01. In order to determine whether there is significant difference in the durability of 3 makes of computers, sample size 5 are selected from each make and the frequency of repair during the first year of purchase is observed. The Results are as follows.

makes

A	B	C
5	8	7
6	10	3
8	11	5
9	12	4
7	4	1

In view of the above data, what conclusion can you draw?

Solution:-

Ho: The 3 makes of computers do not differ in the durability.

H_1: The 3 makes of computers differ in the durability.

Now:

A	B	C
5	8	7
6	10	3
8	11	5
9	12	4
7	4	1
35	45	20

TOTAL = 100

Correction factor $= \frac{T^2}{N} = \frac{(100)^2}{15} = 666.66$

TOTAL sum of squares of all Items $= 5^2+6^2+8^2+9^2+7^2+8^2+10^2+11^2+12^2+4^2+7^2+3^2+5^2+4^2+1^2$ − Correction factor

$= 800 - 666.66 = 133.34$

Total Sum of squares Between makes $= \frac{(35)^2}{5} + \frac{(45)^2}{5} + \frac{(20)^2}{5} - CF$

$= 730 - 666.66 = 63.34$

TOTAL Sum of squares with in makes

= TOTAL Sum of Squares — (Total sum of squares Between makes

= 133·34 — 63·34 = 70

ANOVA TABLE

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE VALUE	F-RATIO
Between Makes	63·34	3 − 1 = 2	$\frac{63.34}{2} = 31.67$	$\frac{31.67}{5.83}$
With in Makes	70	12	$\frac{70}{12} = 5.83$	= 5·43

From F tables, $F_{5\%}\ (\nu_1 = 2,\ \nu_2 = 12) = 3.88$.

Since the calculated value of F is greater than the table value, Hence Null hypothesis Rejected. (i.e.) There is significant difference in the durability of the 3 makes of computers.

Q2. A company appoints 4 salesman A, B, C and D and observes their sales in 3 seasons summer, winter and monsoon. The figures (in lakhs of Rs) are given in the following table.

Season	A	B	C	D
	Salesman			
Summer	36	36	21	35
Winter	28	29	31	32
monsoon	26	28	29	29

Carry out an analysis of variance.

Solution:

Ho :- [Rows] :- There is no significant difference Between the sales and seasons.

Ho :- [columns] :- There is no significant difference Between the sales and salesman.

Subtract 30 from all the elements, we get:

Season	Salesman A	B	C	D	TOTAL
Summer	6	6	−9	5	8
Winter	−2	−1	1	2	0
Monsoon	−4	−2	−1	−1	−8
	0	3	−9	6	Grand total = 0

Correction Factor $= \frac{0^2}{12} = 0$

TOTAL sum of squares for all Items

$= 6^2 + 6^2 + (-9)^2 + (5)^2 + (-2)^2 + (-1)^2 + (1)^2 + (2)^2$

$+ (-4)^2 + (-2)^2 + (-1)^2 + (-1)^2 - CF$

$= 210 - 0 = 210$

TOTAL sum of Squares Between Rows (Seasons)

$= \frac{8^2}{4} + \frac{0^2}{4} + \frac{(-8)^2}{4} - 0$

$= 32 - 0 = 32$

TOTAL sum of squares Between Columns (Salesman)

$= \frac{0^2}{3} + \frac{3^2}{3} + \frac{(-9)^2}{3} + \frac{(6)^2}{3} - CF$

$= 42 - 0 = 42$

Residual $= TSS - (TSR + TSC) = 210 - (32+42) = 136.$

ANOVA TABLE

SOURCE OF VARIATION	TOTAL SUM OF SQUARES	DEGREES OF FREEDOM	Mean Square Value	F - Ratio
BETWEEN ROWS	32	3−1 = 2	$\frac{32}{2} = 16$	$F_R = \frac{22.66}{16} = 1.4162$
BETWEEN columns	42	4−1 = 3	$\frac{42}{3} = 14$	
Residual	136	6	$\frac{136}{6} = 22.66$	$F_C = \frac{22.66}{14} = 1.6185$

From F Tables, $F_{5\%}$ $(v_1 = 6, v_2 = 2)$ = 19.32

From FTables $F_{5\%}$ $(v_1 = 6, v_2 = 3)$ = 8.94.

Since the calculated value of F (Rows and columns) is with in the table value, Hence H_0 is accepted. (ie) There is no significant difference Between the Sales and Season ; and sales and Salesman.

