BITS, PILANI – DUBAI

DUBAI INTERNATIONAL ACADEMIC CITY

(III YEAR – II SEMESTER 2009-2010)

COMPREHENSIVE EXAMINATION (CB)

OPERATIONS RESEARCH
(AAOC C 312)

Max. marks: 120 **Weightage: 40%** **Date: 20-05-2010** **Time: 3 Hours**

Notes:

- SECTION-A, SECTION-B and SECTION-C should be answered in separate answer books.
- Attempt the questions in sequential order.
- Non-programmable calculator is permitted
- Necessary ***statistical table*** *values* are given in the last page

SECTION -A

1. The following data give the ranges of 25 samples each consisting of 4 compression test results on steel forgings, in thousands of pounds per inch square:

Sample	1	2	3	4	5	6	7	8	9
R	2.7	3.1	5.0	1.6	2.2	5.7	6.5	3.6	2.5

Sample	10	11	12	13	14	15	16	17	18
R	1.0	3.9	5.6	2.7	3.1	1.5	2.2	1.4	4.3

Sample	19	20	21	22	23	24	25
R	2.2	2.7	3.0	1.1	2.1	1.6	2.4

a) Use these data to find the central line and control limits for an R chart. (*Values up to three decimal places*)

b) Draw the R chart (*Draw in the answer book, graph paper is not required)*

c) Is the process under control? [10]

2. An experiment is conducted to judge the effect of brand name on quality perception. Nine subjects are recruited for the purpose and are asked to taste and compare two samples of product on a set of scale items judged to be ordinal. The following data are obtained:

Pair	1	2	3	4	5	6	7	8	9
Brand A	73	43	47	53	58	47	52	58	38
Brand B	51	41	43	57	47	49	24	58	43

Use the Wilcoxon's signed rank sum test at 5% level to test H_0 "There is no difference in perceived quality of the two samples", against the two–sided alternative. [10]

3. Let X is N (μ, 16). To test H_0: $\mu = 120$ v/s H_1: $\mu > 120$, a random sample of size 36 is taken from X and H_0 is rejected if sample mean exceeds 121.5. Find
   a) Probability of Type – I error
   b) Probability of Type – II error at $\mu = 121$ [10]

4. The monthly demand of a commodity is 420 units. The replenishment rate is 500 units per month. The costs are as follows:
   Holding cost : AED 5 per unit per month;
   Unit cost: AED 12 per unit ;
   Setup cost: AED 250 per run.
   If shortages (fully backlogged) are allowed and shortage cost is AED 4 per unit per month, then find Economic Order Quantity(EOQ),and Optimum Total cost per unit of time (TCU*). [10]

SECTION -B

5. In a test, the question paper contains three questions. Students have to attempt all three questions. The instructor claimed that X, the number of incorrect answers given by a randomly chosen student, has binomial distribution with parameters $n = 3, p = 0.25$. In a random sample of 64 answer scripts the following results are observed:

No. of incorrect answers	0	1	2	3
No. of students	21	31	12	0

   Use chi-square test for multinomial probabilities to test whether instructor's claim can be accepted. Take $\alpha = 0.01$. [10]

6. A noodle shop has conducted a survey to know whether there is a relation between the age-group of customers and the type of noodle they prefer. A random sample survey yields the following results:

AGE (in year)	TYPE OF NOODLE		
	VEG	CHICKEN	MUTTON
24 or less	15	25	35
25 - 39	23	82	50
40 or more	60	30	20

   Test at 5% level of significance whether the age group and the preference for type of noodle are independent. [10]

7. The following experiment is conducted to compare the effect of four different chemicals (A, B, C, D) in producing water resistance in textiles. A strip of material, randomly selected, is cut into four pieces and the pieces are randomly assigned to receive the four chemical treatments. Here each piece of material is treated with exactly one chemical. The process is replicated three time for producing a randomized block design. Moisture resistances are measured for all the samples and are tabulated below. Low readings indicate low moisture penetration.

