1.787	1.875	2.009	2.109	2.311	1.299	2.678
75	0.254	0.527	0.846	1.517	1.665	1.775	1.861	1.992	2.090	2.287	1.293	2.643
100	0.254	0.526	0.845	1.513	1.660	1.769	1.855	1.984	2.081	2.276	1.290	2.626
1000	0.253	0.525	0.842	1.502	1.646	1.752	1.836	1.962	2.056	2.245	1.282	2.581

Area under the N(0,1) Curve

Z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998
3.5	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998