EXPERIMENT NO: - 07

AIM: To study & Construct $\bar{x}-$ R Chart for given process.

OBJECTIVES: After completing this experiment, you will be able to:

- Draw random samples for inspection.
- Inspect given products as per procedure.
- Compute upper control limit and lower control limit.
- Find process capability.
- Plot $\bar{x}-$ R chart from observation data.

Introduction: -

Variable (continuous data.): Things we can measure. Example includes length, weight, time, temperature, diameter, etc.

Attribute (discrete data.): Things we count. Examples include number or percent defective items in a lot, number of defects per item etc.

Control Charts: A control chart is a graphical representation of the collected information. The information may pertain to measured quality characteristics or judged quality characteristics of samples. It detects the variation in processing and warns if there is any departure from the specified tolerance limits.

Statistical Basis for Control charts: There are two types of quality viz.
1. Variable Quality: This variable quality can be measured. Diameter of shaft, length of bolt, radius of pulley, hardness of materials, strength, density, weight and temperatures are the examples of variable quality.
2. Attribute Quality: This product based quality cannot be measured. Its quality can be said as good (defect less) and bad (defective). For example, concept of surface finishing, brightness of surface, blow holes, dents, spots, color, are the different qualities. If there are blow holes in a casting, then that casting can be said as a defective. Bright surface is good but when the desired brightness of surface is not there, the surface can be said as bad or defective.

Control Charts for variables
Variable control charts are of two types viz.
1. $\bar{x}-$ R chart. **2.** $\bar{x}-$ σ chart.

1. $\bar{x}-$ R Chart: This type of control charts is used for manufactured parts which the inspector checks by measurement and not by gauging. This method of control is more expensive. It reveals much more about the behavior of the process. The $\bar{x}-$ R charts supply a basis on which to judge the stability of the pattern of variation. To found out whether the process is in the state of control or not, control limits are setup. The control chart is usually maintained for averages and not for individual components. The distribution for individual may or may not be normal but the distribution for averages follow normal distribution. In any manufacturing process there is some variation from piece to piece. Two kinds of variation exist in manufacturing, the variation due to chance causes & assignable causes. The chance causes are inevitable in any process. This inherent process variation is a characteristic of the process and is the result of random causes. These random fluctuations cause the process to deviate either side of the average.

2. $\bar{x}-$ σ Chart: By drawing σ chart along with $\bar{x}$ chart the information can be also obtained.

Both these charts are called variable charts. σ Chart is used to control the standard deviation under control by knowing the standard deviation of the process.

Objectives of control charts for variables:

1. To decide whether the manufacturing process is complying the specifications or not.

2. To ascertain product quality.

3. To find and remove the causes of process which is not under control.

4. To obtain information to decide whether to change the method of inspection or to decide the method for inspection.

5. To decide whether the product manufactured is to be accepted or rejected.

Method of drawing variable quality chart:

1. Take random sample from production process, and measure its important quality such as length, diameter. Indicate this dimension as $\bar{x}$**-** variable for all such sub-groups it is necessary to take 4 or 5 observations. For inspection take such 25 sub-groups.

2. Calculate $\bar{x}$ and R for all sub groups. R is the difference between the maximum and minimum value of individual subgroup.

3. The values of **-** and R follows the principle of standard deviation. Calculate the mean of ¯ and R as under:

$$\bar{\bar{\mathbf{x}}} = \frac{\sum \bar{\mathbf{x}}}{\mathbf{n}} \qquad and \qquad \bar{\mathbf{R}} = \frac{\sum \mathbf{R}}{\mathbf{n}}$$

Where $\bar{\bar{x}}$ = mean of or mean of average of subgroup

$\bar{R}$ = mean of Spread-R

$\bar{x}$ = Average or mean of the subgroup

R=spread

N=No. of random sample

$\bar{\bar{x}}$ is the central or middle line of $\bar{x}$ chart

$\bar{R}$ is the central or middle line of R chart

4. Calculate the upper control limit- UCL. This line is at a distance of 3σ from the central line of **chart**, above the line.

$$UCL = \bar{\bar{x}} + 3\sigma \qquad \textit{OR} \qquad UCL = \bar{\bar{x}} + A_2R$$

There is constant which depends upon size of subgroup and can be found from the table of constants.