Q3. The following data represent the number of units of Production Per day turned out by 5 different workers using 4 different types of Machines.

		Machine Type			
		A	B	C	D
Workers	1	44	38	47	36
	2	46	40	52	43
	3	34	36	44	32
	4	43	38	46	33
	5	38	42	49	39

a) Test whether the five men differ with Respect to mean Productivity.

b) Test whether the Mean Productivity is the same for the four different Machine types.

Solution:

H_0 :- (Rows) :- Five workers do not differ significantly with Respect to Mean Productivity.

H_0 :- (columns) :- Four different Machines do not differ significantly with Respect to Mean Productivity.

we subtract 40 from the given values, we get :

		Machine Type				
		A	B	C	D	TOTAL
Workers	1	4	−2	7	−4	5
	2	6	0	12	3	21
	3	−6	−4	4	−8	−14
	4	3	−2	6	−7	0
	5	−2	2	9	−1	8
	TOTAL	5	−6	38	−17	Grand Total = 20

Correction factor

$= \frac{T^2}{N}$

$= \frac{20^2}{20}$

$= 20$

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The Total Sum of Squares of all Items

$$= 4^2 + (-2)^2 + 7^2 + (-4)^2 + (6)^2 + (0)^2 + 12^2 + 3^2 + (-6)^2 + (-4)^2 + 4^2 + (-8)^2$$
$$+ 3^2 + (-2)^2 + 6^2 + (-7)^2 + (-2)^2 + 2^2 + 9^2 + (-1)^2 \text{ — Correction factor}$$

$$= 594 - 20 = 574.$$

TOTAL Sum of Squares Between Rows

$$= \frac{5^2}{4} + \frac{21^2}{4} + \frac{(-4)^2}{4} + \frac{(10)^2}{4} + \frac{(8)^2}{4} - CF$$

$$= 181.5 - 20 = 161.5$$

TOTAL Sum of Squares Between columns

$$= \frac{5^2}{5} + \frac{(-6)^2}{5} + \frac{38^2}{5} + \frac{(-17)^2}{5} - CF$$

$$= 358.8 - 20 = 338.8$$

Residual $= 574 - (161.5 + 338.8)$

$= 73.7$

ANOVA TABLE

Source of variation	Sum of squares	Degrees of freedom	Mean square	F-Ratio.
Between Rows	161.5	$5-1 = 4$	$\frac{161.5}{4} = 40.375$	$F_R = \frac{40.375}{6.142} = 6.57$
Between columns	338.8	$4-1 = 3$	$\frac{338.8}{3} = 112.933$	$F_C = \frac{112.933}{6.142} = 18.39$
Residual	73.7	12	$\frac{73.7}{12} = 6.142$	

From F Tables; $F_{5\%} (v_1 = 4, v_2 = 12) = 3.26$

$F_{5\%} (v_1 = 3, v_2 = 12) = 3.49$

Since the calculated value of F is greater than the table value. Hence H_0 is Rejected. Hence the 5 workers differ significantly and 4 Machine types also differ significantly with Respect to mean Productivity.

04. The following data resulted from an experiment to compare three burners B_1, B_2 and B_3. A Latin Square design was used as the tests were made on 3 engines and were spread over 3 days. (8)

	Engine 1	Engine 2	Engine 3
Day 1	$B_1 - 16$	$B_2 - 17$	$B_3 - 20$
Day 2	$B_2 - 16$	$B_3 - 21$	$B_1 - 15$
Day 3	$B_3 - 15$	$B_1 - 12$	$B_2 - 13$

Test the hypothesis that there is no difference Between the burners.

Solution:.

We subtract 16 from the given values, we get

	E_1	E_2	E_3	TOTAL
D1	0	1	4	5
D2	0	5	-1	4
D3	-1	-4	-3	-8
Total	-1	2	0	Grand TOTAL = 1

Correction factor

$= \frac{T^2}{N} = \frac{1^2}{9} = 0.111$

Total Sum of squares of all Items $= 0^2 + 1^2 + 4^2 + 0^2 + 5^2 + (-1)^2 + (-1)^2 + (-4)^3 + (-3)^2$ — correction factor

$= 69 - 0.111 = 68.889$

Total Sum of squares Between Rows $= \frac{5^2}{3} + \frac{4^2}{3} + \frac{(-8)^2}{3} - CF$

$= 35 - 0.111 = 34.889$

Total sum of squares Between Columns $= \frac{(-1)^2}{3} + \frac{(2)^2}{3} + \frac{0^2}{3} - CF$

