009

THE OPEN UNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY
POSTGRADUATE DIPLOMA IN TECHNOLOGY IN INDUSTRIAL ENGINEERING
FINAL EXAMINATION – 2005/2006
MEX7211/MEP1201 – OPERATIONS RESEARCH

DATE : 06 APRIL 2006 *(Thursday)*
TIME : 0930-1230 HRS
DURATION : *THREE (03) HOURS*

INSTRUCTIONS:

(a) Answer any five (05) questions only. All questions carry equal marks.
(b) Normal distribution and P_0 values for multiple-server model tables are attached to the question paper.

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1. S & T Publishing Company Limited is planning to introduce a new book in Operations Management. The company's marketing department estimates that the prior distribution for likely sales is normal with a mean of 10,000 books. In addition, it has determined that there is a probability of one half, that the likely sales would be fall between 8,000 and 12,000 books.

   The textbook will sell for $10 per copy but the publishing company pays the author 10% of revenue in royalties. The fixed costs for the book are calculated to be $25,000. Using current printing facilities, the variable production costs are $4 per book. However, the S & T publishing Company has the option of hiring a special machine for $14,000, which will reduce the variable production costs to $2.50 per book.

   a) Show that the standard deviation of likely sales is approximately $\sigma = 3{,}000$.
   b) Using $\sigma = 3{,}000$, determine the probability that the company will at least break even if
      i) existing printing facilities are used,
      ii) the special machine is hired.
   c) By comparing expected profits, decide whether or not the publishing company should hire the special machine.
   d) By using the normal distribution it can be shown that the following probability distribution may be applied to book sales:

Sales ('000)	0-5	5-8	8-10	10-12	12-15	15-20
Probability	0.05	0.20	0.25	0.25	0.20	0.05

   By assuming that the actual sales can only take the midpoints of these classes, determine the expected value of perfect information.

(20 marks)

2. A chemical manufacturer is developing three fertilizer compounds for the agricultural industry. The product codes for the three products are X1, X2 and X3 and the relevant information is summarised below.

Chemical constituents: percentage make-up per kg.

	Nitrate	Phosphate	Potash	Filler
X1	10	10	20	60
X2	10	20	10	60
X3	20	10	10	60

Input prices per kg.

Nitrate	Rs. 150.00
Phosphate	Rs. 60.00
Potash	Rs. 120.00
Filler	Rs. 10.00

Maximum available input in kgs. per month

Nitrate	1,200
Phosphate	2,000
Potash	2,200
Filler	No limit

The fertilizers will be sold in bulk and mangers have proposed the following prices per kg:

X1	Rs. 83.00
X2	Rs. 81.00
X3	Rs. 81.00

The manufacturing costs of each type of fertilizer, excluding materials, are Rs. 11.00 per kg.

a) Formulate the above data into a linear programming model so that the company may maximise its profit.

b) Construct the initial simplex tableau and state what is meant by "slack variables". (Define X4, X5 and X6 as the slack variables for X1, X2 and X3 respectively)

c) Indicate, with explanations, which will be the "entering variable" and "leaving variable" in the first iteration. (*You are not required to solve the model*)

d) Interpret the final matrix of the Simplex solution given in table Q2.

Basic Variable	X1	X2	X3	X4	X5	X6	Solution
X1	1	0	3	20	-10	0	4,000
X2	0	1	-1	-10	10	0	8,000
X6	0	0	-0.4	-3	1	1	600
Z	0	0	22	170	40	0	284,000

Table Q2

e) Use the final matrix above to investigate:
   (i) the effect of an increase in nitrate of 100 kg. per month,
   (ii) the effect of a minimum contract from an influential customer for 200 kg of X3 per month to be supplied.

(20 marks)

3. An oil company has three refineries, namely A, B and C that produce oil, which is then, transported to four distribution centers, namely, W, X, Y and Z. The total quantity produced by each refinery and the total requirement of each distribution centre and the associated transportation cost per 1000 barrels are given in table Q3.

