Name _____ Student ID _____

Prince of Songkla University
Department of Industrial Engineering, Faculty of Engineering

Final Examination: Semester 1 — Academic Year: 2007
Date: 1 October 2006 — Time: 09:00 – 12:00
Subject: 225-502 Experimental Designs — Room: A400

ทุจริตในการสอบ โทษขั้นต่ำ คือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียนหนึ่งภาคการศึกษา

Instructions: Read carefully

1. All materials are allowed.
2. There are 6 problems, do all of them. Also show your work clearly and legibly.
3. Answer the questions in this test paper, only.
4. You must write your name and your student ID in every page of the test.
5. Total score is 110 points.

Distribution of Score

Problem	Points	(a)	(b)	(c)
1	20	8	12	-
2	20	8	12	-
3	15	-	-	-
4	15	-	-	-
5	15	-	-	-
6	25	-	-	-

Tests are prepared by
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Problem 1: (20 points) An experiment was performed to improve the yield of a chemical process. Four factors were selected, and two replicates of a completely randomized experiment were run. The results are shown in the following table:

Treatment Combination	Replicate		Treatment Combination	Replicate	
	I	II		I	II
(1)	90	93	*d*	98	95
a	74	78	*ad*	72	76
b	81	85	*bd*	87	83
ab	83	80	*abd*	85	86
c	77	78	*cd*	99	90
ac	81	80	*acd*	79	75
bc	88	82	*bcd*	87	84
abc	73	70	*abcd*	80	80

(a) Consider the data from the first replicate and construct a design with four blocks by confounding *ABC* and *ABD* with blocks.

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(b) Prepare an analysis of variance table from the design in problem (a), and determine which factors are important to the yield of a process. Use $\alpha = 0.05$.

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Problem 2: (20 points) Consider the following data from a specific experiment.

(1) = 7	$d = 8$	$e = 8$	$de = 6$
$a = 9$	$ad = 10$	$ae = 12$	$ade = 10$
$b = 34$	$bd = 32$	$be = 35$	$bde = 30$
$ab = 55$	$abd = 50$	$abe = 52$	$abde = 53$
$c = 16$	$cd = 18$	$ce = 15$	$cde = 15$
$ac = 20$	$acd = 21$	$ace = 22$	$acde = 20$
$bc = 40$	$bcd = 44$	$bce = 45$	$bcde = 41$
$abc = 60$	$abcd = 61$	$abce = 65$	$abcde = 63$

(a) Construct a fractional factorial 2^{5-2}_{III} design with $I = ABD$ and $I = BCE$.

(b) Prepare an analysis of variance table from the design in problem (a), and determine which factors are important to the response variable. Use $\alpha = 0.05$.

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Problem 3: (15 points) A manufacturing engineer is studying the dimensional variability of a particular component that is produced on three machines. Each machine has two spindles, and four components are randomly selected from each spindle. The results follow. Analyze the data, assuming that machines and spindles are fixed factors. Use $\alpha = 0.05$.

	Machine 1		**Machine 2**		**Machine 3**	
Spindle	**1**	**2**	**1**	**2**	**1**	**2**
	12	8	14	12	14	16
	9	9	15	10	10	15
	11	10	13	11	12	15
	12	8	14	13	11	14

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Problem 4: (15 points) An engineer is studying the effect of cutting speed on the rate of metal removal in a machining operation. However, the rate of metal removal is also related to the hardness of the test specimen. Five observations are taken at each cutting speed. The amount of metal removed (y) and the hardness of the specimen (x) are shown in the following table. Analyze the data using an analysis of covariance. Use $\alpha = 0.05$.

Cutting Speed (rpm)					
1000		**1200**		**1400**	
y	x	y	x	y	x
68	120	112	165	118	175
90	140	94	140	82	132
98	150	65	120	73	124
77	125	74	125	92	141
88	136	85	133	80	130

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Problem 5: (15 points) The data from experimental design is shown in the following table.

x_1	x_2	y
-1	-1	54
-1	1	45
1	-1	32
1	1	47
0	0	41
0	0	39
0	0	44
0	0	42
0	0	40

Analyze the data to check whether there is significant effect from curvature. Use $\alpha = 0.10$.