Blocks ↓	**Chemicals**			
	A	**B**	**C**	**D**
1	10.1	11.4	9.9	12.1
2	12.2	12.9	12.3	13.4
3	11.9	12.7	11.4	12.9

Construct the ANOVA table for this experiment and test whether there is any significant difference in moisture penetration of four chemicals. Take $\alpha = 0.5$. [10]

8. i) Generate a value of exponential random variate X with parameter $\lambda = 4$. Use the random number 0.524 to generate the value.
ii) In an $(M/M/1):(FCFS/\infty/\infty)$ queueing system, the arrival times (in minute) and the service times (in minute) are generated as follows:
Arrival times: 2.5, 4.0, 4.5, 5.2, 6.6, 8.0
Service time: 1.2, 1.1, 0.6, 0.4, 1.0
   a) Find the idle time of the server till the departure of the 5th customer.
   b) Find the departure time of the 3rd customer.
   c) Find the net waiting time of the 4th customer in the system. [10]

SECTION –C

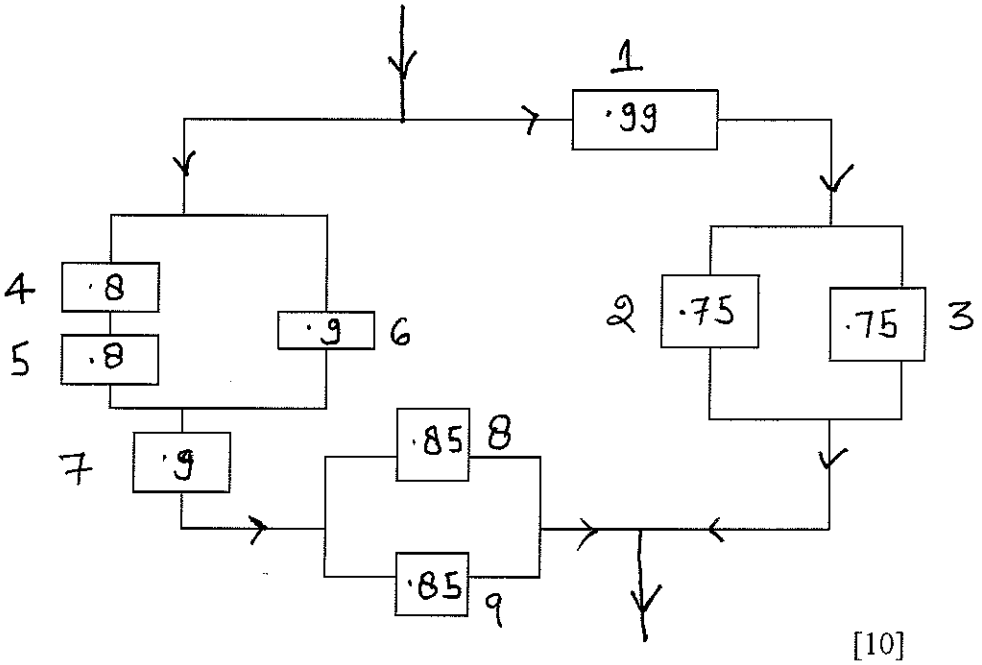
9. A telephone exchange has two long distance operators. During the peak hours, long distance calls arrive in a Poisson process at the mean rate of 15 per hour. The length of service on these calls is approximately exponentially distributed with mean 5 minutes.

   a) What is the probability that a subscriber will have to wait for his long distance call during peak hours?
   b) What is the mean waiting time in queue? [10]

10. Test whether the following data could have come from a uniform distribution on [0, 2]. Use the Kolmogorov-Smirnov test at 5% level of significance.
0.482 0.452 1.32 0.254 1.39 0.128 [10]

11. The life length of a device has exponential distribution . In the past the mean life was 1000 hours. It is suspected that the mean life has been decreased recently. A random sample of 20 devices gave mean life 900 hours. Do the data give sufficient evidence in favour of the suspicion and against the null hypothesis $H_0 : \mu=1000$ hours. Use **5%** level of significance. [10]

