

**ME6317 SIX SIGMA / ME6321 TOOLS FOR EFFECTIVE  
EXPERIMENTATION  
FINAL TEST 2005**

Time: 180 minutes, Max marks: 50

Use of approved Six Sigma Tables is permitted.

1. What is a Cause and Effect diagram? How is it prepared? (3 marks)

2. The mileage of 20 cars is given below. Prepare a neat dot plot of the data and comment.

18	23	20	18	20	22	13
17	20	21	22	19	24	17
20	22	25	19	22	22	

(3 marks)

3. A certain pen has been designed so that true average writing lifetime under controlled conditions (involving the use of a writing machine) is at least 10 hours. A random sample of 18 pens was selected and the writing lifetime of each determined. The arithmetic mean was 12.04 and standard deviation 4.31. Is the design of the pen satisfactory? (3 marks)

4. A computer scientist wanted to compare the time performance of two algorithms. Ten data sets were prepared and the time taken to solve the problem using each algorithm was measured as below. Test whether there is a significant difference between the speed of the two algorithms.

Data Set	1	2	3	4	5	6	7	8	9	10
Algorithm 1	50	50	49	50	51	52	51	52	51	54
Algorithm 2	52	53	52	51	52	51	53	54	51	52

(5 marks)

5. Explain why experiments should be carried out in random order. (2 marks)
6. An experiment was conducted to determine the optimum combination of factors for a soft drink. Each combination was given to a panel of 20 tasters and each taster assigned a score from 1 to 10. The response variable is the sum of all the scores. Two replications were carried out with the following results and effects.

A Rasna (g)	B Sugar (g)	C Temp °C	Rep 1	Rep 2	Average	Effect	Factor
5	15	5	80	67	73.5	100	1
10	15	5	125	120	122.5	15.5	A
5	20	5	80	66	73	0.5	B
10	20	5	133	123	128	3.5	AB
5	15	25	112	116	114	1.5	C
10	15	25	87	91	89	-36.5	AC
5	20	25	112	105	108.5	-2	BC
10	20	25	98	85	91.5	0.5	ABC

Only the factors A and AC are statistically significant. Develop a linear model and predict the score for a Rasna content of 9g, sugar content 16g and Temp of 15°C.

(5 marks)

7. Calculate the residuals for the above problem (Q6). (5 marks)
8. An experiment is being planned to study the factors affecting compressive strength of concrete. From past data, the standard deviation of compressive strength is estimated to be 20MPa. Determine the number of replications required for a full factorial experiment, if there are four factors and it is desired to detect changes in strength of 30MPa with around 0.05 level of significance. (3 marks)

9. An experiment was conducted to study the factors affecting roundness error in turning. The factors considered were type of chuck (3 jaw or 4 jaw), length and diameter of the workpiece. Since changing chucks was difficult, the first four runs used 3 jaw, next four used 4 jaw, the next 4 used 3 jaw and the last four 4 jaw chuck. The other two factors were fully randomized. The results and calculated effects in standard order are given below. Test the significance of effects.

	A	B	C	D			
Run Order	Length	Dia	Chuck	Rep	Roundness	Effects	Var
2	-1	-1	3 jaw	1	14.7	24.7438	1
4	1	-1	3 jaw	1	16	0.6625	A
1	-1	1	3 jaw	1	47.8	31.0625	B
3	1	1	3 jaw	1	48.3	1.5375	AB
6	-1	-1	4 jaw	1	4.3	-11.6625	C
7	1	-1	4 jaw	1	2.4	-0.1875	AC
8	-1	1	4 jaw	1	32.6	-0.6875	BC
5	1	1	4 jaw	1	36.1	1.0875	ABC
10	-1	-1	3 jaw	2	14.3	-1.0625	D
11	1	-1	3 jaw	2	13.8	-0.1875	AD
12	-1	1	3 jaw	2	43.8	-0.7875	BD
9	1	1	3 jaw	2	45.9	0.3875	ABD
13	-1	-1	4 jaw	2	5.3	1.1875	CD
16	1	-1	4 jaw	2	2.9	-0.1375	ACD
14	-1	1	4 jaw	2	32.5	0.1625	BCD
15	1	1	4 jaw	2	35.2	-0.4625	ABCD

(5 marks)

10. Explain the concept of Design Resolution. Why are Resolution V designs considered generally satisfactory for all experiments?

