21/9/17

# MODULE - V

## SMALL SAMPLE TEST

**Definition** :- small sample test is a test statistic, which is used to study the general magnitude of the variation (or) to test the statistical hypothesis about a population parameter by selecting a small sample ($n \leq 30$)

→ The following distributions are good examples for small sampling tests :

(i) Student - t - distribution
(ii) Chi - square distribution (or) $\chi^2$ - distribution
(iii) F - distribution

**Applications of t - distributions** :- some of them are :-

(i) test for mean ($\mu$)
(ii) test for difference of means ($\mu_1 - \mu_2$)
(iii) Paired t - test for difference of means ($\mu_1 - \mu_2$)
(iv) test for correlation coefficient ($\rho$)

**Applications of chi - square distribution** :-

(i) Test for goodness of fit
(ii) Test for independence of attribute
(iii) Test for variance (or) standard deviation

Degrees of freedom Contd ... Similarly, in statistics although observations are independent so independent terms are "n" but if there is any kind of restriction "k" then these restriction should be subtracted so —

## Applications of F-test :-

(i) Test for equality of variances (or) standard deviation ($\sigma_1^2 = \sigma_2^2$)

## TEST FOR SINGLE MEAN (t-test) :-

→ **STEP: 1** Assume $H_0$, there is no significant difference between sample mean and population mean i.e

$$H_0 : \mu = \mu_0$$

v/s

$$H_1 : \mu \neq \mu_0 \quad (\text{- Two tailed})$$

→ **STEP: 2** sample data

$n =$ sample size i.e no of observations

$\bar{x} = \dfrac{\sum x_i}{n}$ i.e mean of the sample

$$\boxed{t = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}}}$$

$\mu =$ mean of the population

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2} \quad (\text{S.D of sample})$$

→ **STEP: 3** degree of freedom $=$ d.f $= n-1$

d.f refers to the number of values involved in the calculation that have the freedom to vary. In other words, it can be defined as the total number of observations minus the number of independent constraints imposed on the observations i.e)

→ **STEP: 4** If $t_{cal} < t_{tab}$, accept $H_0$ i.e conclude that there's no significant difference between sample and population means.

→ **STEP: 4** If $t_{cal} > t_{tab}$, reject $H_0$ i.e we conclude that there's significant difference b/w sample mean and population mean.

→ result degree of freedom becomes "$n-k$"

PROBLEMS :-

1. 10 workers are selected at random, from a large number of workers in a factory. The no of items produced by them on a certain day are found to be 51, 52, 53, 55, 56, 57, 58, 59, 59, 60. In the light of this data would it be appropriate to suggest that the mean number of items produced in the population is 58 at 1% level

Sol:- Let Ho: There's no significant difference b/w sample mean and population mean i.e

$$H_0: \mu = 58;$$

v/s

$$H_1: \mu \neq 58; \quad (\text{- Two tailed})$$

Sample data :- $n = 10$; $\bar{x} = \dfrac{51+52+53+55+56+\cdots+59+60}{10}$

$= 56 \Rightarrow$ Mean

$\mu = 58.$

$$S = \sqrt{\frac{1}{9}\left[(25)+(16)+9+1+0+1+4+9+9+16\right)}$$

$$S = \sqrt{\frac{1}{9}(90)}$$

27
32
31
90

$S = \sqrt{10} \Rightarrow 3.162$

$$t = \frac{(56-58)\sqrt{n}}{S} \Rightarrow \frac{(-2)(3.162)}{3.162} = \underline{\underline{-2}}$$

$d.f = 10-1 \Rightarrow 9.$

3.25

$\therefore t_{tab} = t_{(\frac{0.01}{2}, 9)} =$

$\because t_{cal} < t_{tab}$

Accept Ho

$\therefore$ $t_{cal} < t_{tab}$ . Hence accept $H_0$ i.e There's no significant difference between sample and population mean i.e in the light of this data its appropriate to suggest that mean no of items produced in the population is 58.

23/9/17

$\rightarrow$ Two-Tail & Right tail $\begin{cases} Z_{cal} \leq Z_{tab} \Rightarrow \text{Accept } H_0 \\ Z_{cal} > Z_{tab} \Rightarrow \text{reject } H_0 \end{cases}$

Left Tail $\begin{cases} Z_{cal} \leq Z_{tab} \Rightarrow \text{reject } H_0 \\ Z_{cal} > Z_{tab} \Rightarrow \text{accept } H_0. \end{cases}$

2. A random sample of 10 boys had the following IQ (Intelligent Quotients) 70, 120, 110, 101, 88, 83, 95, 98, 107, 100. Do this data support the assumption of population mean IQ is 100.

Sol:- Let $H_0$ : There's no significant difference between the sample mean IQ and population mean IQ i.e

$H_0$ : $\mu = 100$
v/s
$H_1$ : $\mu \neq 100$ (- Two tailed)

$\bar{x} = 97.2$

$$t = \frac{(\bar{x} - \mu)\sqrt{n}}{S} \Rightarrow \frac{(97.2 - 100)\sqrt{10}}{S}$$

$$= \frac{(97.2 - 100)(3.162)}{}$$

$$S = \sqrt{\frac{1}{9}\left[ 139.84 + 519.84 + 163.84 + 14.44 + 84.64 + 201.64 + 4.84 + 0.64 + 96.04 + 7.84 \right.}$$

$\approx$ 1833.6 / 9 $\Rightarrow$ $S = \sqrt{203.73}$ $\Rightarrow$ $S = 14.27$

$$t = \frac{(97.2 - 100)\,3.162}{14.27}$$

$$t = \frac{2.8 \times 3.162}{14.27}$$

$$= \frac{8.8536}{14.27}$$

$t_{cal} = 0.620$ $\qquad t_{(0.05,\,9)}$

$\therefore$ $\alpha = 0.05\%$ $\quad \therefore$ $\cancel{t_{tab}} = 2.262$

$t_{cal} < t_{tab}$ $\therefore$ Accept $H_0$.

$\therefore$ We conclude that, the given data support the assumption of population mean IQ to be 100.

3. The height of 10 males of a given locality are found to be 70, 67, 62, 68, 61, 68, 70, 64, 64, 66. Is it reasonable to believe that average height is greater than 64 inches.