12. Find the reliability of the system as below, assume that the components function independently. The numbers inside the boxes are reliabilities and the numbers outside the boxes are component number. (*Values up to three decimal places*)



[10]

Table values as per the standard notation:

$\chi^2_{3,0.99} = 11.345,\ \chi^2_{4,0.95} = 9.488,\ F_{3,6,0.95} = 4.7571.$

For n = 4; $A_1 = 1.596$, $A_2 = 0.577$, $D_3 = 0$, $D_4 = 2.282$

Selected Tail Probabilities of Wilcoxon Signed Rank Statistic

n=9		
x	P	x*
39	0.027	6
40	0.020	5
41	0.014	4

$P(z \le 2.25) = 0.9878,\ P(z > 0.75) = 0.2266$

$D_{6,0.05} = 0.519,\ D_{5,0.05} = 0.503$

$\chi^2_{20,0.05} = 10.851,\ \chi^2_{40,0.05} = 26.509$

For (M/M/s): (FCFS/∞/∞)

$$P_0 = \frac{1}{\frac{\rho^s}{s!(1-\frac{\rho}{s})} + \sum_{n=0}^{s-1}\frac{\rho^n}{n!}}, \quad \rho = \frac{\lambda}{\mu},\ \rho < s$$

$$P_n = \frac{\rho^n}{n!}P_0, \quad n = 0, 1, 2, \ldots, s\text{-}1$$

$$= \frac{\rho^n}{s!s^{n-s}}P_0, \quad n = s, s+1, s+2, \ldots\ldots$$

$$W_q = \frac{\rho^s}{s!}\frac{\mu s}{(\mu s-\lambda)^2}P_0.$$

BITS, PILANI – DUBAI
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(III YEAR – II SEMESTER 2009-2010)

TEST– II (OB)

COURSE: OPERATIONS RESEARCH **COURSE NO.: AAOC C 312**

Max. Marks: 60 Weightage: 20% Date: 11-04-2010 Time: 50 Minutes

NOTE:

- Prescribed text book i.e EDD notes and handwritten class notes are allowed.
- Attempt all the questions.

1. a) Simulate a geometric variable (x) with parameter $p = 0.3$. Use the following random numbers in the order in which they are given: 0.534, 0.815, 0.767, 0.525
   b) Simulate a continuous variable (x) which follows the probability distribution that gives distribution of time between n consecutive trials with parameters $n = 4$ and $\alpha = 3$. Use the following random numbers: 0.512, 0.231, 0.700, 0.634. [8]

2. A certain chemical process is said to have produced on an average 15 or less pounds of waste material for every 60 lbs batch with a corresponding standard deviation of 5 lbs. A random sample of 100 batches gives an average of 16 lbs of waste per batch. Test at 10% level whether the average quantity of waste per batch has increased. Compute the power of the test for $\mu = 16$ lbs. If we raise the level of significance to 20%, then how the power of the test for $\mu = 16$ lbs would be affected? [12]

3. The NIPPO Company has developed a new battery. The engineer in charge claims that the average runtime of new battery is longer than the old battery. To test the claim, the company selects a random sample of 15 new batteries and 14 old batteries. The following table indicates the runtimes of sampled batteries in minute:

New	180	175	172	190	170	160	165	182	190	178	165	190	182	178	164
Old	175	165	180	185	175	182	162	168	160	185	160	178	175	185	

Set up appropriate null and alternative hypotheses and test at 5% level of significance whether the engineer's claim should be accepted. Assume that runtimes are independent and having normal distribution with equal variances.