Refinery	Distribution Centre and associated transportation cost in rupees				Supply (Barrels)
	W	X	Y	Z	
A	80	70	50	60	16,000
B	60	90	40	80	20,000
C	50	50	95	90	14,000
Demand (Barrels)	10,000	10,000	12,000	18,000	50,000

Table Q3

a) Suggest the transportation schedule that minimizes the total transportation cost.

b) If the company wants that at least 5,000 barrels of oil be transported from refinery C to distribution center W, will the optimum transportation schedule change? If so, what will be the new schedule?

(20 marks)

4. E-Education is a new start-up that develops and markets MBA courses offered through distance learning. The company is currently located in Bambalapitiya and employs 150 people. Due to rapid growth the company needs an additional office space. The company has several options to cope up with the rapid growth. The first option is leasing additional space at its current location in Bambalapitiya for the next two years, but after that it must be shifted to a new building. Another option that the company is considering is moving the entire operation to a Nugegoda town immediately. The third option is for the company to lease a new building in Bambalapitiya immediately. If the company chooses the first option and leases new

space at its current location, then at the end of two years either it has to lease a new building in Bambalapitiya or move to Nugegoda town.

The following are some additional facts about the alternatives and current situation:

- The company has a 75 percent chance of surviving the next two years.
- Leasing the new space for two years at the current location in Bambalapitiya would cost Rs. 750,000.00 per year.
- Moving the entire operation to a Nugegoda town would cost Rs. 1 million. Leasing space would cost only Rs. 500,000.00 per year.
- Moving to a new building in Bambalapitiya would cost Rs. 200,000.00 and leasing a new building's space would cost Rs. 650,000.00 per year.
- The company can cancel the lease at any time.
- The company will build its own building in five years, if it survives.
- Assume all other costs and revenues are the same no matter where the company is located.

As a management consultant what do advice to E-Education? Clearly explain your decision with reasons.

(20 marks)

5. a) Explain the meaning of the terms "deterministic" and "stochastic" when applied to the planning and control of inventory.

b) SPB Ltd. is a small engineering company, which is open for 50 weeks each year and specializes in assembly of a component used in the motor industry. This component, for which there is an annual demand of 20,000 components, is assembled form two types of bought-in part, A and B. The number of parts used in each component and their associated costs and lead times are given in the following table.

Part	Number per component	Unit Cost ($)	Lead times (weeks)
A	3	5	1
B	8	1	3

Presently SPB retain fairly high stock levels to ensure continuous production, but liquidity difficulties seem to demand a reduction in stock level. SPB's current stock policy for these parts is outlined in the table below.

Part	Re-order quantity	Re-order level
A	5,000	5,000
B	20,000	15,000

It is estimated that each time an order is placed for any part there is a cost of $100 per order plus $0.02 per item ordered. Also it is estimated that the storage costs of parts in stock is 20% per annum of the value of the parts in addition to a fixed annual holding cost of $5,000.

(i) Briefly describe the basic principles of stock control and explain why a good stock control policy is important to the management of SPB Ltd.

(ii) Determine the total annual cost incurred by SPB Ltd for production of these components, using the current stock control policy.

(iii) Assuming, given lead times are constant,

- o show that the optimum re-order quantities for part A and B are 3.464 and 12,649 respectively.
- o find the optimum re-order levels for each part.

Determine the annual saving, both in values and percentage terms that can be obtained by implementing this optimum stock control policy.

(20 marks)

6. (a) Define the four basic waiting (Queue) structures and quote an example to explain the definition of each structure.

(b) A bank has two tellers working on savings accounts. The first teller handles withdrawals only, while the second handles deposits only. It has been found that service time for the both deposits and withdrawals is exponentially distributed with a mean of 3 minutes per customer. Depositors arrive in a Poisson fashion throughout the day with a mean arrival rate of 16per hour, while Depositors arrive in a Poisson fashion throughout the day with a mean arrival rate of 14 per hour.

