

INDIAN STATISTICAL INSTITUTE

End-Semester Examination: 2025–26

M. Tech (QROR) – Second Year, Semester-I (Back-Paper)

Industrial Experimentation

Date:

Maximum Marks: 100

Duration: 3 Hours

Instruction: This question paper consists of three parts. **Part A** is compulsory and comprises twenty short answer type questions, each carrying **one mark**. In **Part B**, candidates are required to answer **any twelve questions out of fourteen**, with each question carrying **five marks**. **Part C** contains numerical questions; candidates must answer **any one question out of two**. F-Table is available on the last page of this question

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Part -A

(Answers all questions in Part-A, each question carries one mark. Answer should be maximum one line)

- i) How many factors are there in a 2^{k-2} fractional factorial design?
- ii) Explain the purpose of including a center point in an experimental design.
- iii) What is the total number of runs in a 2^{k-2} fractional factorial design?
- iv) In fractional factorial design 'defining relation' provides _____.
- v) Identify the problem or flaw in the blocking factorial design given below

Treatment Combination	A	B	Block
l	-1	-1	1
a	1	-1	1
b	-1	1	2
ab	1	1	2

- vi) In fractional factorial design, minimum number of runs is determined based on _____.
- vii) In an orthogonal factorial design, the 'identity element (*I*)' includes only _____ sign.
- viii) The fraction of a full factorial design with $I = +ABC$ usually called as _____.
- ix) In a fractional factorial design alias structure can be found from _____.
- x) In a fractional factorial design, resolution indicates the degree to which the effects are _____ with each other.
- xi) A 2^{5-1} fractional factorial design has been created with five factors *A*, *B*, *C*, *D* and *E* considering the generator as $E=ACD$. The resolution of the design will be _____.

- xii) Plackett and Burman design can be used to run a 2^4 -factorial design. True/False.
- xiii) _____ cannot be estimated in a nested design where factor B is nested under A.
- xiv) A L_8 orthogonal array is used to estimate the main effects of factor A, B and C, and interaction effects AB, AC and BC. Then _____ number of columns in the array will be used for error estimation.
- xv) The Number of columns in a L_{16} OA is _____.
- xvi) The path of steepest ascent always passes through _____ point.
- xvii) The direction of steepest ascent is _____ to the fitted response.
- xviii) In the method of steepest ascent, the presence of a significant quadratic term indicates that we are near the _____.
- xix) The total number of nodes and connecting line in a linear graph associated with L_{16} orthogonal array is equal to _____.
- xx) A L_{12} OA cannot estimate _____.

Part-B

(Answer any 12 questions out of 14. Each question carries 5 marks)

- 1) An experiment was conducted using three factors, **A**, **B** and **C**, each at two levels. The experimental results of the unreplicated 2^3 factorial design in various treatment combinations are given below:

$$(1) = 5; a = 4; b = 6; ab = 3; c = 1; ac = 2, bc = 4, abc = 3$$

Sketch the **AB** interaction plot.

[5]

- 2) Using the data provided in **Question 1**, calculate the main effect of factor **A** and **C**

[5]

- 3) Based on the experimental data given in **Question 1**, determine the constant (intercept) of the fitted regression model."

- 4) An experiment involves three factors—A, B, and C—each at two levels. Only four runs can be performed per day. Considering the day as a block, construct an unreplicated full factorial design incorporating blocking.

[5]

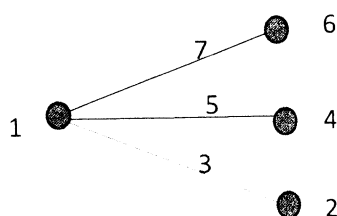
- 5) In a 2^2 factorial design, temperature and pressure are considered as two factors. The temperature levels are 60°C (low) and 80°C (high), while the pressure levels are 20 kg (low) and 30 kg (high). Determine the coded values corresponding to the actual conditions of temperature = 78°C and pressure = 28 kg.

[5]

- 6) Explain the concept of blocking in a factorial design with a suitable real-life example. [5]
- 7) Show the alias structures of factors A, B, C, D , and E in fractional factorial designs of Resolutions III, IV , and V . [5]
- 8) Explain the concept of partial confounding and illustrate it with a suitable example of a factorial design. [5]
- 9) An experimenter plans to conduct an experiment with ten two-level factors ($A, B, C, D, E, F, G, H, I$). The objective is to study all the main effects and the interaction effects AD, AG, BC, AC , and BE . Sketch the required linear graph (RLG). [5]
- 10) An experimenter plans to conduct an experiment with four two-level factors A, B, C , and D — using a 2^{4-1} fractional factorial design with the generator $B = ACD$. Show the primary fraction of this design. [5]
- 11) Construct a 2^{5-2} fractional factorial design for five factors — A, B, C, D , and E — using the generators $D = AB$ and $E = BC$. Determine the resolution of the resulting design. [5]
- 12) A manufacturing engineer is studying the dimensional variability of component that is produced on two machines. Each machines have two spindles. Two components are randomly selected from each spindle. The results are shown below. Determine the interaction effect between machine and spindle.