[12]

4. A machine is producing steel balls. Due to defect in the machine a proportion p of the balls are defective. The value of p is unknown. In a random sample of 200 balls 25 are found defective. Test the following hypothesis based on the above sample:

   $H_0 : p = 0.15$ versus $H_1 : p \neq 0.15$

   Use normal approximation at 5% level of significance. [8]

5. The demand of an item is 125 units per day. The cost of holding inventory is 1.25 item per day. The cost of starting a production run is Rs. 400 per run and the production rate is 250 units per day. No shortages are allowed. The per unit production cost is as follows:

   Rs 4 if $Q < 50$
   Rs 3.5 if $50 \leq Q < 250$
   Rs 3 if $250 \leq Q < 450$
   Rs 2.5 if $450 \leq Q < 600$
   Rs 2 if $Q \geq 600$

   Where Q is the quantity produced in one run. Determine OOC (t*). [12]

6. In a single period probabilistic inventory model where the demand occurs instantaneously at the beginning of the period and filled instantaneously, the demand X of the item is following Uniform distribution *i.e.* U (5, 15). Given that I= 6, $C_0 = 70$ $C_1 = 25$, $C_2 = 125$ and K=0, find probability that no shortage will occur and also find optimum order policy. [8]

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BITS, PILANI – DUBAI
INTERNATIONAL ACADEMIC CITY, DUBAI
(III YEAR – II SEMESTER 2009-2010)

TEST– I (CB)

COURSE: OPERATIONS RESEARCH **COURSE NO.: AAOC C 312**

Max. Marks: 75 Weightage: 25% Date: 28-02-2010 Time: 50 Minutes

- **Attempt all the questions.**

1. XYZ hospital has 3 dentists working who are equally qualified and experienced. It takes, on an average 20 minutes for a patient to get treatment, and the actual time taken is known to vary approximately exponentially around this average. The arrival of patients follows Poisson process with an average of 6 per hour.
   (i) Find the probability that all three dentists are idle (at any instant)?
   (ii) Find the expected number of patients waiting in the queue.
   (iii) If the hospital expands it facilities whereby efficiency of the hospital increases. It takes on an average 15 minutes for a patient to get treatment and the actual time taken is known to vary approximately exponentially around this average. The arrival of patients follows Poisson process with an average of 13 per hour. Specify the minimum number of dentists required in the hospital to avoid an infinite queue, that is, in order that the system achieves steady-state situation. [16]

2. Customers arrive at a one-window drive-in bank in a Poisson process with mean 10 per hour. Service time per customer is exponential with mean 5 minutes. The space in front of the window, including that for the serviced car can accommodate a maximum of 3 cars. Other cars can wait outside this space.
   (i) What is the probability that an arriving car will be served immediately on arrival?
   (ii) Find the average number of customers in the system. [15]

3. An item is produced at the rate of 50 units per day and is consumed at the rate of 25 units per day. If the setup cost is Rs.100 per production run, unit/production cost is Rs.10 per unit and the carrying cost is Rs.2 per unit per day, find EOQ, OOC and the minimum average cost per day. Assume that lead time is zero and the shortages are not permitted. [12]

4. Consider an inventory system where shortages are not permitted and replenishment/delivery rate is infinite. The demand rate is 20 units per day, setup cost is Rs.500 per production run and the holding cost per unit per day is 20% of the unit/production cost. If the TCU* is Rs.400, find the unit cost and the holding cost. [10]

5. At service station cars arrive in a Poisson process at the rate of 4 cars per hour. There are 2 servers working in parallel. The rate of service of each server is 4 cars per hour. Service station can accommodate 4 cars at the maximum.

a) What fraction of customers is lost?
b) What are the average numbers of cars waiting for service in queue?
c) What is proportion of idle time per server?

[22]

FORMULA:

I. For (M/M/s) : (FCFS/m/∞) queuing system

$$P_n = \frac{\rho^n}{n!}P_0, \quad n = 0,1,....,(s-1)$$

$$= \frac{\rho^n}{s!s^{n-s}}P_0, \quad n = s, s+1, ..., m$$

$$= 0, \quad n = m+1, m+2, ...$$

where $$P_0 = \frac{1}{1+\rho^s \frac{\left\{1-\left(\frac{\rho}{s}\right)^{m-s+1}\right\}}{s!\left(1-\frac{\rho}{s}\right)} + \sum_{n=1}^{s-1}\frac{\rho^n}{n!}}, \quad \frac{\rho}{s} \neq 1$$

$$= \frac{1}{1+\frac{s^s}{s!}(m-s+1)+\sum_{n=1}^{s-1}\frac{\rho^n}{n!}}, \quad \frac{\rho}{s} = 1$$