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Problem 6: (25 points) The data from experimental design is shown in the following table.

x_1	x_2	x_3	y
-1	-1	-1	66
-1	-1	1	70
-1	1	-1	78
-1	1	1	60
1	-1	-1	80
1	-1	1	70
1	1	-1	100
1	1	1	75
-1.682	0	0	100
1.682	0	0	80
0	-1.682	0	68
0	1.682	0	63
0	0	-1.682	65
0	0	1.682	82
0	0	0	113
0	0	0	100
0	0	0	118
0	0	0	88
0	0	0	100
0	0	0	85

And the output analysis is also shown in the following section.

Response: Yield

ANOVA for Response Surface Quadratic Model

Analysis of variance table [Partial sum of squares]

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model	3662.00	9	406.89	2.19	0.1194
A	*22.08*	*1*	*22.08*	*0.12*	*0.7377*
B	*25.31*	*1*	*25.31*	*0.14*	*0.7200*
C	*30.50*	*1*	*30.50*	*0.16*	*0.6941*
A^2	*204.55*	*1*	*204.55*	*1.10*	*0.3191*
B^2	*2226.45*	*1*	*2226.45*	*11.96*	*0.0061*
C^2	*1328.46*	*1*	*1328.46*	*7.14*	*0.0234*
AB	*66.12*	*1*	*66.12*	*0.36*	*0.5644*
AC	*55.13*	*1*	*55.13*	*0.30*	*0.5982*
BC	*171.13*	*1*	*171.13*	*0.92*	*0.3602*
Residual	1860.95	10	186.09		
Lack of Fit	*1001.61*	*5*	*200.32*	*1.17*	*0.4353*
Pure Error	*859.33*	*5*	*171.87*		
Cor Total	5522.95	19			

Std. Dev.	13.64	R-Squared	0.6631
Mean	83.05	Adj R-Squared	0.3598
C.V.	16.43	Pred R-Squared	-0.6034
PRESS	8855.23	Adeq Precision	3.882

Use the provided information to find the operating conditions, in term of x_1, x_2, and x_3 if the objective is to maximize the response variable y.

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Factor	Coefficient Estimate	DF	Standard Error	95% CI Low	95% CI High	VIF
Intercept	100.67	1	5.56	88.27	113.06	
A-x1	1.27	1	3.69	-6.95	9.50	1.00
B-x2	1.36	1	3.69	-6.86	9.59	1.00
C-x3	-1.49	1	3.69	-9.72	6.73	1.00
A^2	-3.77	1	3.59	-11.77	4.24	1.02
B^2	-12.43	1	3.59	-20.44	-4.42	1.02
C^2	-9.60	1	3.59	-17.61	-1.59	1.02
AB	2.87	1	4.82	-7.87	13.62	1.00
AC	-2.63	1	4.82	-13.37	8.12	1.00
BC	-4.63	1	4.82	-15.37	6.12	1.00

Response: Yield

ANOVA for Response Surface Reduced Quadratic Model

Analysis of variance table [Partial sum of squares]

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model	3143.00	4	785.75	4.95	0.0095
B	25.31	1	25.31	0.16	0.6952
C	30.50	1	30.50	0.19	0.6673
B^2	2115.31	1	2115.31	13.33	0.0024
C^2	1239.17	1	1239.17	7.81	0.0136
Residual	2379.95	15	158.66		
Lack of Fit	*1520.62*	*10*	*152.06*	*0.88*	*0.5953*
Pure Error	*859.33*	*5*	*171.87*		
Cor Total	5522.95	19			

Std. Dev.	12.60	R-Squared	0.5691
Mean	83.05	Adj R-Squared	0.4542
C.V.	15.17	Pred R-Squared	0.1426
PRESS	4735.52	Adeq Precision	5.778

Factor	Coefficient Estimate	DF	Standard Error	95% CI Low	95% CI High	VIF
Intercept	97.58	1	4.36	88.29	106.88	
B-x2	1.36	1	3.41	-5.90	8.63	1.00
C-x3	-1.49	1	3.41	-8.76	5.77	1.00
B^2	-12.06	1	3.30	-19.09	-5.02	1.01
C^2	-9.23	1	3.30	-16.26	-2.19	1.01

Use the provided information to find the operating conditions, in term of x_1, x_2, and x_3 if the objective is to maximize the response variable y.