5. Calculate lower control limit-LCL. This line is at a distance of 3σ from the central line of chart, below the line.

$$LCL = \bar{\bar{x}} - 3\sigma \qquad \textit{OR} \qquad LCL = \bar{\bar{x}} - A_2\bar{R}$$

6. To draw control lines for R-chart. Calculate as mean of R observations & then find upper control limit (UCL) lower control limit (LCL)**,**

$$UCL = d_4\bar{R} \qquad \& \qquad LCL = d_3\bar{R}$$

Where d_3 & d_4 are constants which are obtained from the table of constants

7. To draw each chart mark, the value of $\bar{x}$ and R & obtain corresponding points. Joint these points by straight lines.
8. Calculate standard deviation using formula as given below:

$$\sigma = \frac{\bar{R}}{d2}$$

9. Calculate Process capability, $\acute{\sigma} = 6 \cdot \sigma$

Where$d$, is the constant for standard deviation which is given in table of constants.
Table for constants: The following is the table of constant:

Sample Size	Constant for -chart	Constants for R-chart		Constant for Standard Deviation
n	A_2	D_3	D_4	d_2
2	1.880	0	3.268	1.128
3	1.023	0	2.574	1.693
4	0.729	0	2.282	2.059
5	0.577	0	2.114	2.326
6	0.483	0	2.004	2.534
7	0.419	0.076	1.924	2.704
8	0.373	0.136	1.864	2.847
9	0.337	0.184	1.816	2.970
10	0.308	0.223	1.777	3.078

Table 7.1: Constant for control charts

Selection of Samples: Following factors are important for the selection of samples:
1. Always take sample as random. Do not fix any time for sample selection.
2. Take samples on which the effect of changes in process is effecting.
3. Keep sample size equal. It is suitable to take 4 to 5 readings per sample. Small sample size containing same no. of parts gives increased dissimilarity in different samples.
4. Samples for control chart can be taken on daily, monthly, and half yearly and yearly production.
5. 25 numbers of samples are considered proper or suitable.

Applications of variable control chart:
1. To decide whether the quality of product is within the specification limit or not.
2. To find assignable causes for process and machines. If any defect is found, then to remove that defect for maintaining the quality of products.
3. To decide which process is the economical out of the available processes.
4. To reduce inspection cost.
5. To decide the process capability.
6. To decide which type of inspection will be needed for quality control.

Exercise:

Construct -R Chart and show calculations for the following:

1. From the given data find out control limits for X-bar & R chart. Calculate standard deviation and process capability.

Observation No.	1	2	3	4	5	6	7	8
$\bar{x}$	26.00	34.00	28.50	32.75	29.25	26.00	27.25	30.25
R	30	17	18	23	30	15	19	18

A_2=0.73, D_4=2.28, d_2=2.059

2. A machine is working to a specification of 12.58 ± 0.05mm. A study of 50 consecutive pieces shows the following measurements for 10 groups of sample:

Construct $\bar{x} -$ **R** chart and show the calculations. Find process capability.

1	2	3	4	5	6	7	8	9	10
12.54	12.58	12.61	12.57	12.57	12.58	12.6	12.65	12.6	12.65
12.58	12.57	12.6	12.61	12.60	12.59	12.62	12.57	12.59	12.61
12.62	12.6	12.64	12.56	12.62	12.59	12.61	12.57	12.6	12.6
12.56	12.6	12.58	12.59	12.61	12.56	12.67	12.56	12.63	12.63
12.59	12.61	12.64	12.59	12.58	12.57	12.6	12.61	12.56	12.62

EXPERIMENT NO: - 08

AIM: To study & Construct P-chart for given process.

