

2007 MEC 623 SIX SIGMA – FINAL EXAM

Time: 180 minutes

Max marks: 50

Use of approved Six Sigma Tables is permitted

- 1) Explain the organization structure recommended for implementation of Six Sigma. (2 marks)
- 2) Why do we prefer graphical tools for analysis of data? (2 marks)
- 3) The number of viewers for two television serials was estimated on several days as follows. Make a comparative Box plot and interpret the results.

Manoranjan	101	99	104	95	106	98	95	96
	109	101	108	106	103	105	106	

Parineeta	121	116	119	117	112	101	108	112
	121	115						

- (4 marks)
- 4) The weight of cough syrup in a bottle is known to be normally distributed with mean 98ml and standard deviation 1.5ml. If a sample of 9 bottles is taken, what is the probability that their mean will exceed 99ml? (2 marks)
 - 5) The twelve times at which a CNC machine broke down are given below:

Breakdown times	1	2	3	4	6	7
	8	9	11	12	31	45

Are they normally distributed?

- (4 marks)
- 6) The weld strength of joints in a boiler is specified as 400MPa minimum. A worker is being tested for his ability to create welds of the necessary strength by taking samples of his weld and tested destructively. Formulate suitable hypotheses to ensure that workers have the required capability. In what case would the other alternative hypothesis be considered? (2 marks)
 - 7) Blood specimens from seven donors were given to two laboratories for analysis of cholesterol level, with results as below:

Donor	Raman	Koman	Soman	Mohd	Sita	Gita	Rita
Medilabs	139	134	135	137	138	128	142
Kala labs	141	136	132	139	142	134	144

Is there a significant difference between the results of the two laboratories?

- (2 marks)
- 8) Explain the difference between repetition and replication. (2 marks)
 - 9) An automobile manufacturer uses engines from three companies – Amigo, Borax and Chevro in their car. It is required to conduct an experiment to study the effect of engine make, load and speed on the fuel efficiency of the car. The load can be 100kg or 200kg. The average speed can be 40km/hr or 60km/hr. Write down a table showing a full factorial experiment in these factors with two replications randomized in two blocks, so that a person unfamiliar with DoE can carry out the experiment. (4 marks)
 - 10) The effects and interactions for a 2^3 full factorial experiment with **three** replications have been calculated using Yates algorithm as given next page. Identify the factors which are statistically significant.

A	B	C	Rep1	Rep2	Rep3	Average	1	2	3	Effects	Factors
-1	-1	-1	96	97	98	97	233	440	805	100.63	1
1	-1	-1	134	138	136	136	207	365	159	39.75	A
-1	1	-1	83	84	85	84	172	78	-5	-1.25	B
1	1	-1	123	121	125	123	193	81	-3	-0.75	AB
-1	-1	1	67	63	65	65	39	-26	-75	-18.75	C
1	-1	1	109	106	106	107	39	21	3	0.75	AC
-1	1	1	77	78	76	77	42	0	47	11.75	BC
1	1	1	118	114	116	116	39	-3	-3	-0.75	ABC

(4 marks)

- 11) A 2^3 experiment was conducted to study the time for fluid to flow out through a hole in a bottle. The factors chosen were hole size (A), height of hole from bottom (B) and fluid viscosity (C). The results and calculated effects are given in table below. Only factor A, and interaction AB are significant. Predict the flow through a hole of area 8sqmm at a height of 250mm using a fluid of viscosity 0.13Pas.

Hole size (sqmm)	Height (mm)	Viscosity (Pas)	Time (s)		Average	1	2	3	Effects	Factors
			Rep 1	Rep 2						
5	200	0.1	11	8	9.5	37	81	162	20.25	1
10	200	0.1	26	29	27.5	44	81	43	10.75	A
5	400	0.1	19	21	20	36	22	16	4	B
10	400	0.1	25	23	24	45	21	-33	-8.25	AB
5	200	0.2	7	9	8	18	7	0	0	C
10	200	0.2	29	27	28	4	9	-1	-0.25	AC
5	400	0.2	21	23	22	20	-14	2	0.5	BC
10	400	0.2	25	21	23	1	-19	-5	-1.25	ABC

(4 marks)

- 12) The time of flight of a paper helicopter was studied in an experiment. The factors considered were length and breadth of wings and the results are given below. Is curvature significant?

Length	Breadth	Rep1	Rep2
-1	-1	11	14
1	-1	6	8
-1	1	9	7
1	1	12	13
0	0	7	8
0	0	9	6

(4 marks)

- 13) The pulse rate of three individuals was measured on different days. Test whether there is a significant difference between them

Dev	70	72	72	69	73		
Raj	75	74	70	71	73	74	
Sam	74	75	76	72	76	74	72

(4 marks)

- 14) Determine the alias structure of the 2^{6-2} design with the generators E=ABC, F=BCD.

(4 marks)

- 15) A factory produced 25000 switches in a month, of which 15 were defective. Each switch has 10 critical to quality characteristics. Determine the sigma level of the factory. Assume that no switch has more than one defect.