(i) What would be the effect on the average waiting time for depositors and withdrawals if each teller could handle both withdrawals and deposits?

(ii) What would be the effect on the average waiting time by increasing the service time to 3.5 minutes?

(20 marks)

(Formulae available at the end of this question paper)

7. (a) What is simulation? Briefly explain the steps of simulating a system.

(b) A wholesaler stocks an item for which demand is uncertain. He wishes to assess two re-ordering policies, i.e. order 10 units at a re-order level of 10, or order 15 units at a re-order level of 15 units, to see which is most economical over a 10-day period.

The following information is available:

Demand per day (units)	**Probability**
4	0.10
5	0.15
6	0.25
7	0.30
8	0.20

Carrying costs Rs. 15.00 per unit per day. Ordering costs Rs. 50.00 per order. Loss of goodwill for each unit due to out of stock is cost Rs. 30.00. Lead time is 3 days. Opening stock is 17 units.

Simulate the inventory operation for a 10-day period using the following random numbers, and recommend most economical ordering policy.

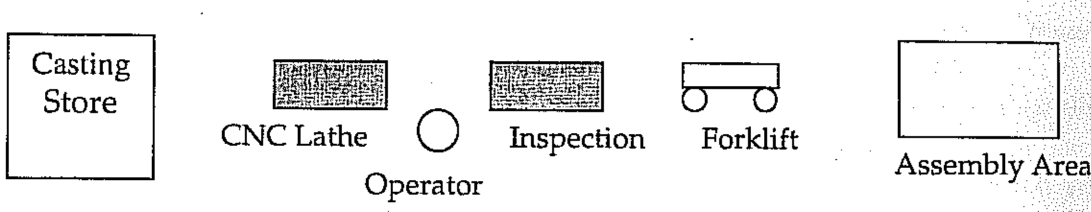
Random numbers:

41	92	05	44	66	07	00	00	14	62
20	07	95	05	79	95	64	26	06	48

Note: The reorder level is physical stock *plus* any replenishment orders outstanding.

(20 marks)

8. The production cell shown below is a part of an industrial valve manufacturing plant. This cell processes two different types of large valves, namely Types A and B. The production cell consists of a CNC lathe, an inspection machine and an operator.



The production cycle begins when the storekeeper (at casting store) receives a request for castings. The company practices Just-In-Time philosophy hence castings are processed when only those are required in subsequent assembly operations. The storekeeper records the time at which castings are released. This information has been analyzed to obtain the distributions of time between subsequent releases;

Type A :	Exponential Distribution	Mean =	38 minutes
Type B :	Exponential Distribution	Mean =	45 minutes

A crane delivers castings to the cell and the crane is normally available whenever a delivery is required. The average delivery time is 3 minutes.

The operator loads the castings to CNC lathe only one at a time. The average loading time is 3.0 minutes. Once loaded, the lathe works automatically. The average processing time for Part A and Part B on the CNC lathe is 10 minutes and 15 minutes respectively. Once processed, castings can be quickly unloaded.

All processed parts are checked at the inspection station and an operator is required for inspection process. Irrespective of the type of casting, average inspection time is 12 minutes. According to the past information, 86% of products have no defects and 85% of defective components can be reworked. The average rework time is 5 minutes.

Finally, finished parts are placed on pallets, which can take 5 parts of any combination. The forklift delivers pallets from the inspection station to the assembly area. The distance that forklift travels each way is about 25m. The average speed of the forklift is 5 m/min.

(i) Draw an Arena flowchart model representation for simulate this system. Label each module by name.

(ii) Discuss briefly how this simulation model can be used to improve the performance of the existing system.