OBJECTIVES: After completing this experiment, you will be able to:

- Know attribute quality and carry out inspection by attribute quality checking.
- Divide good quality as acceptable and bad quality as projectable.
- Compute control limits and mean.
- Plot P chart.
- Infer causes of variations.
-

Introduction: -

Attribute (discrete data.): Things we count. Examples include number or percent defective items in a lot, number of defects per item etc.

Control Charts for Attribute Quality:

When the quality of product is not measurable then for quality control of each product, control charts for attribute quality are drawn. Due to the certain characteristics of the product, it can be said good or defective. If such quality does not exhibit by the product, it is said defective. This way the products can be divided into two groups namely defective & defect less. The appearance, brightness, color, cracks, blow holes, spots, surface finishing, etc. is called the attribute quality of the product. Such quality can only be seen or observed but cannot be measured. From production process certain size of samples are taken at random. Products of such samples are observed and the defects in them are found out. In some products there may be more than one defect listed above. Over and above using 'GO' and 'NO GO' gauge defective products are found out in mass productions.

Defect: The characteristics of the product which render a product unacceptable is called defect.

Defective: The product having one or more defect is called defective.

Fraction Defective: The ratio of defective products in a sample to the sample size is called fraction defective.

Types of Attribute Quality Charts:

1. P chart: Fraction defective
2. 100P-Chart: Percentage defective
3. np-Chart: No. of defective chart

1. P-Chart: Samples are taken from manufactured product and numbers of faults or defects in it are counted. The size of the defect is not measured. For example, say 100 pins are inspected out of which 12 are found defective then it is rejected. Note that the size, location or shape of the defects is not important and not measured. Fraction defective, **P** is defined as the ratio of number of defective units in each lot inspected to the number of units in the lot. Suppose we have taken a lot of 'n' number of products from the process, out of which'd' number of products found defective, then fraction defective of that lot can be found out as under:

$$fraction\ defective, \mathbf{p} = \frac{\boldsymbol{d}}{\boldsymbol{n}}$$

The P-chart is based on binomial distribution. So the standard deviation for p-chart can be found out using the following:

$$standard\ deviation, \sigma_{\mathrm{p}} = \sqrt{\frac{\bar{\mathrm{p}}(1-\bar{\mathrm{p}})}{n}}$$

Where, =Average fraction defective of the lot from which the same is taken

n= Sample taken

Average fraction defective, $\boldsymbol{\bar{p}}$ can be calculated as follows:

$$\bar{\mathrm{p}} = \frac{\sum \mathrm{p}}{\mathrm{N}}$$

Σp = Number of defective products in all samples

N = Number of samples taken

Control limits of the P-chart can be calculated as follows:

1. Upper Control Limit: $UCL = \bar{p} + 3\sqrt{\frac{\bar{\mathrm{p}}(1-\bar{\mathrm{p}})}{n}}$

2. Lower control Limit: $LCL = \bar{p} - 3\sqrt{\frac{\bar{\mathrm{p}}(1-\bar{\mathrm{p}})}{n}}$

Exercise:

1. There are 10 samples of shaft taken for inspection. Draw P-chart and state whether the process is under control or not, from the data given as under:

Number of Products	200	200	200	200	200	200	200	200	200	200
Defective Products	12	4	8	3	7	6	0	8	5	9

2. In a production of bearings 10 samples each of sample size of 100 were taken and inspected. After inspection, following defectives as shown in table under were observed. Draw P-chart and state whether the process is under control or not, from the data given as under:

Sample No.	1	2	3	4	5	6	7	8	9	10
Defective bearings in a Sample	12	4	8	3	7	6	0	8	5	9

3. No. of defectives Spark plugs for ten samples are 4,3,4,5,3,4,5,3,5,4 in a sample size of 100. Selecting suitable control chart, find upper control limit and lower control limit. Also give your comment either the process is under control or not.

4. For observing 10 samples of 150 each defective pieces noted as 4,7,5,6,4,8,7,10,8,9. Find out control limits for appropriate chart and give your comment regarding process.