(3 marks)

- 16) A sample of 24 parts were checked for hardness and the results are in table below. The specification is 270BHN minimum. Calculate Cpk assuming that the process is stable, and that a square root transformation $y = \sqrt{x}$ will make the distribution normal.

304	283	284	288	298	296	320	325
274	316	315	317	273	289	314	320
339	291	307	271	318	277	292	273

(5 marks)

- 17) The specification limits for the centre distance of a hole are 50 ± 0.1 . A sample of 25 parts had a mean of 49.89 with standard deviation 0.042. Determine Cpm and Cpmk. (2 marks)
- 18) Ten parts were measured by an operator twice, using the same instrument in random order. The results are:

Part Number	Trial 1	Trial 2
1	47	48
2	50	52
3	53	54
4	50	49
5	49	47
6	50	49
7	49	51
8	50	49
9	51	54
10	50	50

Estimate the repeatability of the instrument. If the specifications are 50 ± 10 , comment on the gage capability. How good is the discriminating power of the instrument?

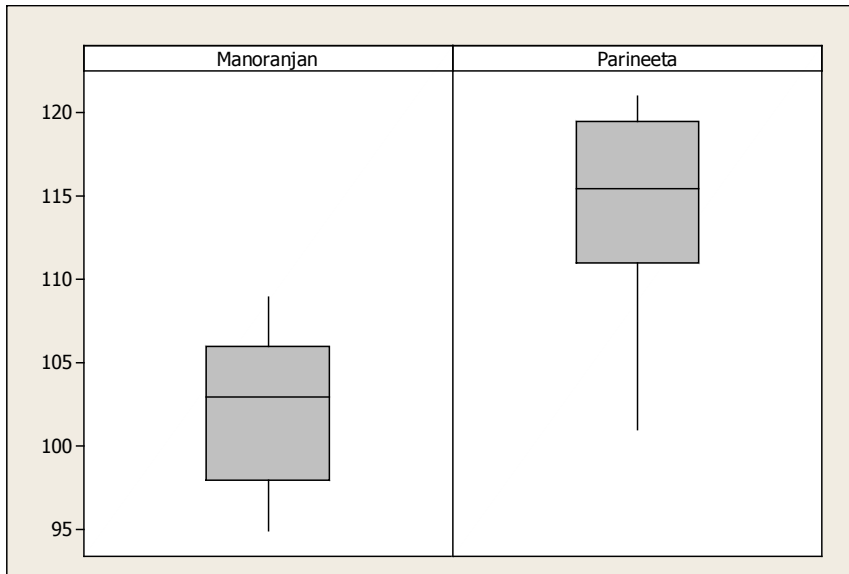
(2 marks)

- 19) a) Give one good point about this course b) Give one suggestion which you think will best improve this course.

SOLUTIONS TO NUMERICALS:

3.

	Manoranjan	Parineeta
Lower limit	86	101.5
Min	95	101
Q1	98	112
Q2	103	115.5
Q3	106	119
Max	109	121
1.5IQR	12	10.5
Upper limit	118	129.5



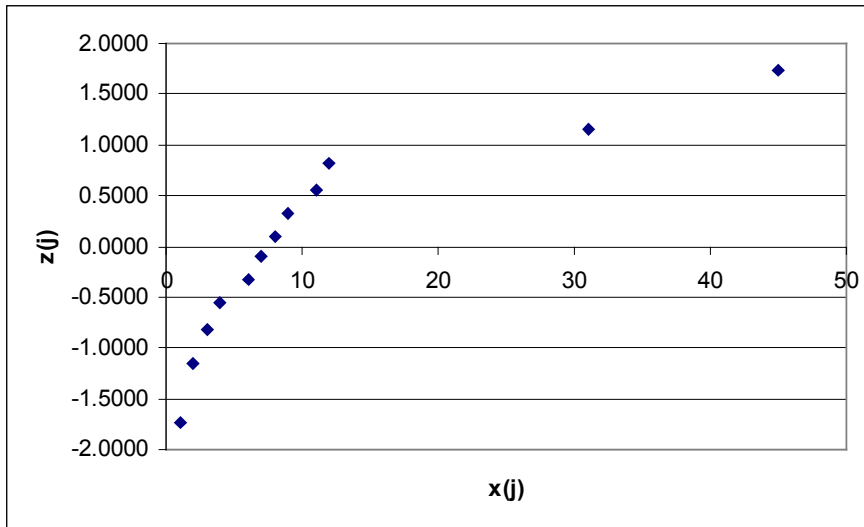
Viewership for Parineeta appears to be higher.

4.