2) $$L_q = \frac{\rho^{s+1}}{s!s}\left[\frac{1-(m-s+1)U^{m-s}+(m-s)U^{m-s+1}}{(1-U)^2}\right]P_0 \quad \text{when } U = \frac{\rho}{s} \neq 1$$

$$= \frac{s^s}{s!}\frac{(m-s)(m-s+1)}{2}P_0 \quad \text{when } U = \frac{\rho}{s} = 1.$$

3) $$L = L_q + (1-P_m)\rho.$$

4) $$\overline{\lambda} = \lambda(1-P_m).$$

II. For (M/M/s): (FCFS/∞/∞) queuing system,

1) $$P_0 = \frac{1}{\frac{\rho^s}{s!(1-\frac{\rho}{s})} + \sum_{n=0}^{s-1}\frac{\rho^n}{n!}}, \quad \rho = \frac{\lambda}{\mu}, \ \rho < s$$

2) $$L_q = \frac{\rho^s}{s!}\frac{\lambda\mu s}{(\mu s-\lambda)^2}P_0.$$

3) $$L = L_q + \rho$$

A

BITS, PILANI – DUBAI

International Academic City, Dubai

(III year – II semester 2009-2010)

QUIZ – II (CB)

Course Title: Operations Research **Course No. : AAOC C 312**

Max. Marks: 21 **Weightage: 7%** **Date: 03.05.2010** **Time:15 min.**

Name:

Id. No. :

Instructions: i) All questions are compulsory
ii) Encircle the correct answer

1. Consider the following 12 pairs of responses in a paired design for testing the null hypothesis that two treatments (T-1 and T-2) are alike against the alternative that T-1 is inferior to T-2:

Pair No.	1	2	3	4	5	6	7	8	9	10	11	12
Response for T-1 (X)	82	75	48	55	72	30	65	88	29	89	53	48
Response for T-2 (Y)	80	55	69	65	35	54	54	80	63	55	65	66

If *Wilcoxon's Signed Rank-sum* test is applied, the observed value of the test statistic is

a) 36.5 b) 41.5 c) 40 d) None of these

2. In a randomized block design, the factor A has 6 levels and the blocking factor has 5 levels. To test the null hypothesis that all levels of A are alike, the suitable test statistic has F_{n_1,n_2} distribution. The value of n_1 and n_2 are

a) $n_1 = 5$, $n_2 = 20$ b) $n_1 = 5$, $n_2 = 4$ c) $n_1 = 4$, $n_2 = 20$

d) None of these.

3. In a randomized design for comparing two treatments, 30 experimental units are selected at random and are divided in two groups consisting of 14 and 16 members. The group of 14 is exposed to treatment-1 and the other to the treatment-2. Responses of treatment-1 and treatment-2 are X and Y respectively. The test statistic W_x for Wilcoxon's rank-sum test can be approximated by normal distribution with mean μ and the variance σ^2. If all 30 observations are distinct, then μ and σ^2 values are

a) μ=217, σ^2= 578.67 b) μ=248, σ^2=578.67 c) μ=217, σ^2=558.6

d) None of these.

4. The data of six observations are given by the readings 28, 39, 45, 45.5, 47, 21. Using Kolmogorov Smirnov test at 5% level we would like to test if the data could have come from normal distribution. The value of F_6 (39) is
(a) 0.5 (b) 0.333 (c) 0.833 (d) None of these.

5. (i) The missing value (*rounding it to the next integer*)of the following *randomized block design is*:

		FACTOR			
B		A	B	C	D
L	I	15	12	8	10
O	II	8	---	9	15
C	III	6	7	12	10
K	IV	4	0	8	9

(a) 6 (b) 8 (c) 10 (d) None of these.