EXPERIMENT NO: - 09

AIM: To study & Construct C-chart for given process.

OBJECTIVES: After completing this experiment, you will be able to:

- Identify number of defects in single unit of production.
- Inspect each unit of production as per standards laid down.
- Plot C-Chart.

Introduction:

C-Chart: When more than one defect is occurring in the manufactured product, then C-chart is drawn. E.g. sample from a cloth of a 900 meter is inspected by taking 100 square meter as a unit of sample. The radio manufacturer wants to know the defects in the products. One radio set can be considered as unit and subjected for inspection. The inspection results can be complied for investigation. There can be number of such situations where C-chart can be successfully applied. More examples can include inspection of furniture, inspection of weldments, etc.

It is reasonable to assume the distribution of variations in the number of defects per unit following very closely Poisson distribution.

The number of defects per unit can always be translated into fraction defective which must be quite less. It satisfies the condition of small number of defects & large sample size. This is possible only when the number of defects per unit can be converted into fraction defective. Defects in assembly of engine, T.V. set, Radio, etc. are shown by C-chart.

The control limit of C-Chart is based on Poisson's distribution. So the center line of C-chart can be found out using the following:

$$Average\ defect, C = \frac{total\ number\ of\ defects}{no.of\ assembly\ inspected}$$

Control limits of the C-chart can be calculated as follows:

1. Upper Control Limit: $UCL = C + 3\sqrt{C}$

2. Lower control Limit: $LCL = C - 3\sqrt{C}$

Exercise:

1. During the production of Nano Car, 10 cars were inspected and defects in each car were as under. Draw C-chart, control limits and comment about the process:

Nano Car No.	1	2	3	4	5	6	7	8	9	10
Defects in Nano Car	1	3	13	4	2	5	3	3	4	5

2. In a car manufacturing company, 10 assembly of a car was inspected and the defects were found as under. Draw C-chart, control limits and comment about the process:

Car Assembly No.	1	2	3	4	5	6	7	8	9	10
Number of defects	5	4	4	10	5	9	7	3	2	1

3. The following table shows the number of point defects in the surface of a bus body on august 2011. Construct C-Chart for the data given below:

Body No.	1	2	3	4	5	6	7	8	9	10
Number of defects	2	2	4	7	5	6	7	14	2	9

Body No.	11	12	13	14	15	16	17	18	19	20
Number of defects	3	0	5	1	3	10	4	3	12	6

EXPERIMENT NO: - 10

AIM: To study about Sampling Plans & Decide about acceptance or rejection of a particular product using sampling plans.

OBJECTIVES: After completing this experiment, you will be able to:

- Identify number of defects in single unit of production.
- Inspect each unit of production as per standards laid down.
- Plot C-Chart.

Introduction: -

Acceptance Sampling: Acceptance sampling or acceptance by sample is a technique for quality control by which material, components & product samples are inspected and based on inspection outcome, the acceptance or rejection decisions for whole lot is taken.
Therefore, a procedure and decision rules are fixed up to finalize the size of a sample and the minimum number of defective it could contain for the whole lot to be acceptable. This method or procedure is called acceptance sampling.
Acceptance sampling attempts to assure the quality rather than controlling the quality. It is an inspection technique and not a quality control method. It is the purpose of control charts to control the quality.

Techniques of material acceptance: There are two main methods of inspecting the material & components purchased by industries from outside:
A. No inspection.
B. 100% inspection
C. Arbitrary inspection.
D. Scientific inspection

Principle of Inspection by Samples:
It is impossible to inspect whole lot produced but it can be done easily with the help of sample inspection. Methods for inspection of samples are as under:
1. Divide the lot in different parts or sub-lots, which has taken for inspection.
2. Take sample of pre-decided size from the lot at random.
3. Check the quality of items of the sample.
4. Accept or reject the lot based on the information gathered by inspection.

Acceptance sampling on the basis of variable quality: Acceptance sampling on the basis of variable, i.e. actual measurement of the dimensions, i.e. measuring weight, density, length, width, diameter, etc.