(3 marks)

**PART A: For ME6317 SIX SIGMA only**

11. Explain the Breakthrough strategy of Six Sigma.

(3 marks)

12. Determine the DPMO for a 4.5 sigma process.

(3 marks)

13. The noise output of 30 ICs was measured and results are given below:

289	125	254	572	131	226	162	195	42	427
196	177	304	268	209	35	222	318	423	313
490	116	569	151	234	122	269	214	241	469

If the specified noise is 600 max, determine the process capability index Cpk. Assume that the process is in control and that a square root transformation is appropriate.

(5 marks)

14. An operator measured ten parts twice in random order with the following results:

Part Number		1	2	3	4	5	6	7	8	9	10
Operator	Trial 1	63	49	64	64	59	60	51	51	54	60
	Trial 2	61	48	59	60	55	62	52	53	58	57

Estimate the repeatability as a fraction of the total variability.

(5 marks)

**PART B: For ME6321 TOOLS FOR EFFECTIVE EXPERIMENTATION only**

11. Determine the alias structure for the 8 run six factor fractional factorial experiment with generators D=AB, E=AC and F=BC, for all main effects and two factor interactions.

(5 marks)

12. Sketch a contour plot for the response variable  $Y=20+5A+10B-7AB$ , where A and B are the factors in coded form. Show contours for  $Y=5, 15, 20$  and  $25$ , with at least 4 points for each.

(5 marks)

13. A factorial experiment was conducted to study the factors affecting time of flow of sand through a hopper. The 2 factors that were found to be significant were Area (low=12sqcm, high=16sqcm), and Height (low=20cm, high=30cm). If a central composite design is to be used to augment this design, determine the next set of experiments in uncoded form. Hint: Six centre points are required.

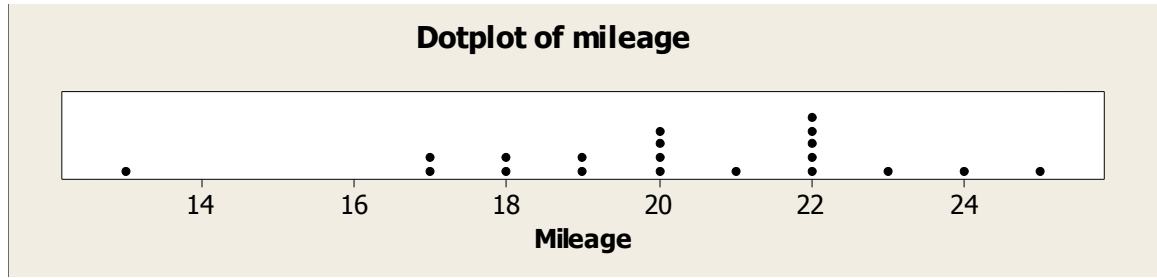
(3 marks)

14. What are Box-Behnken designs? Compare them with Central Composite designs.

(3 marks)

**SOLUTIONS TO NUMERICALS**

2.



13 may be an outlier, data does not appear normal.

3.

N	Mean	StDev	SE Mean	to	tcrit
18	12.04	4.31	1.0159	2.01	1.74

Hence the design appears to be satisfactory

4.

d	-2 -3 -3 -1 -1 1 -2 -2 0 2
dbar	-1.1
sd	1.66332999
t	-2.09129003
tcrit	2.26215889

There does not appear to be a significant difference between the algorithms

6.

$$Y=100 + (15.5/2)*(A-7.5)/(10-7.5) + (1.5/2)*(C-15)/(25-15) + (-36.5/2)*(A-7.5)/(10-7.5)*(C-15)/(25-15)=100+7.75*0.6=104.65$$

7.

Effect	Last column	Eliminating	Inverting	1	2	3	Div/8	Inverting	Res 1	Res 2
100	800	800	0	0	-140	722	90.25	73.25	6.75	-6.25
15.5	62	62	0	-140	862	890	111.25	125.25	-0.25	-5.25
0.5	2	0	-146	0	152	722	90.25	73.25	6.75	-7.25
3.5	14	0	6	862	738	890	111.25	125.25	7.75	-2.25
1.5	6	6	0	0	-140	1002	125.25	111.25	0.75	4.75
-36.5	-146	-146	0	152	862	586	73.25	90.25	-3.25	0.75
-2	-8	0	62	0	152	1002	125.25	111.25	0.75	-6.25
0.5	2	0	800	738	738	586	73.25	90.25	7.75	-5.25

8.

Sp	20
δ	30
nF	28.4444
r	1.77778
r	2

9.

sw	1.1875	sE	0.4212
tC	-9.8211	tA	1.5727
tcrit	12.7062	tB	73.7396
		tAB	3.6499
		tAC	-0.4451
		tBC	-1.6321
		tABC	2.5816
		tcrit	2.4469

B, AB, and ABC appear to be significant.