Mean	98
s	1.5
n	9
x	99
Probability	0.02275

5.

j	$(j-0.5)/n$	$z(j)$	$x(j)$
1	0.0417	-1.7317	1
2	0.1250	-1.1503	2
3	0.2083	-0.8122	3
4	0.2917	-0.5485	4
5	0.3750	-0.3186	6
6	0.4583	-0.1046	7
7	0.5417	0.1046	8
8	0.6250	0.3186	9
9	0.7083	0.5485	11
10	0.7917	0.8122	12
11	0.8750	1.1503	31
12	0.9583	1.7317	45



They do not appear to be normally distributed.

6. $H_0: \mu = 400\text{MPa}$; $H_a: \mu > 400\text{MPa}$. Other alternative, when we would like to give the benefit of doubt to the worker.

7.

d	-2	-2	3	-2	-4	-6	-2
---	----	----	---	----	----	----	----

Average	-2.142857
Sd	2.734262
tO	-2.073491
tcrit	2.446914

Hence there is no significant difference between the laboratories.

9.

StdOrder	RunOrder	Blocks	Make	Load	Speed
14	1	2	Amigo	100	60
16	2	2	Amigo	200	60
17	3	2	Borax	100	40
21	4	2	Chevro	100	40
15	5	2	Amigo	200	40
20	6	2	Borax	200	60
23	7	2	Chevro	200	40
24	8	2	Chevro	200	60
18	9	2	Borax	100	60
13	10	2	Amigo	100	40
19	11	2	Borax	200	40
22	12	2	Chevro	100	60
7	13	1	Borax	200	40
2	14	1	Amigo	100	60
4	15	1	Amigo	200	60
9	16	1	Chevro	100	40
5	17	1	Borax	100	40
8	18	1	Borax	200	60
6	19	1	Borax	100	60
11	20	1	Chevro	200	40
10	21	1	Chevro	100	60
12	22	1	Chevro	200	60
1	23	1	Amigo	100	40
3	24	1	Amigo	200	40

10.

Effects	Factors	Var	dof	tO
100.63	1	1	2	148.633
39.75	A	4	2	58.7146
-1.25	B	1	2	-1.8464
-0.75	AB	4	2	-1.1078
-18.75	C	4	2	-27.6956
0.75	AC	3	2	1.1078
11.75	BC	1	2	17.3559
-0.75	ABC	4	2	-1.1078
	Sp ²	2.75		
	SE	0.677		
	tcrit	2.1199		

11.

Hole size (sqmm)	Height (mm)	Viscosity (Pas)	Flow
8	250	0.13	
0.2	-0.5	-0.4	20.7375

12.

Var	dof	
4.5	1	4.5
2	1	2
2	1	2
0.5	1	0.5
1.6667	3	5
		14
	Varp	2
	Sp	1.41421356

Corner	10
Centre	7.5
C	-2.5
sC	0.866
tC	-2.887
tcrit	2.3646

Curvature appears to be significant.

13.

	Count	Sum	Average	Variance
Dev	5	356	71.2	2.7
Raj	6	437	72.833	3.7667
Sam	7	519	74.143	2.8095

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	25.287	2	12.644	4.0794	0.0385	3.6823
Within Groups	46.49	15	3.0994			
Total	71.778	17				

14.

I = ABCE = BCDF = ADEF
 A = BCE = ABCDF = DEF
 B = ACE = CDF = ABDEF

AC = BE = ABDF = CDEF
 AD = BCDE = ABCF = EF
 AE = BC = ABCDEF = DF

C = ABE = BDF = ACDEF
 D = ABCDE = BCF = AEF
 E = ABC = BCDEF = ADF
 F = ABCEF = BCD = ADE
 AB = CE = ACDF = BDEF

AF = BCEF = ABCD = DE
 BD = ACDE = CF = ABEF
 BF = ACEF = CD = ABDE
 ABD = CDE = ACF = BEF
 ABF = CEF = ACD = BDE

15. $DPMO = 15 \times 10^6 / 250000 = 60$, Sigma level = 5.35

16.

17.4356	16.823	16.852	16.971	17.263	17.205	17.889	18.028
16.55295	17.776	17.748	17.804	16.523	17	17.72	17.889
18.41195	17.059	17.521	16.462	17.833	16.643	17.088	16.523

	Before trfm	After trfm
Max	339	18.412
Min	271	16.462
Ave	299.3333	17.292
SD	19.52627	0.5637
LSL	270	16.432
Cpk	0.50075	0.509

17.

USL	50.1
LSL	49.9
xbar	49.89
s	0.042
T	50
Z	-2.619
Cp	0.7937
Cpm	0.2831
Cpk	-0.079
Cpkm	-0.028

18.

R1	R2	Ave	R
47	48	47.5	1
50	52	51	2
53	54	53.5	1
50	49	49.5	1
49	47	48	2
50	49	49.5	1
49	51	50	2
50	49	49.5	1
51	54	52.5	3
50	50	50	0
		50.1	1.4
		sgauge	1.2411
		6sg	7.4468
		P/T	0.3723
		UCLR	3.1948
		UCLx	52.732
		LCLx	47.468

Since $P/T > 0.1$ gauge is not capable. Only one point is outside the control limit, hence the discriminating power is poor!