Acceptance sampling on the basis of attribute quality: Acceptance sampling on the basis of attributes, i.e. GO & NO GO gauges. Items are checked for color, finishing, blowholes, spots, scratch etc. If it is sound good, then the lot is accepted.

Uses of Acceptance Sampling: In general, acceptance sampling is used under the assumption when the quality characteristics of the product are under control and relatively homogenous.
However, this technique is extensively used when:

1. Possible losses by passing defective items are not great and the cost of inspection is relatively high. In the limiting situation, this can mean no inspection at all.
2. The destructive testing is inevitable and hence 100% inspection is prohibited. Therefore, sampling method is the solution under such situation. For example, when it is necessary to determine the strength of the component by pulling it apart, under this situation, acceptance of the entire lot can be based on the acceptance of sample.
3. Handling of any kind is likely to induce defects, or when mental or physical fatigue is an important factor in inspection.

Sampling Plan: There are four sampling plans
In all the sampling plans, following symbols will be used:
N= number of products in a given batch or lot.
n= number or random samples drawn from the batch or lot of N.
C= Acceptance number. It is the maximum number of defectives, allowed in a sample size of it.

Some important definitions used in sampling plans:
1. Lot: It may be defined as the number of items or component parts, drawn from a lot, batch or population for the purpose of inspection.
2. Sample: It may be defined as the number of items or component parts, drawn from a lot, batch or population for the purpose of inspection.
3. Acceptance Number: It may be defined as the Number of defective items can be allowed in a lot for its acceptance. Acceptance number is denoted by letter 'a' or 'c'.
4. Rejection Number: It may be defined as the Number of defective items in a lot for its rejection. Rejection number is denoted by letter 'r'.
5. Item: It may be defined as an object or part on which inspection is done. Item may or may not comply the specification framed for it.

Acceptance Quality Level (AQL):
It indicates a small proportion of bad components in a lot such that the lots having less than this proportion of bad components have a high probability of acceptance or getting accepted. It is the highest percentage of defective in a lot which is acceptable to the purchaser. It is considered satisfactory as process average.
Suppose that 3% acceptance quality level is fixed for a lot for its acceptance/rejection. It means that 3% defective items of the lot are acceptable to the purchaser. This acceptance level is fixed as an understanding between seller and purchaser.

Inspection Level:
How much tight inspection is carried out during acceptance sampling, there are five levels of inspection. The range of inspection from too light to tight has been divided into 5levels. The number I, II and III are assigned to the light types of inspection. Whereas by accepting the defective item, the loss occurring is less, the light levels I, II and III are used. The inspections IV and V are used to carry out tight inspection.

Types of Sampling Plans:
1. Single sampling plan.
2. Double sampling plan.
3. Multiple sampling plan.
4. Sequential sampling plan.

Single sampling plan:
In this plan only one sample is drawn & inspected to take the decision of acceptance or rejection of the lot. The method of using single sampling plan is as under:
There is always a difference of 1 in acceptance & rejection numbers. Therefore, either the lot will be accepted or rejected.