**PART A: ME 6317 SIX SIGMA**

12.

$$DPO = [1-\Phi(6.0)]+[1-\Phi(3.0)] = 0.00000000987+0.001349898032 = 0.001349899019000$$

$$DPMO = 1350ppm$$

13.

17.000	11.180	15.937	23.917	11.446	15.033	12.728	13.964	6.481	20.664
14.000	13.304	17.436	16.371	14.457	5.916	14.900	17.833	20.567	17.692
22.136	10.770	23.854	12.288	15.297	11.045	16.401	14.629	15.524	21.656

$$\bar{x}=15.481 \quad s=4.4462 \quad USL(\text{Transformed})=24.4948 \quad Cpk=0.67578$$

14.

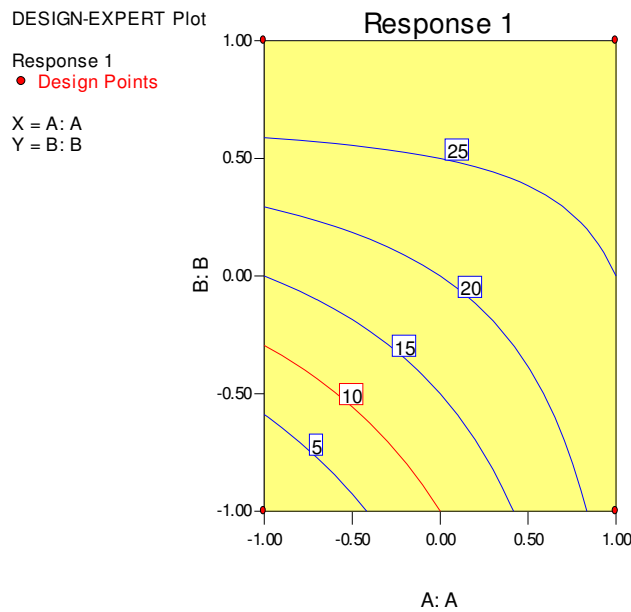
Range 2 1 5 4 4 2 1 2 4 3  
 $R_{bar} = 2.800, s_{gauge} = 2.482, s_{total} = 5.037, s_{gauge}/s_{total} = 0.4928$

**PART B: ME6321 TOOLS FOR EFFECTIVE EXPERIMENTATION**

11. I=ABD=ACE=BCF=BCDE=ACDF=ABEF=DEF

- A=BD=CE=ABCF=ABCDE=CDF=BEF=ADEF
- B=AD=ABCE=CF=CDE=ABCDF=AEF=BDEF
- C=ABCD=AE=BF=BDE=ADF=ABCEF=CDEF
- D=AB=ACDE=BCDF=BCE=ACF=ABDEF=EF
- E=ABDE=AC=BCEF=BCD=ACDEF=ABF=DF
- F=ABDF=ACEF=BC=BCDEF=ACD=ABE=DE
- AB=D=BCE=ACF=ACDE=BCDF=EF=ABDEF
- AC=BCD=E=ABF=ABDE=DF=BCEF=ACDEF
- AD=B=CDE=ABCDF=ABCE=CF=BDEF=AEF
- AE=BDE=C=ABCEF=ABCD=CDEF=BF=ADF
- AF=BDF=CEF=ABC=ABCDEF=CD=BE=ADE
- BC=ACD=ABE=F=DE=ABDF=ACEF=BCDEF
- BD=A=ABCDE=CDF=CE=ABCF=ADEF=BEF
- BE=ADE=ABC=CEF=CD=ABCDEF=AF=BDF
- BF=ADF=ABCEF=C=CDEF=ABCD=AE=BDE
- CD=ABC=ADE=BDF=BE=AF=ABCDEF=CEF
- CE=ABCED=A=BEF=BD=ADEF=ABCF=CDF
- CF=ABCDF=AEF=B=BDEF=AD=ABCE=CDE
- DE=ABE=ACD=BCDEF=BC=ACEF=ABDF=F
- DF=ABF=ACDEF=BCD=BCEF=AC=ABDE=E
- EF=ABDEF=ACF=BCE=BCDF=ACDE=AB=D

12.



13.

Type	Area	Height
Centre	14	25
Centre	14	25
Centre	14	25
Centre	14	25
Centre	14	25
Centre	14	25
Corner	8.172	17.93
Corner	16.828	17.93
Corner	8.172	32.07
Corner	16.828	32.07