NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCE

DEPARTMENT OF STATISTICS AND OPERATIONS RESEARCH

B.Sc. SORS and SBA PART II

SORS2202: DESIGN AND ANALYSIS OF EXPERIMENTS

MARCH 2025 EXAMINATION

Time: 3 Hours
Total Marks: 100

Candidates may attempt **ALL** questions in Section **A** and at most **THREE** questions in Section **B**. Show all working where necessary. You may use a calculator. Graph paper and Statistical Tables will be provided.

SECTION A: Attempt **ALL** questions in this section **[40 marks].**

A1. An experiment is carried out to determine if there is a significant difference in the mean number of lesions 0n tobacco leaves from two preparations of mosaic virus, Prep1 and Prep2. A single leaf is taken from 11 different tobacco plants. Each leaf is divided in half, and one half is treated with Prep1 and the other half with Prep2, and the results in Table 1 are obtained.

Table 1: Number of lesions.

Plant	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Prep1	18	20	9	14	38	26	15	10	25	7	13
Prep2	14	15	6	12	32	30	9	2	18	3	6

(i) Carry out an appropriate t-test at the 5% level of significance to determine if there is a significant difference in the mean number of lesions from the two preparations of mosaic virus. **[8]**

(ii) Carry out an appropriate Analysis of Variance to determine if there is a significant difference in the mean number of lesions from the two preparations of mosaic virus. Use the 5% level of significance. **[8]**

(iii) Indicate the similarities between tests (i) and (ii). **[4]**

A2. An experiment was conducted to compare the mean number of tapeworms in the stomachs of lambs that had been treated for worms using a certain drug against the mean number of worms in those that were untreated. A sample of 22 worm infected lambs was randomly divided into two groups. Eleven lambs were injected with the drug and the remaining eleven were left untreated. After a six month period, the lambs were slaughtered and the number of worms counted are as shown in Table 2.

Table 2: Number of worms counted.

Untreated	26	14	9	7	13	25	15	20	38	18	10
Treated	15	12	3	6	18	30	9	14	32	6	2

(i) Carry out an appropriate t-test at the 5% level of significance to determine if there is a significant difference in the mean number of worms between treated and untreated lambs. [8]

(ii) Carry out an appropriate Analysis of Variance to determine if there is a significant difference in the mean number of worms between treated and untreated lambs. Use the 5% level of significance. [8]

(iii) Indicate the similarities between tests (i) and (ii). [4]

SECTION B: Attempt any **THREE** questions from this section **[60 marks]**.

B3. Table 3 shows the time, **x** (in hours) that the fish were placed in ice packing after being caught and a measure of fish quality, **y,** seven days later.

Table 3: Time, **x** (in hours) and measure of fish quality, **y**.

x	0	0	3	3	6	6	9	9	12	12
y	8.5	8.4	7.9	8.1	7.8	7.6	7.3	7.0	6.8	6.7

(a) Fit the straight line model and test for the significance of the slope. [**6**]

(b) Compute the fitted values and the residuals. Plot the residuals against fitted values and comment on the appropriateness of the straight line model. [**7**]

(c) Carry out the lack-of-fit test. [**7**]

B4. A horticulturist conducted an experiment to compare two varieties of roses; variety **WR** and variety **RR** on yield of marketable roses (y). The plots were not of the same size, hence the horticulturist wished to use plot size (x) as the concomitant variable. Six replicates were made for each treatment. The results in Table 4 were obtained.

Table 4: Yield, **y** and plot size, **x**.

Variety WR		**Variety RR**	
y	x	y	x
98	15	55	4
60	4	60	5
77	7	75	8
80	9	65	7
95	14	87	13
64	5	78	11

(a) Ignore the variable (x) and carry out a One-Way Analysis of Variance to determine whether there is a significant difference in mean marketable yield of the two varieties at the 5% level of significance. [**6**]

(b) Considering the variable (x), perform the appropriate analysis to test whether there is a significant difference in mean marketable yield of the two varieties. Use the 5% level of significance. Compare your conclusion here with that in (a) and explain the difference if any. [**14**]

B5. The data in Table 5 are the percent effectiveness of a pain reliever and the amounts of three different medications (in milligrams) present in each capsule.

Table5: Percent effectiveness, **y** and amounts (in mg) of $\mathbf{x_1}$, $\mathbf{x_2}$, and x_3.

Percent Effectiveness (y)	**Medication A (x_1)**	**Medication B (x_2)**	**Medication C (x_3)**
47	15	20	10
54	15	20	20
70	30	30	10
76	15	30	20
59	30	20	20
67	30	20	10
71	15	30	10
83	30	30	20

(a) Appropriately code the regressor variables, and then estimate (fit) the multiple linear regression equation:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon.$$ [7]

(b) Partition the regression sum of squares into three single-degree-of-freedom components attributable to x_1, x_2, and x_3, respectively. Construct an analysis of variance table indicating significance tests on each regressor variable. Draw your conclusion. [9]

(c) Compute the standard errors for the four regression coefficients. [4]

B6. A bacteriologist is interested in the effect of two different culture mediums and two different times on the growth of a particular virus. He performs six replicates of a 2^2 factorial experiment, making the runs in random order. The results in Table 6 are obtained.

Table 6: Growth of a particular virus.

	Culture Medium (Factor B)			
Time (Factor A)	**1**		**2**	
20 hr	21 23 20	22 28 26	25 24 29	26 25 27
30 hr	37 38 35	39 38 36	31 29 30	34 33 35

(a) Make a table of signs of contrasts showing treatment combinations in standard order and their totals. [8]

(b) Compute the sums of squares for both main effects and the two factor interaction by the contrast method. [6]

(c) Construct an ANOVA table and test for the significance of main effects and interaction. [6]

B7. The heat evolved in joules per gram of cement, y, is thought to be a function of the amount of each of four ingredients in the mix; *tricalcium aluminate,* x_1, *tricalcium silicate,* x_2, *tetracalcium alumina ferrite,* x_3, and *dicalcium silicate,* x_4. Thirty (30) observations were obtained in the investigation of this functional relationship. All possible linear regression models which included a constant term were examined and their residual sums of squares , RSS_p, are as presented in Table 7.

Table 7: Heat evolved, **y** (in joules per gram), and amounts of $\mathbf{x_1}$, $\mathbf{x_2}$, $\mathbf{x_3}$, and $\mathbf{x_4}$.

Regressors	**p**	**RSS_p**	**C_p**	**S_p**
Constant		1054.80		
x_1		436.35		
x_2		447.22		
x_3		923.98		
x_4		785.65		
x_1x_2		234.90		
x_1x_3		431.09		
x_1x_4		357.25		
x_2x_3		441.77		
x_2x_4		438.49		
x_3x_4		712.22		
$x_1x_2x_3$		214.81		
$x_1x_2x_4$		230.32		
$x_1x_3x_4$		354.51		
$x_2x_3x_4$		435.13		
$x_1x_2x_3x_4$		213.09		

(a) Complete Table 5 above by filling in the p-value and computing the C_p and S_p values. Use the C_p and S_p statistics to select the 'best' linear regression model. **[10]**

(b) Use Forward Selection to select the 'best' model. **[5]**

(c) Use Backward Elimination to select the 'best' model. **[5]**

END OF QUESTION PAPER