Sol: Let

$H_0 : \mu = 64$

v/s

$H_1 : \mu > 64$ (→ Right tailed)

$$t = \frac{(\bar{x} - \mu)\sqrt{n}}{s} \Rightarrow \quad \bar{x} = \frac{660}{10} = 66$$

$$= \frac{66 - 64\,(3.162)}{s} = \frac{2\,(3.162)}{s}$$

$$s = \sqrt{\frac{1}{9}(16 + 1 + 16 + 4 + 25 + 4 + 16 + 4 + 4 + 0)}$$

$$= \sqrt{\frac{1}{9}(48 + 16 + 26)}$$

$$\sqrt{\frac{1}{9}(42 + 48)}$$

$$s = \sqrt{\frac{90}{9}}$$

$s = \cdot\cdot$

$\therefore s = \sqrt{10} \Rightarrow$

$$t = \frac{2 \times \cancel{3.162}}{\cancel{3.1620}}$$ $t_{cal} = 2$

$$t_{cal} = \frac{\cancel{0.632}}{2}; \quad \alpha = 5\% \Rightarrow 1.833$$

$$t_{cal} > t_{(0.05, 9)} = 1.833$$

$\therefore$ ~~Accept Ho~~ //. Reject Ho

$\therefore$ We conclude that average is greater than 64 inches.

$$\mu \in \left(\bar{x} - t_{\frac{\alpha}{2}} \cdot \frac{s}{\sqrt{n}},\ \bar{x} + t_{\frac{\alpha}{2}} \frac{s}{\sqrt{n}}\right.$$

## 8. t- test for difference of means :-

Let $H_0$: There's no significant difference b/w two sample means. i.e

$$H_0 : \mu_1 = \mu_2$$

v/s

$$H_1 : \mu_1 \neq \mu_2$$

test statistic :- $$\frac{\bar{x}_1 - \bar{x}_2}{S\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

$\bar{x}_1$ = 1st sample mean ; $\bar{x}_2$ = 2nd sample mean

$$S = \sqrt{\frac{1}{n_1+n_2-2}\left[(n_1-1)S_1^2 + (n_2-1)S_2^2\right]}$$

$$S_1 = \sqrt{\frac{1}{n_1-1}\sum_{i=1}^{n_1}(x_i - \bar{x}_1)^2}$$

$$S_2 = \sqrt{\frac{1}{n_2-1}\sum_{i=1}^{n_1}(x_i - \bar{x}_2)^2}$$

→ If tcal ≤ tTab ⇒ accept $H_0$ else

tcal > tTab ⇒ reject $H_0$.

$\boxed{d.f = n_1 + n_2 - 2}$ (or)

$$S = \sqrt{\frac{1}{n_1+n_2-2}\left[\Sigma(x_i-\bar{x}_1)^2 + \Sigma(x_i-\bar{x}_2)^2\right]}$$

1. Two types of drugs were imposed on 5 and 7 patients, for reducing their weight. The ~~degree~~ decrease in weight after using drugs for 6 months was as follows :-

drug A : 10, 12, 13, 11, 14

drug B : 8, 9, 12, 14, 15, 10, 9

Is there a significant difference in the efficiency of two drugs.

Sol :- Let $H_0$ : There is no significant difference in the efficiency of two drugs i.e

$H_0 : \mu_A = \mu_B$

v/s

$H_1 : \mu_A \neq \mu_B$ (- Two tailed)

$$\bar{x}_A = \frac{10 + 12 + 13 + 11 + 14}{5}$$

$$= \frac{60}{5} \rightarrow 12$$

$$\bar{x}_B = \frac{8 + 9 + 12 + 14 + 15 + 10 + 9}{7}$$

$$= \frac{29 + 29 + 19}{7}$$

$$\bar{x}_B = 11$$

$n_1 = 5$ ; $n_2 = 7$ ; $\alpha = 5\%$

$$\frac{12 - 11}{s\sqrt{\frac{1}{5} + \frac{1}{7}}} = \frac{1}{s\sqrt{\frac{12}{35}}}$$

$$s_1 = \sqrt{\frac{1}{4}(4+0+1+1+4)}$$

$$s_1 = \sqrt{\frac{10}{4}}$$

$$\Sigma(x_i - \bar{x}_1) = 10$$

$$s_1 = \sqrt{\frac{5}{2}}$$

$$s_1 = \sqrt{2.5}$$

$$s_1 =$$

$$\Sigma(x_i - \bar{x}_2)^2 = 9+4+1+9+16+1+4$$

$$= 44$$

$$\therefore s = \sqrt{\frac{1}{10}(10+44)}$$

$$s = \sqrt{\frac{54}{10}}$$

$$s = \sqrt{5.4}$$

$$s = 2.324$$

$$t_{cal} = \frac{1}{2.324 \times \sqrt{0.342}}$$

$$= \frac{1}{2.324 \times 0.584}$$

$$= \frac{1}{1.357}$$

$$t_{cal} = 0.735$$

d.f. $n_1 + n_2 - 2$ , $t_{tab}(0.05, 10) = 2.228$

$\therefore$ $t_{cal} < t_{tab}$

Accept $H_0$

$\therefore$ There's no significant difference in efficiency of two drugs.

25/9/17

3. In a test given to two groups of students, the marks obtained are as follows:-

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| I group : | 18 | 20 | 36 | 50 | 49 | 36 | 34 | 49 | 41 |
| II group : | 29 | 28 | 26 | 35 | 30 | 44 | 46. | | |

Examine the significance of difference b/w the arithmetic mean of the marks obtained by the students of the two groups.