	Machine-1		Machine-2	
Spindle	1	2	1	2
2	1	2	2	0
1	0	1	1	2

- [5]
- 13) In an experimental investigation involving five two-level factors (A, B, C, D, E), it is required to study the main effects as well as the interactions $A \times B$, and $A \times E$. Using the given linear graph for the L_8 orthogonal array, allocate the factors and the specified interactions appropriately on the column of the array.



- 14) The sums of two replicates from a 2^3 factorial experiment are given below. Draw the interaction plot for the factors A and B (AB interaction).

Treatment combination	Sum of three replication (I+II)
(1)	7
a	10
b	11
ab	14
c	12
ac	11
bc	16
abc	12

[5]

Part-C

(Answer any one question from Questions 15 and 16.)

- 15) An experiment was conducted in a chemical plant to improve yield. Three factors, each at two levels, were studied. The factors and their levels are as follows:

A: Pressure (15 kg, 25kg)

B: Reaction time (60 s, 80 s)

C: Temperature (40°C, 50°C)

A 2^3 factorial experiment was conducted with two replications. The observed responses for each treatment combination are given below:

(1) = 2,1 ; a = 6,7 ; b = 1,2 ; c = 5,6 ; ab = 6,8 ; ac = 3,4 ; bc = 8,9 ; abc = 2,1

- Sketch main effects and two factor interaction plots.
- Determine the optimum operating conditions based on the above plots.

[10+10]

16) To improve the process yield, five two-level factors — A, B, C, D, E, in a manufacturing process for an integrated circuit were investigated. The experimenter is interested in estimating the main effects and the interactions: AC, BC, , and DE.

(a) Allocate the main effects and specified interactions to an L_{16} orthogonal array by suitably modifying the standard linear graph (SLG) provided below.

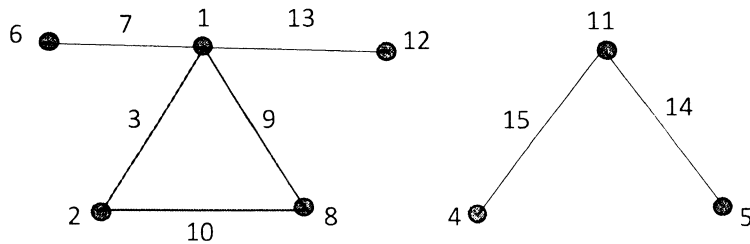


Fig: Standard Linear graph for L16 OA

b) Calculate main effects and required interaction effects if the unreplicated responses corresponding to the 16 runs of the L_{16} orthogonal array are as follows:

2, 3, 8, 12, 6, 4, 14, 18, 6, 1, 4, 10, 11, 14, 16, 12.

Table: L16 Orthogonal Array

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
3	1	1	1	2	2	2	2	1	1	1	1	2	2	2	2
4	1	1	1	2	2	2	2	2	2	2	2	1	1	1	1
5	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2
6	1	2	2	1	1	2	2	2	2	1	1	2	2	1	1
7	1	2	2	2	2	1	1	1	1	2	2	2	2	1	1
8	1	2	2	2	2	1	1	2	2	1	1	1	1	2	2
9	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
10	2	1	2	1	2	1	2	2	1	2	1	2	1	2	1
11	2	1	2	2	1	2	1	1	2	1	2	2	1	2	1
12	2	1	2	2	1	2	1	2	1	2	1	1	2	1	2
13	2	2	1	1	2	2	1	1	2	2	1	1	2	2	1
14	2	2	1	1	2	2	1	2	1	1	2	2	1	1	2
15	2	2	1	2	1	1	2	1	2	2	1	2	1	1	2
16	2	2	1	2	1	1	2	2	1	1	2	1	2	2	1

[10+10]

Table V. Critical values for F-test for Alpha = 0.05

	Numerator Degrees of Freedom										
	1	2	3	4	5	6	7	8	9	10	
Denominator Degrees of Freedom	1	161.45	199.50	215.71	224.58	230.16	233.99	236.77	238.88	240.54	241.88
	2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40
	3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79
	4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96
	5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74
	6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06
	7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64
	8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35
	9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14
	10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98
	11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85
	12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75
	13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67
	14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60
	15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54
	16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49
	17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45
	18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41
	19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38
	20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35
	21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32
	22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30
	23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27
	24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25
	25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28	2.24
	26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22
	27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20
	28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19
	29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18
	30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16
	∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83