MURANG'A UNIVERSITY OF TECHNOLOGY

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF APPLIED SCIENCES

UNIVERSITY ORDINARY EXAMINATION

2017/2018 ACADEMIC YEAR

EXAMINATION FOR MASTER OF SCIENCE IN STATISTICS

AMS 601: EXPERIMENTAL DESIGN I

DURATION: 3 HOURS

DATE: 23RD AUGUST, 2018

TIME: 9.00 A.M. – 12.00 NOON

Instructions to Candidates:

1. Answer **Any Four** questions.
2. Mobile phones are not allowed in the examination room.
3. You are not allowed to write on this examination question paper.

QUESTION ONE (25 Marks)

a) Explain how to conduct the following types of analysis of variance in R giving an example in each case

i. One way ANOVA (2 marks)

ii. Randomized block design (2 marks)

iii. Two way factorial design (2 marks)

b) Describe the guidelines for designing experiments (7 marks)

c) Illustrate the analysis of the single factor fixed effects model (3 marks)

d) A manufacturer suspects that the batches of raw material furnished by his supplier differ significantly in calcium content. There are five batches currently in the warehouse. A chemist makes five determinations on each batch and obtains the following data:

Batch 1	Batch 2	Batch 3	Batch 4	Batch 5
23.46	23.59	23.51	23.28	23.29
23.48	23.46	23.64	23.40	23.46
23.56	23.42	23.46	23.37	23.37
23.39	23.49	23.52	23.46	23.32
23.40	23.50	23.49	23.39	23.38

Is there significant variation in calcium content from batch to batch? Use $\alpha = 0.05$.

(9 marks)

QUESTION TWO (25 Marks)

a) Describe the following types of designs

i. Randomized complete block design (2 marks)

ii. Latin square design (2 marks)

b) An experiment was conducted in which a shape factor was determined for several different nozzle designs at six levels of jet efflux velocity. Interest focused on potential differences between nozzle designs, with velocity considered as a nuisance variable. The data are shown below:

Nozzle Design	Jet Efflux Velocity (m/s)					
	11.73	**14.37**	**16.59**	**20.43**	**23.46**	**28.74**
1	0.78	0.80	0.81	0.75	0.77	0.78
2	0.85	0.85	0.92	0.86	0.81	0.83
3	0.93	0.92	0.95	0.89	0.89	0.83
4	1.14	0.97	0.98	0.88	0.86	0.83
5	0.97	0.86	0.78	0.76	0.76	0.75

Does nozzle design affect the shape factor? Use $\alpha = 0.05$. (10 marks)

c) The effect of five different ingredients (*A, B, C, D, E*) on the reaction time of a chemical process is being studied. Each batch of new material is only large enough to permit five runs to be made. Furthermore, each run requires approximately hours, so only five runs can be made in one day. The experimenter decides to run the experiment as a Latin square so that day and batch effects may be systematically controlled. She obtains the data that follow. Analyse the data from this experiment (use $\alpha = 0.05$) and draw conclusions.

Day	**Batch**				
	1	**2**	**3**	**4**	**5**
1	A=8	B=7	D=1	C=7	E=3
2	C=11	E=2	A=7	D=3	B=8
3	B=4	A=9	C=10	E=1	D=5
4	D=6	C=8	E=6	B=6	A=10
5	E=4	D=2	B=3	A=8	C=8

(11 marks)

QUESTION THREE (25 Marks)

a) Describe the following types of designs

i. Balanced incomplete block designs (2 marks)

ii. Graeco-Latin square design (2 marks)

b) Seven different hardwood concentrations are being studied to determine their effect on the strength of the paper produced. However, the pilot plant can only produce three runs each day. As days may differ, the analyst uses the balanced incomplete block design that follows. Analyze the data from this experiment (use $\alpha = 0.05$) and draw conclusions.

Hardwood Concentration (%)	Days						
	1	2	3	4	5	6	7
2	114				120		117
4	126	120				119	
6		137	117				134
8	141		129	149			
10		145		150	143		
12			120		118	123	
14				136		130	127

(10 marks)

c) The yield of a chemical process was measured using five batches of raw material, five acid concentrations, five standing times (*A, B, C, D, E*), and five catalyst concentrations ($\alpha, \beta, \gamma, \delta, \varepsilon$). The Graeco-Latin square that follows was used. Analyse the data from this experiment (use $\alpha = 0.05$) and draw conclusions.

