Analysis of Variance

(ANOVA)

With TI

What is **ANOVA**?

It is a method used whenever we test for the equality of at least three population means simultaneously.

How do we set up H_0 and H_1 for this method?

$H_0 : \mu_1 = \mu_2 = \mu_3 = \cdots = \mu_k$

$H_1 :$ At least one population mean is different.

ANOVA uses F-distribution and it is always a **Right-Tail Test**.

How do we find df when working with ANOVA ?

$$\text{Ndf} = k - 1$$

$$\text{Ddf} = n - k$$

Where

- k is the number of groups or samples.
- n is the total sample size of all groups or samples.

Example:

The table below shows the number of defects for three models in an assembly line.

Model 1:	5	7	6	6		
Model 2:	5	4	3	5	3	4
Model 3:	7	6	8	9	5	

Find the degrees of freedom for attempting to compare three population means.

Solution:

We begin by finding the following

- $k = 3$ & $Ndf = k - 1 = 2$
- $n = 15$ & $Ddf = n - k = 12$

Example:

Use the last example to test the claim at the 0.02 level of significance that the average number of defects is not the same for the three models.

Solution:

We begin by setting up H_0 and H_1.

$H_0 : \mu_1 = \mu_2 = \mu_3$

$H_1 :$ At least one mean is different. Claim & RTT

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Store the data elements from each group in L_1, L_2, and L_3.

L1	L2	L3 3
5	5	7
7	4	6
6	3	8
6	5	9
------	3	5
	4	

L3(6) =

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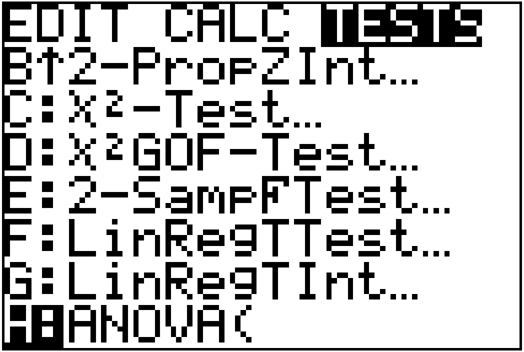
Now press **STAT**, go to **TESTS**, then find **ANOVA**.



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Select **ANOVA**, then enter L_1, L_2, and L_3 separated by comma.

```
ANOVA(L1,L2,L3
```

Press **ENTER** to execute **ANOVA**.

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The display below shows the output by the **ANOVA** command.

```
One-way ANOVA
F=9.65
p=.0031755682
Factor
 df=2
 SS=25.7333333
↓ MS=12.8666667
```

Now we have the P-Value $p = 0.003$. $p-$**value** is less than 0.02 significance level, therefore H_1 is valid, we fail to reject the claim.

Example:

In a biological experiment 4 mixtures of a certain chemical are used to enhance the growth of a certain type of plant over a specific time period. The following growth data, in centimeters, are recorded for the plants that survive.

Mixture 1:	8.2	8.7	9.4	9.2		
Mixture 2:	7.7	8.4	8.6	8.1	8.0	
Mixture 3:	6.9	5.8	7.2	6.8	7.4	6.1
Mixture 4:	6.8	7.3	6.3	6.9	7.1	

Test the claim that there is no significant difference in the average growth of these plants for the different mixtures of the chemical. Use a 0.01 level of significance.

Solution:

We begin by setting up H_0 and H_1.

$H_0 : \mu_1 = \mu_2 = \mu_3 = \mu_4$ Claim

$H_1 :$ At least one mean is different. RTT

- $k = 4$ & $Ndf = k - 1 = 3$
- $n = 20$ & $Ddf = n - k = 16$
- $\alpha = 0.01$

Using **TI** command **ANOVA**, we get the P-Value $p = 8.03 \times 10^{-6}$.

$p-$**value** is less than 0.01 significance level, therefore H_0 is invalid, we reject the claim.

Example:

The following table shows randomly selected exam scores from 4 different colleges of the same exam in the same semester and modality.

Citrus:	80	88	78	68	92	70
Chaffey:	75	84	86	92	65	100
ELAC:	69	88	92	79	100	80
Mt. SAC:	65	78	83	99	100	70

Test the claim that the mean of all exam scores in these colleges are the same.

Solution:

We begin by setting up H_0 and H_1.

$H_0 : \mu_1 = \mu_2 = \mu_3 = \mu_4$ Claim

$H_1 :$ At least one mean is different. RTT

- $k = 4$ & $Ndf = k - 1 = 3$
- $n = 24$ & $Ddf = n - k = 20$
- **No Significance Level Given** & **Use** $\alpha = 0.05$

Using **TI** command **ANOVA**, we get the P-Value $p = .879$.

$p-$**value** is greater than 0.05 significance level, therefore H_0 is valid, we fail to reject the claim.

Example:

Suppose we are given **CTS** $F = 2.678$ for 5 groups and the total size of 50.

- Find the corresponding **p-Value**
- Select α values from $\{0.1, 0.05, 0.02, 0.01\}$ to support H_0.
- Select α values from $\{0.1, 0.05, 0.02, 0.01\}$ to reject H_0.

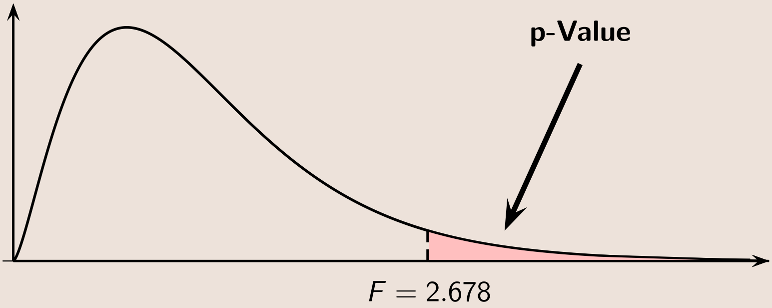
Solution:

We begin by finding **Ndf** and **Ddf**.

- $k = 5$ & $Ndf = k - 1 = 4$
- $n = 50$ & $Ddf = n - k = 45$

We now have necessary information to find the corresponding **p-Value**.

Solution Continued:



p-Value=fcdf(2.678, E99, 4, 45) $\approx$ **0.044**

- To support H_0, we need **p-Value** $> \alpha$ therefore we choose α to be 0.02 or 0.01 from the recommended values.
- To reject H_0, we need **p-Value** $\leq \alpha$ therefore we choose α to be 0.05 or 0.1 from the recommended values.