(20 marks)

** END **

Formulae for Question No. 6

	Single Server Model	Multiple Server Model
Average number of customers in the queuing system	$L = \dfrac{\lambda}{\mu - \lambda}$	$L = \dfrac{\lambda\mu(\lambda/\mu)^s}{(s-1)!(s\mu-\lambda)^2} P_0 + \dfrac{\lambda}{\mu}$
Average number of customers in the queue	$L_q = \dfrac{\lambda^2}{\mu(\mu-\lambda)}$	$L_q = L - \dfrac{\lambda}{\mu}$
Average time a customer spends in the queuing system	$W = \dfrac{1}{\mu - \lambda}$	$W = \dfrac{L}{\lambda}$
Average time a customer spends in the queue	$W_q = \dfrac{\lambda}{\mu(\mu-\lambda)}$	$W_q = W - \dfrac{1}{\mu}$

λ = mean arrival rate;
μ = mean service rate;
s = number of servers

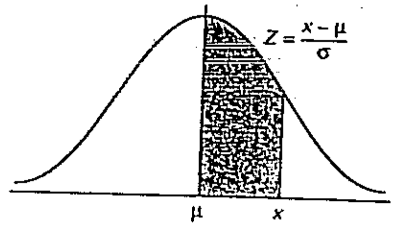


TABLE Normal Curve Areas

Z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990

TABLE Selected Values of P_0 for the Multiple-Server Model

$\rho = \lambda / s\mu$ — *Number of Channels: s*

ρ	2	3	4	5	6	7	8	9	10	15
0.02	0.96079	0.94177	0.92312	0.90484	0.88692	0.86936	0.85215	0.83527	0.81873	0.74082
0.04	0.92308	0.88692	0.85215	0.81873	0.78663	0.75578	0.72615	0.69768	0.67032	0.54881
0.06	0.88679	0.83526	0.78663	0.74082	0.69768	0.65705	0.61878	0.58275	0.54881	0.40657
0.08	0.85185	0.78659	0.72615	0.67032	0.61878	0.57121	0.52729	0.48675	0.44983	0.30119
0.10	0.81818	0.74074	0.67031	0.60653	0.54881	0.49659	0.44933	0.40657	0.36788	0.22313
0.12	0.78571	0.69753	0.61876	0.54881	0.48675	0.43171	0.38289	0.33960	0.30119	0.16530
0.14	0.75439	0.65679	0.57116	0.49657	0.43171	0.37531	0.72628	0.28365	0.24660	0.12246
0.16	0.72414	0.61838	0.52720	0.44931	0.38289	0.32628	0.27804	0.23693	0.20190	0.09072
0.18	0.69492	0.58214	0.48660	0.40653	0.33959	0.28365	0.23693	0.19790	0.16530	0.06721
0.20	0.66667	0.54795	0.44910	0.36782	0.30118	0.24659	0.20189	0.16530	0.13534	0.04979
0.22	0.63934	0.51567	0.41445	0.33277	0.26711	0.21437	0.17204	0.13807	0.11080	0.03688
0.24	0.61290	0.48519	0.38244	0.30105	0.23688	0.18636	0.14660	0.11532	0.09072	0.02732
0.26	0.58730	0.45640	0.35284	0.27233	0.21007	0.16200	0.12492	0.09632	0.07427	0.02024
0.28	0.56250	0.42918	0.32548	0.24633	0.18628	0.14082	0.10645	0.08045	0.06081	0.01500
0.30	0.53846	0.40346	0.30017	0.22277	0.16517	0.12241	0.09070	0.06720	0.04978	0.01111
0.32	0.51515	0.37913	0.27676	0.20144	0.14644	0.10639	0.07728	0.05612	0.04076	0.00823
0.34	0.49254	0.35610	0.25510	0.18211	0.12981	0.09247	0.06584	0.04687	0.03337	0.00610
0.36	0.47059	0.33431	0.23505	0.16460	0.11505	0.08035	0.05609	0.03915	0.02732	0.00452
0.38	0.44928	0.31367	0.21649	0.14872	0.10195	0.06981	0.04778	0.03269	0.02236	0.00335