Sol:- Let $H_0$: There's no significance difference b/w the A.M's of the two groups.

i.e $H_0$: $\mu_1 = \mu_2$

v/s

$H_1 : \mu_1 \neq \mu_2$ (- Two tailed)

$n_1 = 9$ ; $n_2 = 7$

$df = 9 + 7 - 2 = 14$

$$\bar{x}_1 = \frac{18 + 20 + 36 + 50 + 49 + 36 + 34 + 49 + 41}{9} = \frac{333}{9}$$

$$= 37$$

$$\bar{x}_2 = \frac{29 + 28 + 26 + 35 + 30 + 44 + 46}{7}$$

$$= \frac{238}{7} = 34$$

$\therefore$ $S = \sqrt{\frac{1}{n_1+n_2-2}\left[\sum_{i=1}^{9}(x_i-\bar{x}_1)^2 + \sum_{j=1}^{7}(x_j-\bar{x}_2)^2\right.}$

$\sum_{i=1}^{9}(x_i-\bar{x}_1)^2 = 1134$ ; $\sum_{j=1}^{7}(x_j-\bar{x}_2)^2 = 386$

$S = \sqrt{\frac{1}{14}(1134+386)}$

$= \sqrt{\frac{1}{14}(1520)}$

$= \sqrt{108.571}$

$\simeq 10.42$

$\therefore$ Test statistic $(t) = \frac{\bar{x}_1-\bar{x}_2}{S\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} = \frac{37-34}{10.42\sqrt{\frac{1}{9}+\frac{1}{7}}}$

$= 0.571$

$\alpha = 5\%$

$\therefore t_{Tab} = t_{(0.05,\,14)} = 2.145$

$t_{cal} = .571$ ; $t_{tab} = 2.145$

$t_{cal} < t_{tab}$ $\therefore$ Accept $H_0$

$\therefore$ There's no significance difference between the A.M's of the two groups of students.

3: Samples of two types of electrical light bulbs were tested for length of light and follo data was obtained.

| | Type - I | Type - II |
|---|---|---|
| Sample no | $n_1 = 8$ | $n_2 = 7$ |
| " mean | $\bar{x}_1 = 1234$ hrs | $\bar{x}_2 = 1036$ hrs |
| " S.D's | $s_1 = 36$ hrs | $s_2 = 40$ hrs. |

Is the difference in the means sufficient to warrant that type I is superior to type - II regarding length of light.

Sol:

$H_0 : \mu_I = \mu_2$

v/s

$H_1 : \mu_1 > \mu_2$

$$S = \sqrt{\frac{1}{n_1+n_2-2}\left((n_1-1)s_1^2 + s_2^2(n_2-1)\right)}$$

$$= \sqrt{\frac{1}{13}\left((7)(1296) + 1600(6)\right)}$$

$$\sqrt{\frac{1}{13}\left[(9072) + 9600\right]}$$

$$\simeq \sqrt{\frac{18\cancel{1174}672}{13}}$$

$\cancel{\sqrt{1435.69}}$

$S \cancel{= 37.35}$

$\simeq$

$\sqrt{1436.30} = 37.89$

test statistic $= \dfrac{\bar{x}_1 - \bar{x}_2}{S\left(\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}\right)}$

$$= \frac{1234 - 1036}{37.89\left(\sqrt{\frac{1}{8} + \frac{1}{7}}\right)}$$

$$= \frac{198}{37.85\sqrt{\frac{15}{56}}}$$

$$= \frac{198}{37.35\,(0.516)}$$

$$= \frac{198}{19.27}$$

$$= \cancel{10.27}\ 10.09$$

$\therefore\ t_{cal} = 10.09,\quad t_{tab} = 1.77$

$\therefore\ t_{cal} > t_{tab}$ (Reject $H_0$)

$\therefore$ Type - I average is superior than Type - II regarding the length.

## PAIRED T-TEST FOR DIFFERENCE OF MEANS ($\mu_1 - \mu_2$) :-

→ It can be used to test the significant difference between the hypothetical mean differences of given population, under the following assumptions.

(i) The sample observations are not independent.

(ii) The sample observations are paired and equal.

(iii) Test procedure :-

Let Ho : There's no significant difference between the hypothetical means of a population ~~under the above Two~~ i.e

$H_0: \mu_1 = \mu_2$

v/s

$H_1: \mu_1 \neq \mu_2$ (- Two tailed)

Sample data :-

Sample size :- $n_1 = n_2 = n$

" observations :- $x_i, y_i$. Here $d_i = x_i - y_i$

and $\bar{d} = \bar{x} - \bar{y}$

∴ test statistic $\boxed{(t) = \dfrac{\bar{x} - \bar{y}}{S/\sqrt{n}} \text{ (or) } \dfrac{(\bar{d})\sqrt{n}}{S}}$

where $S^2 = \dfrac{1}{n-1} \sum (d_i - \bar{d})^2$

degree of freedom = $n-1$

∴ If $t_{cal} \leq t_{tab}$ accept Ho otherwise reject Ho.

Confidence limits :- If $\mu_1 - \mu_2$ is unknown then, its estimated by

$$\boxed{\mu_1 - \mu_2 \in \left( \bar{d} - t_{\alpha/2} \cdot \frac{s}{\sqrt{n}}, \bar{d} + t_{\alpha/2} \cdot \frac{s}{\sqrt{n}} \right)}$$

1. From a class of a college, the sample of 10 students are selected at random, and found to be, slow learners. The marks obtained by them before and after special classes are given below :-

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Student No :- | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Before Test :- | 0 | 1 | 3 | 4 | 4 | 5 | 6 | 0 | 3 | 7 |
| After Test :- | 7 | 8 | 6 | 10 | 8 | 8 | 10 | 12 | 11 | 9 |

Test that with the help of the special classes, the average performance of students is improved at 5% level.

Sol :- Let $H_0$ : The performance of students is same before and after test

$H_0 : \mu_1 = \mu_2$ ;

v/s

$H_1 : \mu_1 < \mu_2$

$n = 10$

$$\bar{x} = \frac{1+3+4+4+5+6+7+7}{10}$$

$$= 3.3$$

$$\bar{y} = \frac{7+8+6+10+8+8+10+12+11+9}{10}$$

$$= 8.9$$

$d_i = x_i - y_i$

$= -7; -7; -3; -6; -4, -3; -4, -12, -8, -2$

$\bar{d} = \bar{x} - \bar{y} = -5.6$

$d_i - \bar{d} \Rightarrow -1.4, -1.4, 2.6, -0.4, 1.6, 2.6, 1.6,$

$-6.4, -2.4, 3.6$

$(d_i - \bar{d})^2 = 1.96, 1.96, 6.76, 0.16, 2.56, 6.76, 2.52,$

$40.96, 5.76, 12.96$

$$\Sigma(d_i - \bar{d})^2 = 82.4 \Rightarrow S = \sqrt{\frac{\Sigma(d_i-\bar{d})^2}{n-1}} = \sqrt{\frac{82.4}{10-1}} = \sqrt{10}$$

$$t = \frac{56-58}{\sqrt{10}/\sqrt{10}} = -2$$

$d.f = \nu = n-1 = 10-1 = 9$

$\therefore\ t_{Tab} = t_{(0.01,\ 9)} = \cancel{2.821}\ -1.83$

$t_{cal} \leq t_{tab}$

Ho is rejected in left tail

$\therefore$ t cal <

$\therefore$ We conclude that, there's improvement in average performance of student, w.r.t special classes at 5% level.

