Exercises for Lectures 7-9

1. Suppose there are 3 farrows of pigs B1-B3. In each farrow, there are 3 pigs. Feed the 3 pigs in each farrow with different kinds of forages A1-A3. The added weights of the pigs are as follows:

Forage	Farrow		
	B1	B2	B3
A1	1.26	1.21	1.19
A2	1.29	1.23	1.22
A3	1.38	1.27	1.23

Use ANOVA to show if the kinds of forage and farrows have significant impact on the weights.

2. Consider 3 rice varieties A1, A2 and A3. Plant them in three densities B1, B2 and B3. For each combination, we have 3 replications. The data of yield is as follows:

Rice variety	Replication	Planting density		
		B1	B2	B3
A1	Rep1	8	7	6
	Rep2	8	7	5
	Rep3	8	6	6
A2	Rep1	9	7	8
	Rep2	9	9	7
	Rep3	8	6	6
A3	Rep1	7	8	10
	Rep2	7	7	9
	Rep3	6	8	9

Use ANOVA to show if the rice variety and planting density have impact on the yields. Are there any significant interactions between variety and density?

3. Suppose there are 3 cages, and 4 mosquitoes within each cage. Here are the 2 independent measurements per mosquito.

Cage I				Cage II				Cage III			
1	2	3	4	1	2	3	4	1	2	3	4
58.5	77.8	84.0	70.1	69.8	56.0	50.7	63.8	56.6	77.8	69.9	62.1
59.5	80.9	83.6	68.3	69.8	54.5	49.3	65.8	57.5	79.2	69.2	64.5

Compute ANOVA for the observed data. Then compute the errors for two factors.

4. A research engineer studied the time efficiency of four construction methods (A, B, C, D) for an electronic component. Four technicians were selected for the study. The construction

process produces fatigue such that the required construction time by the technicians increases as they change from one method to another regardless of the order of construction methods. The engineer used a Latin square design with columns as "technician" and row as "time period". The construction methods were randomized to the technicians and time periods according to the Latin square arrangement. The values are construction times in minutes required for the component with the construction method indicated in parentheses.

Time period	Technician			
	1	2	3	4
1	90 (C)	96 (D)	84 (A)	88 (B)
2	90 (B)	91 (C)	96 (D)	88 (A)
3	89 (A)	97 (B)	98 (C)	98 (D)
4	104 (D)	100 (A)	104 (B)	106 (C)

(1) Compute ANOVA for the observed data. (2) Then compute the errors for treatment means. (3) Compute the relative efficiency.

5. Make a Latin square design with 5 levels of treatments A-E.

6. Make a BIBD with 5 treatments (A-E) in 10 blocks of 2 experimental units each.

7. A horticulturalist studied the germination of tomato seed with four different temperatures (25℃, 30℃, 35℃ and 40℃) in a balanced incomplete block design because there were only two growth chambers available for the study. Each run of the experiment was an incomplete block consisting of the two growth chambers as the experimental units (k=2). Two experimental temperatures were randomly assigned to the chambers for each run. The data that follow are germination rates of the tomato seed.

Run	25℃	30℃	35℃	40℃
1	24.65	-	-	1.34
2	-	24.38	-	2.24
3	29.17	21.25	-	-
4	-	-	5.90	1.83
5	28.90	-	18.27	-
6	-	25.53	8.42	-

Compute ANOVA for the observed data.

8. An incomplete block design consists of the following arrangement of blocks (1, 2, 3, 4, 5) and treatments (A, B, C, D, E).

Block		
	1	(B, C, D, E)
	2	(A, B, D, E)
	3	(A, C, D, E)
	4	(A, B, C, D)
	5	(A, B, C, E)

(1) What are the design parameters *t*, *r*, *k* and *b*? (2) Verify that the design is balanced.

9. Make an orthogonal design which considers 4 factors A, B, C and D. For each factor, there are 2 levels. Here we will not consider interactions.

10. Make an orthogonal design which considers 3 factors A, B and C. For each factor, there are 2 levels. Here we will only consider interaction AxC. In the design, the three factors should be in Column 1, 2 and 4.

11. In an orthogonal design $L_9(3^4)$, there are 4 factors A, B, C, and D. Each factor has 3 levels. y is the observation. The design is as follows:

Trial	Factor				Observation (y)
	A	B	C	D	
1	1	1	1	1	31
2	1	2	2	2	54
3	1	3	3	3	38
4	2	1	2	3	53
5	2	2	3	1	49
6	2	3	1	2	42
7	3	1	3	2	57
8	3	2	1	3	62
9	3	3	2	1	64

Compute ANOVA for the observed data. Here we will not consider any interactions.

12. In an orthogonal design $L_8(2^7)$, there are 4 factors A, B, C and D. Each factor has 2 levels. y is the observation. The design is as follows:

Trial	Factor							Observation (y)
	A	B	AXB	C	AXC		D	
1	1	1	1	1	1	1	1	350
2	1	1	1	2	2	2	2	325
3	1	2	2	1	1	2	2	425
4	1	2	2	2	2	1	1	425
5	2	1	2	1	2	1	2	200
6	2	1	2	2	1	2	1	250
7	2	2	1	1	2	2	1	275
8	2	2	1	2	1	1	2	375

Compute ANOVA for the observed data. Here we will consider interactions AxB and AxC.