(ii) The degrees of freedom for the error term in the above mentioned RBD are
(a) 3 (b) 9 (c) 8 (d) None of these.

6. To test the hypothesis whether a given set of 15 observations have come from an exponential distribution (parameter not known), the χ^2 test for the goodness of fit is used. The degrees of freedom of χ^2 statistic is
(a) 13 (b) 14 (c) 15 (d) None of these.

SPACE FOR ROUGH WORK

B

BITS, PILANI – DUBAI

International Academic City, Dubai

(III year – II semester 2009-2010)

QUIZ – II (CB)

Course Title: Operations Research **Course No. : AAOC C 312**

Max. Marks: 21 **Weightage: 7%** **Date: 03.05.2010** **Time:15 min.**

Name:

Id. No. :

Instructions: i) All questions are compulsory
ii) Encircle the correct answer

1. Consider the following 12 pairs of responses in a paired design for testing the null hypothesis that two treatments (T-1 and T-2) are alike against the alternative that T-1 is inferior to T-2:

Pair No.	1	2	3	4	5	6	7	8	9	10	11	12
Response for T-1 (X)	82	75	48	55	72	30	65	88	29	89	53	48
Response for T-2 (Y)	80	55	69	65	35	54	54	80	63	55	65	66

If *Wilcoxon's Signed Rank-sum* test is applied, the observed value of the test statistic is

a) 41.5 b) 36.5 c) 40 d) None of these

2. In a randomized block design, the factor A has 6 levels and the blocking factor has 5 levels. To test the null hypothesis that all levels of A are alike, the suitable test statistic has F_{n_1,n_2} distribution. The value of n_1 and n_2 are

a) $n_1 = 4$, $n_2 = 20$ b) $n_1 = 5$, $n_2 = 4$ c) $n_1 = 5$, $n_2 = 20$

d) None of these.

3. In a randomized design for comparing two treatments, 30 experimental units are selected at random and are divided in two groups consisting of 14 and 16 members. The group of 14 is exposed to treatment-1 and the other to the treatment-2. Responses of treatment-1 and treatment-2 are X and Y respectively. The test statistic W_x for Wilcoxon's rank-sum test can be approximated by normal distribution with mean μ and the variance σ^2. If all 30 observations are distinct, then μ and σ^2 values are

a) μ=248, σ^2= 578.67 b) μ=217, σ^2=578.67 c) μ=217, σ^2=558.6

d) None of these.

4. The data of six observations are given by the readings 28, 39, 45, 45.5, 47, 21. Using Kolmogorov Smirnov test at 5% level we would like to test if the data could have come from normal distribution. The value of F_6 (45.5) is

(a) 0.5 (b) 0.333 (c) 0.833 (d) None of these.

5. (i) The missing value (*rounding it to the next integer*)of the following *randomized block design is*:

		FACTOR			
B		A	B	C	D
L	I	15	12	8	10
O	II	8	---	9	15
C	III	6	7	12	10
K	IV	4	0	8	9

(a) 6 (b) 10 (c) 8 (d) None of these.

(ii) The degrees of freedom for the error term in the above mentioned RBD are

(a) 8 (b) 9 (c) 3 (d) None of these.

6. To test the hypothesis whether a given set of 15 observations have come from an exponential distribution (parameter not known), the χ^2 test for the goodness of fit is used. The degrees of freedom of χ^2 statistic is

(a) 15 (b) 14 (c) 13 (d) None of these.

SPACE FOR ROUGH WORK

A

BITS, PILANI – DUBAI

International Academic City, Dubai

(III year – II semester 2009-2010)

QUIZ – I (CB)

Course Title: Operations Research **Course No. : AAOC C 312**

Max. Marks: 24 **Weightage: 8%** **Date: 22.03.2010** **Time: 20 min.**

Name: _____

Id. No. : _____ **Section:** _____

Instructions: i) All questions are compulsory
ii) No marks will be given for incorrect, overwritten, multiple answers.