26/9/17

Q. A certain stimulus administered to each of the 12 patients, resulted in the following increase of blood pressure.

B.P: 5, 2, 8, -1, 3, 0, -2, 1, 5, 0, 4, 6. Can it be concluded that, this stimulus will in general be accompanied by an increase in blood pressure.

Sol:- Let Ho: There is no significant difference in the blood pressure readings of the patients before and after the drug.

i.e

$H_0: \mu_x = \mu_y$

V/S

$H_1: \mu_x < \mu_y$ ( Left ~~Right~~ Tailed

Sample data:- $n = 12$ ;

$d$: 5, 2, 8, -1, 3, 0, -2, 1, 5, 0, 4, 6

$d^2$: 25, 4, 64, 1, 9, 0, 4, 1, 25, 0, 16, 36

$$\boxed{s^2 = \frac{1}{n-1} \Sigma (d - \bar{d})^2 = \frac{1}{n-1} \left\{ \Sigma d^2 - \frac{(\Sigma d)^2}{n} \right\}}$$

$d = 31$ ; $d^2 = 185$

$$s^2 = \frac{1}{11} \left[ 185 - \frac{(31)^2}{12} \right]$$

$$= \frac{1}{11} \left[ \cancel{\frac{1850 - 961}{10}} \right]$$

$$= 9.5382 \Rightarrow s = \sqrt{9.5382}$$

$\therefore$ $\bar{d} = \frac{\Sigma d}{n} = \frac{31}{12} = 2.58.$

$\therefore$ Test statistic $t = \frac{\bar{d} \cdot \sqrt{n}}{s} = \frac{2.58 \times \sqrt{12}}{\sqrt{9.5382}}$

$t$ cal = 2.89

d.f = $n - 1 = 12 - 1 = 11$

L.O.S $\alpha$ = 5% = 0.05

$\therefore$ $t_{(0.05,\ 11)} = -1.796 = t_{tab}$

$\therefore$ $t$ cal > $t$ tab

Accept $H_0$

$\therefore$ There's no significant difference in blood pressure readings of the patients before and after the drug.

H.W

3. From a survey, the following sample difference of deviations are obtained as

$d_i$: $-3, -2, -1, 0, 1, 2, 3, 4, -5, 6$. Test that is there any difference of means

$d_i = x_i - y_i$ at 1% LOS.

## $\chi^2$ - square distribution :-

→ The square of a standard Normal Variate is known as a chi - square variate. with one degree of freedom.

→ i.e $\chi^2 = \left(\frac{x-\mu}{\sigma}\right)^2$ is a chi - square variate with one degree of freedom.

similarly $\chi^2 = \sum_{i=1}^{n} \left(\frac{x_i - \mu_i}{\sigma_i}\right)^2$ is a chi - square variate with n degree of freedom.

→ Chi - square measures the deviation of between observed and expected frequencies.

### i) Chi - square Test for goodness of fit :-

→ The value of $\chi^2$ is used to test whether the deviations of the observed frequencies from the expected frequencies are significant or not.

→ It is also used to test how will a set of observations fit a given distribution.

PROCEDURE :-

Step : 1 Ho: There's no significant difference between observed and expected frequencies.

Step : 2 Sample size = n ($\leq 30$)

$d.f = n-1$

Step : 3 test statistic $\chi^2_{cal} = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$

Step : 4 Conclusion :- Compute and Compare $\chi^2$ calculated, $\chi^2$ tab.

Step : 5 If $\chi^2_{cal} < \chi^2_{tab}$, then accept Ho

i.e there's no significant difference between observed and expected frequencies and fit is considered to be good.

→ If $\chi^2_{cal} > \chi^2_{tab}$, then reject Ho, i.e there's significant difference between observed frequencies and expected frequencies and fit is considered to be poor.

5/10/17

NOTE :-

(i) In general, theoretical or expected frequencies are unknown which are calculated by using some fitting procedures etc.

(ii) If any one individual frequency is less than 5, then it is adjusted by nearer to frequency which is greater than ($\geq$) 5.

In this case, the d.f can be reduced by the total degree of freedom and number of frequencies less than five. i.e

$$\boxed{d.f = (n-1) - (\text{no of frequencies} \leq 5)}$$

PROBLEMS :-

1. The demand for a particular spare part in a factory was found to vary from day to day. In a sample study, the following information was obtained

| Days :- | Mon | Tue | Wed | Thu | Fri | Sat |
|---|---|---|---|---|---|---|
| No. of parts demanded : | 1124 | 1125 | 1110 | 1120 | 1126 | 1115 |

Test the hypothesis that the number of spare parts demanded doesn't depend on day of the ~~week~~ week.

Sol :- Let Ho : There's no significant ~~metho~~ difference b/w $O_i$'s and $E_i$'s.

i.e

Ho : Number of spare parts demanded doesn't depend on the day of the week i.e $H_0 : \Sigma O_i = \Sigma E_i$

v/s

$H_1 : \Sigma O_i \neq \Sigma E_i$ (- Two Tail)

Under $H_0$; Expected frequencies are given by

$$E_i = \frac{1124 + 1125 + 1110 + 1120 + 1126 + 1115}{6}$$

$$= \frac{6720}{6}$$

$$E_i = 1120$$

1124
1125
1110
1120
1126
1115
6720

| Days | $O_i$ | $E_i$ | $(O_i - E_i)^2$ | $(O_i - E_i)^2 / E_i$ |
|---|---|---|---|---|
| Mon | 1124 | 1120 | 16 | 0.014 |
| Tue | 1125 | 1120 | 25 | 0.022 |
| Wed | 1110 | 1120 | 100 | 0.089 |
| Thu | 1120 | 1120 | 0 | 0 |
| Fri | 1126 | 1120 | 36 | 0.032 |
| Sat | 1115 | 1120 | 25 | 0.022 |
| | | | | Total = 0.179 |

$$\sum \frac{(o_i - e_i)^2}{e_i} = 0.179$$

$$\therefore \chi^2_{cal} = \sum_{i=1}^{6} \frac{(O_i - E_i)^2}{E_i} = 0.179$$

d.f = 6 − 1 = 5 ; $\alpha = 5\%$ ⇒ ~~$\alpha/2$ = 2.5% = 0.025~~

$$\therefore \chi^2_{tab} = \chi^2_{(0.025,\ 5)} = 11.07$$

$\therefore \chi^2_{cal} < \chi^2_{tab} \quad \therefore$ Accept $H_0$

$\therefore$ ~~there's no~~ Number of spare parts demanded doesn't depend on the day of the week.