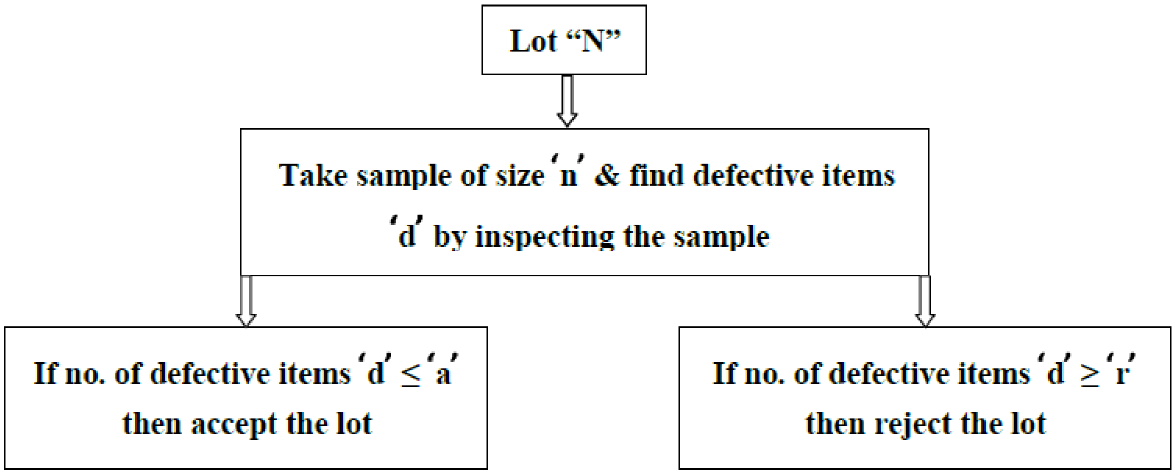

Figure 10.1: Single Sampling Plan

Double sampling plan:
In double sampling plan the decision on acceptance or rejection of the lot is based on two samples. A lot may be accepted at once if the first sample is good enough or rejected at once if the first sample is bad enough. If the first sample is neither good or bad enough, the decision is based on the evidence of first and second sample combined.