1. To generate a pair of values of the random variable X having $N(20,36)$ distribution, two random numbers are generated. If these two random numbers are $u_1 = 0.856$ and $u_2 = 0.565$, the generated values of X are _____ and _____ . *(Write answer correct to at least 3 decimal places)*

2. To apply discrete event simulation in a $(M/M/1):(FCFS/\infty/\infty)$ queueing system, the inter-arrival and service times of first three customers are generated. If the inter-arrival times are 2.5, 2.8, 1.5 and the service times are 1.6, 2.1, 1.8 respectively, then the departure time of second customer is _____ and the idle time of the server till the 3rd departure is _____.

3. To generate a value of the binomial varate X with $n = 5$ and $p = 0.25$ the following random numbers are generated: 0.728, 0.677, 0.821, 0.224, 0.772. The generated value of X is _____ .

4. The moment generating function of Pascal distribution with parameters r and p is _____.

5. The moment generating function of Poisson distribution is $e^{2(e^t - 1)}$. The mean of Poisson distribution as per the moment generating function is _____.

6. An item can be produced at a rate of 100 per month and it is sold at a rate of 50 per month. The holding cost is Rs. 20 per unit per month and the setup cost is Rs. 1000. if back ordering is allowed with cost Rs 30 per unit of back order per month. Then EOQ (or Q*) is _____

7. By using the same values K, D, C_1 and C_2 of above problem 6, if delivery rate is infinite then optimum order cycle OOC (or t*) is _____

8. In a single period probabilistic inventory model where the demand occurs instantaneously at the beginning of the period and filled instantaneously, the demand X of the item is following Normal distribution . Given that $C_0 = 40$ $C_1 = 5$, $C_2 = 60$ and K=0, then probability that no shortage will occur *i.e.* $P(X \leq R^*)$ is _____ .

B

BITS, PILANI – DUBAI

International Academic City, Dubai

(III year – II semester 2009-2010)

QUIZ – I (CB)

Course Title: Operations Research **Course No. : AAOC C 312**

Max. Marks: 24 **Weightage: 8%** **Date: 22.03.2010** **Time: 20 min.**

Name:

Id. No. : **Section:**

Instructions: i) All questions are compulsory
ii) No marks will be given for incorrect, overwritten, multiple answers.

1. To generate a pair of values of the random variable X having $N(20, 49)$ distribution, two random numbers are generated. If these two random numbers are $u_1 = 0.856$ and $u_2 = 0.565$, the generated values of X are _____ and _____ . *(Write answer correct to at least 3 decimal places)*

2. To apply discrete event simulation in a $(M/M/1):(FCFS/\infty/\infty)$ queueing system, the inter-arrival and service times of first three customers are generated. If the inter-arrival times are 2.5, 2.8, 1.5 and the service times are 1.6, 2.1, 1.8 respectively, then the departure time of third customer is _____ and the idle time of the server till the 3rd departure is _____.

3. To generate a value of the binomial varate X with $n = 5$ and $p = 0.30$ the following random numbers are generated: 0.728, 0.677, 0.821, 0.224, 0.772. The generated value of X is _____ .

4. The moment generating function of Pascal distribution with parameters r and p is _____.

5. The moment generating function of Poisson distribution is $e^{4(e^t - 1)}$. The mean of Poisson distribution as per the moment generating function is _____.

6. An item can be produced at a rate of 100 per month and it is sold at a rate of 50 per month. The holding cost is Rs. 10 per unit per month and the setup cost is Rs. 1000. if back ordering is allowed with cost Rs 30 per unit of back order per month. Then EOQ (or Q*) is _____

7. By using the same values K, D, C_1 and C_2 of above problem 6, if delivery rate is infinite then optimum order cycle OOC (or t*) is _____

8. In a single period probabilistic inventory model where the demand occurs instantaneously at the beginning of the period and filled instantaneously, the demand X of the item is following Normal distribution . Given that $C_0 = 40$ $C_1 = 5$, $C_2 = 50$ and K=0, then probability that no shortage will occur *i.e.* $P(X \leq R^*)$ is _____ .