Q. The number of road accidents in various days of a week in a city were 14, 16, 8; 12, 11, 9, 14 Find whether the accidents are uniformly distributed over the week.

Sol: Let $H_0$: No of accidents are uniformly distributed

i.e $H_0 : \Sigma O_i = \Sigma E_i$

v/s

$H_1 : \Sigma O_i \neq \Sigma E_i$

$$E_i = \frac{14+16+8+12+11+9+14}{7} = \frac{84}{7} = 12$$

| $O_i$ | $E_i$ | $(O_i - E_i)^2$ | $(O_i - E_i)^2/E_i$ |
|---|---|---|---|
| 14 | 12 | 4 | ~~1.75~~ 0.33 |
| 16 | 12 | 16 | 1.33 |
| 8 | 12 | 16 | 1.33 |
| 12 | 12 | 0 | 0 |
| 11 | 12 | 1 | 0.08 |
| 9 | 12 | 9 | 0.75 |
| 14 | 12 | 4 | ~~1.75~~ 0.33 |
| | | | Total = 4.15 |

$\therefore \chi^2_{cal} = \sum_{i=1}^{7} \Sigma (O_i - E_i)^2/E_i = 4.15$

d.f = 7 − 1 = 6 ; $\alpha$ = 5% = ~~$\alpha/2$ = 2.5% = 0.025~~

$\therefore \chi^2_{tab} = \chi^2_{(0.05, 6)} = 12.59$

Accept $H_0$

$\therefore \chi^2_{cal} < \chi^2_{tab}$ $\therefore$ Accept $H_0$

$\therefore$ No of accidents are uniformly distributed

3. A set of 5 similar coins are tossed 320 times and result is

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Oi No of heads | : | 0 | 1 | 2 | 3 | 4 | 5 |
| Frequencies | : | 6 | 27 | 72 | 112 | 71 | 32 |

$\Rightarrow$ Total = 320 (N)

Test the hypothesis that the data follows Binomial Distribution.

Sol :- Assume $H_0$: There's no significant difference b/w Oi's and Ei's.

i.e $H_0$ : Data follows Binomial Distribution

i.e $H_0$ : $P = 1/2$, $q = 1/2$

v/s

$H_1$ : ~~P~~ Data doesn't follow Binomial Distribut'n.

i.e $H_1$ : $P \neq 1/2$, $q \neq 1/2$

$\therefore$ $Ei = N \times P(X = x) = N \cdot {}^nC_x p^x q^{n-x}$

where $320 \times {}^5C_x (1/2)^x \cdot (\frac{1}{2})^{5-x}$

For $x = 0 \Rightarrow P_0 \Rightarrow 320 \times {}^5C_0 (\frac{1}{2})^0 (\frac{1}{2})^5$

$= \frac{320}{32} = 10$

$x = 1 \Rightarrow P_1 = 320 \times {}^5C_1 (\frac{1}{2})(\frac{1}{2})^4$

$= \frac{5 \times \cancel{4} \times 3 \times 2 \times 1}{4!} \Rightarrow 50$

$x = 2 \rightarrow \quad 320 \times {}^5C_2 \left(\frac{1}{2}\right)^2 \left(\frac{1}{2}\right)^3$

$\rightarrow \quad 320 \times {}^5C_2 \cdot \frac{1}{4} \times \frac{1}{8}$

$= \quad 10 \times \frac{5 \times \cancel{4}^{2} \times \cancel{3!}}{\cancel{3!} \times \cancel{2} \times 1}$

$= \quad 100$

$x = 3 \rightarrow \quad 320 \times {}^5C_3 \times \left(\frac{1}{2}\right)^3 \left(\frac{1}{2}\right)^2$

$\Rightarrow \quad 320 \times \frac{5 \times \cancel{4}^{2} \times \cancel{3} \times \cancel{2!}}{\cancel{2!} \times \cancel{3} \times \cancel{2} \times 1}$

$= \quad \cancel{3200} \quad 100$

$x = 4 \rightarrow \quad 320 \times {}^5C_4 \left(\frac{1}{2}\right)^4 \left(\frac{1}{2}\right)$

$= \quad 50$

$x = 5 \Rightarrow \quad 320 \times {}^5C_5 \left(\frac{1}{2}\right)^5 \left(\frac{1}{2}\right)^0$

$= \quad 10$

| $x$ | $O_i$ | $E_i$ | $(O_i - E_i)^2$ | $(O_i - E_i)^2 / E_i$ |
|---|---|---|---|---|
| 0 | 6 | 10 | 16 | 1.6 |
| 1 | 27 | 50 | 529 | 10.58 |
| 2 | 72 | 100 | 784 | 7.84 |
| 3 | 112 | 100 | 144 | 1.44 |
| 4 | 71 | 50 | 441 | 8.82 |
| 5 | 32 | 10 | 484 | 48.4 |
| | N = 320 | | | Total = 78.68 |

$\therefore \chi^2_{cal} = \sum_{i=0}^{5} \frac{(O_i - E_i)^2}{E_i} = 78.68$

$d.f = 6 - 1 = 5$

$\alpha = 5\% \Rightarrow \cancel{\alpha/2 = 2.5\% = 0.025}$

$(\because$ Two tailed$)$

$\therefore \chi^2_{tab} = \chi^2_{0.05} = \cancel{12.83}\ 11.07$

$\therefore \chi^2_{cal} > \chi^2_{tab} \Rightarrow$ Reject $H_0$

$\therefore$ The data doesn't follow Binomial distribution.

$\therefore$ The fit is poor.