$= 1.67 - 0.111 = 1.559$

Total sum of squares Between treatments (or) letters $= \frac{(-5)^2}{3} + \frac{(-2)^2}{3} + \frac{(8)^2}{3} - \frac{1}{9}$

$= 31 - 0.111$

$= 30.889$

Residual $= 68.899 - (34.889 + 1.559 + 30.889)$

$= 1.552$

ANOVA TABLE

Source of Variations	Sum of Squares	Degrees of Freedom	Mean Square value	F-Ratio
Between Rows (days)	34.889	3−1 = 2	$\frac{34.889}{2} = 17.445$	$F_R = \frac{17.445}{0.775} = 22.51$
Between Columns (engines)	1.559	3−1 = 2	$\frac{1.559}{2} = 0.7795$	$F_C = \frac{0.7795}{0.775} = 1.005$
Between letters (Burners)	30.889	3−1 = 2	$\frac{30.889}{2} = 15.445$	$F_L = \frac{15.445}{0.775} = 19.93$
Residual.	1.552	2	$\frac{1.55}{2} = 0.775$	

F Tables (Rows) $F_{5\%}$ $(v_1 = 2, v_2 = 2) = 19.00$

F Tables (Columns) $F_{5\%}$ $(v_1 = 2, v_2 = 2) = 19.00$

F − Tables (letters) $F_{5\%}$ $(v_1 = 2, v_2 = 2) = 19.00$

Ho : There is no significant difference Between burners.

Since the calculated value of F is greater than the table value, Hence Ho is Rejected. (ie) There is a significant difference Between the Burners.

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05. Analyse the variance in the following Latin Square of yields (in kgs) of Paddy where A, B, C, D denote the different methods of cultivation.

D 122	A 121	C 123	B 122
B 124	C 123	A 122	D 125
A 120	B 119	D 120	C 121
C 122	D 123	B 121	A 122

Examine whether the different methods of cultivation have given significantly different yields.

Solution::

Ho :- (letters):: There is no significant difference between the method of cultivation.

We subtract 120 from the given values, we get :

	1	2	3	4	TOTAL
1	2	1	3	2	8
2	4	3	2	5	14
3	0	-1	0	1	0
4	2	3	1	2	8
TOTAL	8	6	6	10	Grand TOTAL = 30

Correction factor $= \frac{T^2}{N} = \frac{(30)^2}{16} = 56.25$

Total Sum of squares of all Items

$= 2^2 + 1^2 + 3^2 + 2^2 + 4^2 + 3^2 + 2^2 + 5^2 + 0^2 + (-1)^2 + 0^2 + 1^2 + 2^2 + 3^2$

$+ 1^2 + 2^2$ – correction factor

$= 92 - 56.25 = 35.75$

Total sum of squares Between Rows $= \frac{8^2}{4} + \frac{14^2}{4} + \frac{0^2}{4} + \frac{8^2}{4} - 56.25$

$= 81 - 56.25 = 24.75$

Total sum of squares Between Columns $= \frac{8^2}{4} + \frac{6^2}{4} + \frac{6^2}{4} + \frac{10^2}{4} - 56.25$

$= 59 - 56.25 = 2.75$

Total sum of squares Between letters $= \frac{5^2}{4} + \frac{6^2}{4} + \frac{9^2}{4} + \frac{10^2}{4} - CF$

$= 60.50 - 56.25 = 4.25$

Residual $= 35.75 - (24.75 + 2.75 + 4.25)$

$= 4$

ANOVA TABLE :-

SOURCE OF VARIATION	TOTAL SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F-RATIO
BETWEEN ROWS	24·75	4 − 1 = 3	$\frac{24.75}{3} = 8.25$	$F_R = \frac{8.25}{0.67} = 12.3$
Between Columns	2·75	4 − 1 = 3	$\frac{2.75}{3} = 0.92$	$F_C = \frac{0.92}{0.67} = 1.373$
Between letters	4·25	4 − 1 = 3	$\frac{4.25}{3} = 1.42$	$F_L = \frac{1.42}{0.67} = 2.12$
Residual.	4	6	$\frac{4}{6} = 0.67$	

from F Tables $F_{5\%} (V_1 = 3, V_2 = 6) = 4.76$

$F_L = 2.12$

Since the calculated value F is greater than the table value, Hence H_0 is Rejected. (ie) The difference between the methods of cultivation is not significant.

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