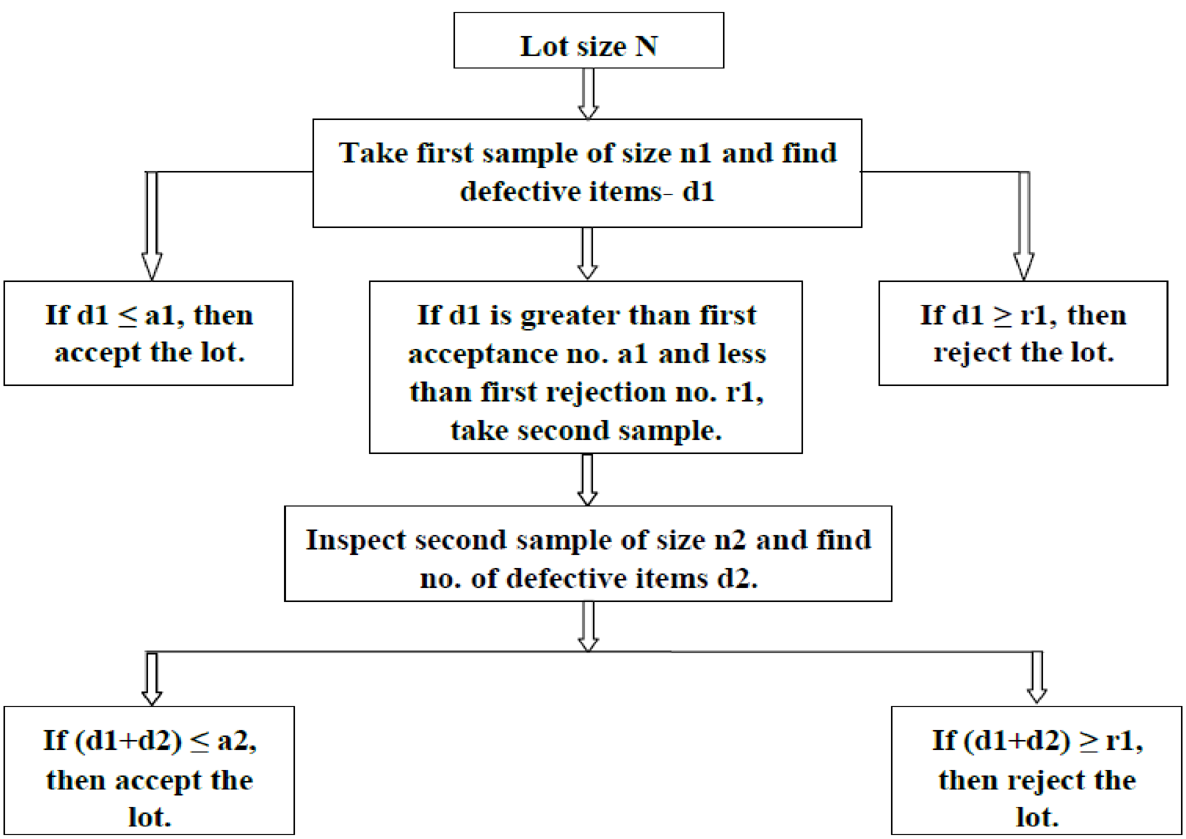

Figure 10.2: Double Sampling Plan

Exercise:

1. Following data is related to Double Sampling Plan used for Inspection of 2400 Gudgeon pin lot. Take AQL as 4 %

Sample	**Sample Size (n)**	**Acceptance no. (a)**	**Rejection no. (r)**
First	80	5	9
Second	80	12	13

Draw the plan and Explain how it is operated.

2. Explain double sampling plan for the following data with usual notations.
N=2400; n1=150; n2=150; a1=4; a2=9; r1=8; r2=10.

EXPERIMENT NO: - 11
Tutorial - 1

Examples

1) A company is to decide on the location of a new plant. It has narrowed down the choice to 3 locations A, B, and C; data in respect of which is furnished below: Use suitable criterion and advise the company on the best choice.

Cost in Rs	Location		
Data	A	B	C
Wages & salaries	20000	20000	20000
Power, water supply expenses	20000	30000	25000
Raw material & other supplies	80000	75000	60000
Total initial investment	200000	300000	250000
Distribution expenses	50000	40000	60000
Miscellaneous expenses	40000	25000	30000
Expected sales per year	225000	250000	225000

Hint: Solution based on the economics of various sites.

2) From the given table choose a best suitable location for a plant. Relative weightage will be given in the table.

Cost in Rs	Location		Values (Relative weightage)
Factors	A	B	
Cost of land, building, construction	500000	300000	4
Power cost	20000	30000	4
Taxes	20000	50000	4
Community attitude	1.5	2	1
Product quality	3	2	6
Flexibility to expansion	1	6	3
Union attitude	2	4	5

Hint: Solution based on Dimensional analysis

3) A company intends to select one of the three locations. All the relevant data for the location are given below:

Cost in Rs. (in Thousands)	Location		
Particulars	A	B	C
Total initial investment	250	325	270
Total Revenue	410	515	360
Cost of raw material	89	100	98
Distribution cost	40	60	30
Utilities Expenses	50	40	25
Wages & salaries	25	30	28

Hint: Solution based on Dimensional analysis

EXPERIMENT NO: - 12
Tutorial – 2

Examples

1) The past data on the load on the machine is shown below:

Sr. no.	Month	Load
1	May-17	-
2	June-17	585
3	July-17	610
4	Aug-17	675
5	Sep-17	750
6	Oct-17	860
7	Nov-17	970

a) Compute the load on the machine centre using 3rd and 5th moving average for the month of Dec. 1996.

b) Compute a weighted three month moving average for Dec. 1996 where the weights are 0.5 for last month, 0.3 and 0.2 other month respectively.

Formulas: The formula for a simple moving average is

$$F_t = \frac{A_{t-1} + A_{t-2} + A_{t-3} + \ldots\ldots\ldots + A_{t-n}}{n}$$

The formula for a weighted moving average is

$F_t = w_1 A_{t-1} + w_2 A_{t-2} + w_3 A_{t-3} + \ldots\ldots\ldots + w_n A_{t-n}$

2) The past data regarding the sales of SPMS for the last five years is given. Using the least square method, fit a straight line, estimate the sales for the year 2013 and 2017.

Year	2013	2014	2015	2016	2017
Sales (‘00)	35	56	79	80	40

3) N Forecast the demand for the following series by exponential smoothing method. (Take α = 0.3)

Period	1	2	3	4	5	6	7	8	9	10
Actual demand	10	12	8	11	9	10	15	14	16	15