5/10/17

4. Fit a binomial distribution for the following data :-

| | | | | | | |
|---|---|---|---|---|---|---|
| x : | 0 | 1 | 2 | 3 | 4 | 5 |
| f : | 2 | 14 | 20 | 34 | 22 | 8 |

$$\begin{array}{r} \overset{1}{7}6 \\ 24 \\ \hline 100 \end{array}$$

Test the hypothesis that, the data follows binomial distribution.

sol :- Let $H_0$ : Data follows binomial distribution

~~Mean~~ $N = \Sigma f_i = 100$

(Mean) $\Rightarrow \mu = \frac{\Sigma f_i x_i}{N} \Rightarrow$

| $f_i x_i$ |
|---|
| 0 |
| 14 |
| 40 |
| 102 |
| 88 |
| 40 |
| 284 |

$$\begin{array}{r} 1 \\ 102 \\ 14 \\ 40 \\ 88 \\ 40 \\ \hline 284 \end{array}$$

$\mu = \cancel{28.4}\ 2.84$

$x = 0, 1, 2, \cdots 5$

$n = 5$

$\mu = np$

$p = \frac{2.84}{5}$

$p = 0.568$

$q = 1 - 0.568$

$q = 0.432$

$E_i = \cancel{2+}\ N \times P(X = x)$

$= 100 \times 5_{C_x} (0.568)^x (0.432)^{5-x}$

$\Rightarrow 100 \times 5_{C_0} (0.568)^0 (0.432)^5 = 1.5045 \approx 2$

$\Rightarrow 100 \times 5_{C_1} (0.568)^1 (0.432)^4 = 9.8912 \approx 10$

$\Rightarrow 100 \times 5_{C_2} (0.568)^2 (0.432)^3 = 26.0096 \approx 26$

$\Rightarrow 100 \times 5_{C_3} (0.568)^3 (0.432)^2 = 34.198 \approx 34$

$\Rightarrow 100 \times 5_{C_4} (0.568)^4 (0.432)^1 = 22.482 \approx 22$

$\Rightarrow 100 \times 5_{C_5} (0.568)^5 (0.432)^0 = 5.912 \approx 6$

| x | f(x) | Ei | $(O_i - E_i)^2$ | $(O_i - E_i)^2/E_i$ |
|---|---|---|---|---|
| 0 | 2 | 2 | 0 | 0 |
| 1 | 14 | 10 | 16 | 1.6 |
| 2 | 20 | 26 | 36 | 1.38 |
| 3 | 34 | 34 | 0 | 0 |
| 4 | 22 | 22 | 0 | 0 |
| 5 | 8 | 6 | 4 | 0.66 |
| | | | | 3.645 |

$\therefore \chi^2_{cal} = \sum_{i=0}^{5} \frac{(O_i - E_i)^2}{E_i} = 3.645$

$d.f \Rightarrow n-1 \Rightarrow 6-1 \Rightarrow 5$

$\chi^2_{tab} = \chi^2\left(\overset{0.05}{\cancel{0.025}}, 5\right) = \cancel{12.83}\ 11.07$

$\therefore \chi^2_{cal} < \chi^2_{tab}$ $\therefore$ Accept $H_0$

ie ~~Bin~~ Data follows Binomial distribution.

i.e fit is good.

5. Fit a poisson distribution to the following data and test for it's goodness of fit at 5% LOS

| | | | | | | |
|---|---|---|---|---|---|---|
| x : | 0 | 1 | 2 | 3 | 4 | |
| f : | 419 | 352 | 154 | 56 | 19 | (N=1000) |

(Hint :- $E_i = N \times P(X=x) = N \times \frac{e^{-\lambda} \cdot \lambda^x}{x!}$

$\lambda = \mu =$ mean (avg)

Mean $\lambda = \frac{\sum f_i x_i}{N} =$

$f_i x_i \Rightarrow$

0
23
352
308
168
76
$\cancel{810}$ 904 $/1000 \Rightarrow$

$\lambda = 0.904$

$x = 0, 1, \ldots 4$ $(n = 4)$

$E_0 = 404.9$

$E_1 = 366$

$E_2 = 165.4$

6. Fit a P.D for follo data and test goodness of fit.

(Repeat)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| x : | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| f. | 275 | 72 | 30 | 7 | 5 | 2 | 1 |

Mid-II

7. A survey of 320 families with 5 children, each revealed the following distribution.

| | | | | | | |
|---|---|---|---|---|---|---|
| No of Boys :- | 5 | 4 | 3 | 2 | 1 | 0 |
| No of Girls :- | 0 | 1 | 2 | 3 | 4 | 5 |
| No of families :- | 14 | 56 | 110 | 88 | 40 | 12 |

. Is the result consistent with the hypothesis that male and female births are equally probable at 99% confidence level. ($\alpha = 1\%$)

Sol :- Let $H_0$: Male and female births are equally probable

i.e

Now $p = 1/2$ ; $q = 1/2$

$n = 5$ $N = 320$

$E_i = 320 \times$

for $x = 0 \Rightarrow P(X=0) = 320 \times {}^5C_0 \left(\frac{1}{2}\right)^0 \left(\frac{1}{2}\right)^5 =$

$P(X=1) = {}^5C_1 \left(\frac{1}{2}\right)^1 \left(\frac{1}{2}\right)^4 =$

6/10/17

2) $\chi^2$ - Test for independence of attributes :-

→ It is used to test the association or significant relation between two or more attributes or qualitative characteristics.

PROCEDURE:-

Let $H_0$: There's no association b/w 2 attributes

i.e

$H_0$ : given 2 attributes are independent

v/s

$H_1$ : There's some association b/w 2 attributes

i.e

$H_1$ : 2 attributes are dependent.

Sampling Data About the observed frequencies and level of significance $\alpha$ will ~~be~~ be given.

Test statistic under $H_0$ is

$$\boxed{\chi^2 = \sum_{i=1}^{m} \sum_{j=1}^{n} \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \sim \chi^2_{(m-1)(n-1)}}$$

where $O_{ij}$ = Observed frequency of $i^{th}$ row & $j^{th}$ column

$E_{ij}$ = Expected frequency of $i^{th}$ row & $j^{th}$ column

Here

$$\boxed{E_{ij} = \frac{i^{th} \text{ row total} \times j^{th} \text{ column total}}{\text{Total frequency}} = \frac{(R_i)(C_j)}{N}}$$

Calculation :

Using sample data compute calculated value of $\chi^2$ test statistic.