Batch	Acid Concentration				
	1	2	3	4	5
1	$A\alpha = 26$	$B\beta = 16$	$C\gamma = 19$	$D\delta = 16$	$E\varepsilon = 13$
2	$B\gamma = 18$	$C\delta = 21$	$D\varepsilon = 18$	$E\alpha = 11$	$A\beta = 21$
3	$C\varepsilon = 20$	$D\alpha = 12$	$E\beta = 16$	$A\gamma = 25$	$B\delta = 13$
4	$D\beta = 15$	$E\gamma = 15$	$A\delta = 22$	$B\varepsilon = 14$	$C\alpha = 17$
5	$E\delta = 10$	$A\varepsilon = 24$	$B\alpha = 17$	$C\beta = 17$	$D\gamma = 14$

(11 marks)

QUESTION FOUR (25 Marks)

a) Describe the statistical analysis of the two factor fixed effects model (4 marks)

b) The percentage of hardwood concentration in raw pulp and the pressure are being investigated for their effects on the strength of paper. Four levels of hardwood concentration and four levels of pressure are selected. A factorial experiment with four replicates is conducted, and the following data are obtained. Analyse the data and draw conclusion. Use $\alpha = 0.05$.

Percentage of hardwood concentration	Pressure							
	400		500		650		800	
2	113	125	144	146	160	135	134	165
	110	131	150	122	156	124	135	167
4	121	155	145	168	186	183	202	172
	154	131	171	147	180	190	174	169
8	136	158	183	164	202	217	207	226
	155	137	175	180	210	185	242	241
10	182	174	195	192	243	218	269	247
	164	153	218	198	223	231	243	258

(10 marks)

c) A medical researcher is studying the effect of lidocaine on the enzyme level in the heart muscle of beagle dogs. Three different commercial brands of lidocaine (*A*), three dosage levels (*B*), and three dogs (*C*) are used in the experiment, and two replicates of a 3^3 factorial design are run. The observed enzyme levels follow.

Lidocaine Brand	Dosage Strength	Replicate I			Replicate I		
		Dog			Dog		
		1	2	3	1	2	3
1	1	96	84	85	84	85	86
	2	94	99	98	95	97	90
	3	101	106	98	105	104	103
2	1	85	84	86	80	82	84
	2	95	98	97	93	99	95
	3	108	114	109	110	102	100
3	1	84	83	81	83	80	79
	2	95	97	93	92	96	93
	3	105	100	106	102	111	108

Analyse the data from this experiment. Use α = 0.05. (11 marks)

QUESTION FIVE (25 marks)

a) Describe the statistical analysis of the two factor factorial with random effects model . (4 marks)

b) Describe the statistical analysis of the split plot design. (4 marks)

c) An experiment was performed to investigate the capability of a measurement system. Ten parts were randomly selected, and two randomly selected operators measured each part three times. The tests were made in random order, and the data are shown below

Part No.	**Operator 1**			**Operator 2**		
	1	**2**	**3**	**1**	**2**	**3**
1	50	49	50	50	48	51
2	52	52	51	51	51	51
3	53	50	50	54	52	51
4	49	51	50	48	50	51
5	48	49	48	48	49	48
6	52	50	50	52	50	50
7	51	51	51	51	50	50
8	52	50	49	53	48	50
9	50	51	50	51	48	49
10	47	46	49	46	47	48

i. Analyze the data from this experiment. Use α = 0.05. (5 marks)

ii. Estimate the variance components using the ANOVA method. (3 marks)

d) Three different Pinot Noir wines were evaluated by a panel of eight judges. The judges are considered a random panel of all possible judges. The wines are evaluated on a 100 - point scale. The wines were presented in random order to each judge, and the following results obtained.

Judge	**Wine**		
	1	**2**	**3**
1	85	88	93
2	90	89	94
3	88	90	98
4	91	93	96
5	92	92	95
6	89	90	95
7	90	91	97
8	91	89	98

Is there a difference in wine quality? Use $\alpha = 0.05$ (9 marks)