0.40	0.42857	0.29412	0.19929	0.13433	0.09032	0.06065	0.04069	0.02729	0.01830	0.00248
0.42	0.40845	0.27559	0.18336	0.12128	0.07998	0.05267	0.03465	0.02279	0.01498	0.00184
0.44	0.38889	0.25802	0.16860	0.10944	0.07080	0.04573	0.02950	0.01902	0.01225	0.00136
0.46	0.36986	0.24135	0.15491	0.09870	0.06265	0.03968	0.02511	0.01587	0.01003	0.00101
0.48	0.35135	0.22554	0.14221	0.08895	0.05540	0.03442	0.02136	0.01324	0.00826	0.00075
0.50	0.33333	0.21053	0.13043	0.08010	0.04896	0.02984	0.01816	0.01104	0.00671	0.00055
0.52	0.31579	0.19627	0.11951	0.07207	0.04323	0.02586	0.01544	0.00920	0.00548	0.00041
0.54	0.29870	0.18273	0.10936	0.06477	0.03814	0.02239	0.01311	0.00767	0.00448	0.00030
0.56	0.28205	0.16986	0.09994	0.05814	0.03362	0.01936	0.01113	0.00638	0.00366	0.00022
0.58	0.26582	0.15762	0.09119	0.05212	0.02959	0.01673	0.00943	0.00531	0.00298	0.00017
0.60	0.25000	0.14599	0.08306	0.04665	0.02601	0.01443	0.00799	0.00441	0.00243	0.00012
0.62	0.23457	0.13491	0.07550	0.04167	0.02282	0.01243	0.00675	0.00366	0.00198	0.00009
0.64	0.21951	0.12438	0.06847	0.03715	0.01999	0.01069	0.00570	0.00303	0.00161	0.00007
0.66	0.20482	0.11435	0.06194	0.03304	0.01746	0.00918	0.00480	0.00251	0.00131	0.00005
0.68	0.19048	0.10479	0.05587	0.02930	0.01522	0.00786	0.00404	0.00207	0.00106	[illegible]
0.70	0.17647	0.09569	0.05021	0.02590	0.01322	0.00670	0.00338	0.00170	0.00085	[illegible]
0.72	0.16279	0.08702	0.04495	0.02280	0.01144	0.00570	0.00283	0.00140	0.00069	0.00002
0.74	0.14943	0.07875	0.04006	0.01999	0.00986	0.00483	0.00235	0.00114	0.00055	0.00001
0.76	0.13636	0.07087	0.03550	0.01743	0.00845	0.00407	0.00195	0.00093	0.00044	[illegible]
0.78	0.12360	0.06335	0.03125	0.01510	0.00721	0.00341	0.00160	0.00075	0.00035	[illegible]
0.80	0.11111	0.05618	0.02730	0.01299	0.00610	0.00284	0.00131	0.00060	0.00028	0.00001
0.82	0.09890	0.04933	0.02362	0.01106	0.00511	0.00234	0.00106	0.00048	0.00022	[illegible]
0.84	0.08696	0.04280	0.02019	0.00931	0.00423	0.00190	0.00085	0.00038	0.00017	0.00000
0.86	0.07527	0.03656	0.01700	0.00772	0.00345	0.00153	0.00067	0.00029	0.00013	[illegible]
0.88	0.06383	0.03060	0.01403	0.00627	0.00276	0.00120	0.00052	0.00022	0.00010	[illegible]
0.90	0.05263	0.02491	0.01126	0.00496	0.00215	0.00092	0.00039	0.00017	0.00007	[illegible]
0.92	0.04167	0.01947	0.00867	0.00377	[illegible]	0.00068	0.00028	0.00012	0.00005	[illegible]
0.94	0.03093	0.01427	0.00627	[illegible]	[illegible]	[illegible]	0.00019	0.00008	[illegible]	[illegible]
0.96	0.02041	0.00930	0.00403	0.00170	[illegible]	[illegible]	0.00012	0.00005	[illegible]	[illegible]
0.98	0.01010	0.00454	0.00191	0.00081	0.00033	0.00013	0.00005	0.00002	0.00001	[illegible]