Conclusion :- Now compare calculated value of $\chi^2$ test statistic with table value ((critical value) at given $\alpha$ with d.f. i.e

$$\boxed{d.f = (m-1)(n-1)}$$

→ If $\chi^2_{cal} \leq \chi^2_{tab}$, accept $H_0$, otherwise reject $H_0$

ASSUMPTIONS :-

(i) All sample observations are independent.
(ii) Individual frequencies greater than or equal 5.
(iii) The parent population is normal.
(iv) All events are mutually disjoint.
(v) Sum of observed frequencies is always ≥ 50

PROBLEMS :-

1. Test that is there any association between literacy and criminality with following data at 5 % LOS.

| Attributes | Literacy | Non-literacy |
|---|---|---|
| Criminality | 20 | 15 |
| Non- " | 10 | 25 |

Sol :- Let $H_0$ : There's no association between literacy and criminality

v/s

$H_1$ : There's association b/w literacy & criminality.

Sample Data :-

| | L | N.L | (total) |
|---|---|---|---|
| C | $O_{11}$ 20 | $O_{12}$ 15 | 35 |
| N.C | $O_{21}$ 10 | $O_{22}$ 25 | 35 |
| Total | 30 | 40 | 70 (N) |

* 2×2 contingency table

$$E_{11} = \frac{(1^{st} \text{ row total}) \times (1^{st} \text{ column total})}{N} = \frac{R_1 \times C_1}{N} = \frac{\overset{5}{\cancel{35}} \times 3\cancel{0}}{\cancel{7}\cancel{0}} = 15$$

$$E_{12} = \frac{(1^{st} \text{ row total}) \times (2^{nd} \text{ column total})}{N} = \frac{\overset{5}{\cancel{35}} \times 4\cancel{0}}{\cancel{7}\cancel{0}} = 20$$

$$E_{21} = \frac{\overset{5}{\cancel{35}} \times 3\cancel{0}}{\cancel{7}\cancel{0}} = 15$$

$$E_{22} = \frac{\overset{5}{\cancel{35}} \times 4\cancel{0}}{\cancel{7}\cancel{0}} = 20$$

$\therefore$

| | $O_{ij}$ | $E_{ij}$ | $(O_{ij} - E_{ij})^2$ | $(O_{ij} - E_{ij})^2 / E_i$ |
|---|---|---|---|---|
| (1,1) | 20 | 15 | 25 | $\cancel{3.6}$ 1.6 |
| (1,2) | 15 | 20 | 25 | 1.2 |
| (2,1) | 10 | 15 | 25 | $\cancel{3.6}$ 1.6 |
| (2,2) | 25 | 20 | 25 | 1.2 |
| | | | | 5.6 |

$$\therefore \chi^2_{cal} = \sum_{i=1}^{2} \sum_{j=1}^{2} \frac{(O_{ij} - E_{ij})^2}{E_{ij}} = 5.6$$

$\alpha = 5\%$

$d.f = (m-1)(n-1) = 1$

$\chi^2_{tab} = \chi^2_{(5\%, 1)} = 3.84$

$\therefore \chi^2_{cal} > \chi^2_{tab}$

$\therefore$ Reject $H_0$

$\therefore$ There is association between literacy and criminality at 5% LOS.

3. The following data is collected on 2 characters cinegous and Non- cinegoers
Cinemagoer (A person who attends the cinema)

| | C | N.C |
|---|---|---|
| literate | 83 | 57 |
| illiterate | 45 | 68 |

Based on this can you conclude that there's no relation b/w cinema going and literates.

Cal = 9.37
Tab = 3.84

Sol: Let $H_0$: there's no relation

v/s

$H_1$: there is relation.

sample data:

| | Cinegous | Non-CG | Total |
|---|---|---|---|
| literate | 83 | 57 | 140 |
| non-lit | 45 | 68 | 113 |
| Total | 128 | 125 | 253 |

$$E_{11} = \frac{R_1 \times C_1}{N} = \frac{140 \times 128}{253} = 70.83$$

$$E_{12} = \frac{R_1 \times C_2}{N} = \frac{140 \times 125}{253} = 69.16$$

$$E_{21} = \frac{R_2 \times C_1}{N} = \frac{128 \times 113}{253} = 57.16$$

$$E_{22} = \frac{R_2 \times C_2}{N} = \frac{113 \times 125}{253} = 55.83.$$

| $O_{ij}$ | $E_{ij}$ | $(O_{ij} - E_{ij})^2$ | $(O_{ij} - E_{ij})^2 / E_{ij}$ |
|---|---|---|---|
| 83 | 70.83 | 148.10 | 2.09 |
| 57 | 69.16 | 147.8 | 2.138 |
| 45 | 57.16 | 147.86 | 2.58 |
| 68 | 55.83 | 148.10 | 2.65 |
| | | | 9.46 |

$$\chi^2 = \sum_{i=1}^{2} \sum_{j=1}^{2} \frac{(O_{ij} - E_{ij})^2}{E_{ij}} = 9.46$$

df = $(m-1)(n-1) = 1$

$\chi^2_{tab} = (5\%, 1) = 3.84$

$\chi^2_{cal} = 9.46 > \chi^2_{tab}$

$\Rightarrow$ Reject $H_0$

7/10/17

**F - Distribution** :- We define F-variable by ratio of two independent $\chi^2$ - variants (or) $t^2 = F$.

★ **Testing of equality of variances** :- It is also known as Variance of Ratio test.

→ It is used to test the significant difference between hypothetical population variances of two independent populations (may be same) under the following assumptions :-

(i) All the sample observations are independent.

(ii) population variances are equal.

**PROCEDURE** :-

Let $H_0: \sigma_1^2 = \sigma_2^2$

v/s

$H_1: \sigma_1^2 \neq \sigma_2^2$

**Sample data** :-

| Sample I | Sample II |
|---|---|
| $n_1 \leq 30$ | $n_2 \leq 30$ |
| $\bar{x}$ | $\bar{y}$ |
| $s_1^2$ | $s_2^2$ |

$\alpha = 5\%$ (or) $1\%$.

where $s_1^2 = \frac{1}{n_1 - 1} \Sigma (x - \bar{x})^2$

$s_2^2 = \frac{1}{n_2 - 1} \Sigma (y - \bar{y})^2$

Test statistic :-

$$F = \frac{s_1^2}{s_2^2} \text{ if } s_1 > s_2 \text{ where } \sim F(n_1-1, n_2-1)$$

(or)

$$F = \frac{s_2^2}{s_1^2} \text{ if } s_2 > s_1 \text{ where } \sim F(n_2-1, n_1-1)$$

Calculation :- By using the sample data, find the calculated value of F and tabulated value of F.

$F(\alpha, (n_1-1, n_2-1))$

(or)

$F(\alpha, (n_2-1, n_1-1))$

Conclusion :- If $F_{cal} < F_{tab}$, then accept Ho otherwise reject H.o.

PROBLEMS :-

1. From a class of a college, a sample of 12 and 13 students selected at random. The variation of marks of 2.5 and 3.5 respectively. Test that can we assume the variation of marks are equal of the students at 5% LOS.

Sol :- $H_0 : \sigma_1^2 = \sigma_2^2$

v/s

$H_1 : \sigma_1^2 \neq \sigma_2^2$

Sample data :-

| | I | II |
|---|---|---|
| | $n_1 = 12$ | $n_2 = 13$ |
| | $s_1^2 = 2.5$ | $s_2^2 = 3.5$ |

$\therefore \alpha = 5\%$

Test statistic :- As $s_2^2 > s_1^2 \Rightarrow F = \frac{s_2^2}{s_1^2}$

$\Rightarrow s_2 > s_1$ (because of positive nature)

$\therefore F = \frac{S_2^2}{S_1^2} = \frac{35}{25} = \frac{7}{5} = 1.4$

$\therefore F_{tab} \approx F_{critical} = F_{(\alpha, (n_2 - 1, n_1 - 1))}$

$= F_{(5\%, (12, 11))} \approx F_{(12, 11)}$ at 0.05 LOS

12 :- $df_1$ and 11 :- $df_2$

$\therefore F_{(0.05, (12, 11))} = 2.788.$

$\therefore$ $F_{cal} < F_{tab} \Rightarrow$ accept Ho.

9/10/17

2. Test the variances are equal at 1% LOS for the following sample data.

| | | | | | | |
|---|---|---|---|---|---|---|
| Sample A : | 3 | 4 | 5 | 6 | 7 | 8 |
| Sample B : | 3 | 6 | 9 | 5 | 2 | 3 |

sol:- Ho : $\sigma_1^2 = \sigma_2^2$

v/s

$H_1$ : $\sigma_1^2 \neq \sigma_2^2$

$\bar{x} = \frac{3+4+5+6+7+8}{6} = \frac{33}{6} = 5.5$

$\bar{y} = \frac{3+6+9+5+2+3}{6} = \frac{28}{6} = 4.6$

$(x - \bar{x})^2 = (-2.5)^2 \quad (-1.5)^2 \quad (-0.5)^2 \quad (0.5)^2 \quad (1.5)^2 \quad (2.5)^2$

$(y - \bar{y})^2 = (-1.6)^2 \quad (1.4)^2 \quad (4.4)^2 \quad (0.4)^2 \quad (-2.6)^2 \quad (-1.6)^2$

$\Sigma(x - \bar{x})^2 = 17.5$

$\Sigma(y - \bar{y})^2 = 33.36$

Sample - I size. $n_1 = 6$

II " $n_2 = 6$

$$s_1^2 = \frac{1}{n_1 - 1} \sum_i (x_i - \bar{x})^2 = \frac{1}{5}(17.5) = 3.5$$

$$s_2^2 = \frac{1}{n_2 - 1} \sum_j (y_j - \bar{y})^2 = \frac{1}{6-1}(33.36) = 6.671$$

$\therefore s_2^2 > s_1^2 \Rightarrow S_2 > S_1$

Test statistic $F_{cal} = \frac{S_2^2}{S_1^2} = \frac{6.671}{3.5} = 1.906$

$\alpha = 1\%$

$F_{tab} = F(1\%)(5, 5) = 10.967$

$\therefore F_{cal} < F_{tab} \therefore$ accept $H_0$.

** 3. In one sample of 10 observations, the sum of the squares of the ~~observations~~ deviations of the sample values from the sample mean was 120. In another sample of 12 observations, it was 314; Test whether, this difference is significant at 5% LOS.

Sol:- $H_0 : \sigma_1^2 = \sigma_2^2$

v/s

$H_1 : \sigma_1^2 \neq \sigma_2^2$

Sample data :- $n_1 = 10$ ; $n_2 = 12$

~~$\bar{x} = 120$~~ ; $\sum (x_i - \bar{x})^2 = 120$

$\sum (y - \bar{y})^2 = 314$

$$\therefore s_1^2 = \frac{1}{n_1 - 1} \sum (x_i - \bar{x})^2 = \frac{1}{9}(120) = 13.33$$

$$s_2^2 = \frac{1}{11} \sum (y - \bar{y})^2 = \frac{1}{11}(314) = 28.54$$

$$F = \frac{S_2^2}{S_1^2}$$

$$= \frac{28.54}{13.33}$$

$$= 2.141$$

$\alpha = 5\%$

$F(5\% \, (\overset{11}{9}; \overset{9}{11})) = 3.102$

$F_{cal} < F_{tab} \Rightarrow$ accept $H_0$.

4. Two random samples drawn from two normal populations are

Sample : I : 20 16 26 27 23 22 18 24 25 19

Sample : II 27 33 42 35 32 34 38 28 41 43 30 37

Test whether, two populations have the same variance

Sol:- $H_0 : \sigma_1^2 = \sigma_2^2$

v/s

$H_1 : \sigma_1^2 \neq \sigma_2^2$

$$\bar{x} = \frac{20+16+26+27+23+22+18+24+25+19}{10}$$

$$= \frac{220}{10} = 22$$

$$\bar{y} = \frac{27+33+42+35+32+34+38+28+41+43+30+37}{12}$$

$$= \frac{420}{12} = 35$$

$(x_i-\bar{x}) \Rightarrow$ 4, 36, 16, 25, 1, 0, 16, 4, 9, 9

Total: 120

$(y_i-\bar{y}) =$ 64, 4, 49, 0, 9, 1, 9, 49, 36, 64, 25, 4

Total: 314

$$S_1^2 = \frac{1}{9}(120) = 13.33$$

$$S_2^2 = \frac{1}{11}(314) = 28.54$$

$$F = \frac{S_2^2}{S_1^2} = 2.141$$

$$F_{(5, (11, 9))} = 3.102$$

$F_{cal} < F_{tab}$ $\therefore$ Accept $H_0$//

<u>Conclusion</u>: Two populations have the same variance.

No significance difference b/w 2 variations.