# NORTH MAHARASHTRA UNIVERSITY
# JALGAON

# SYLLABUS UNDER
## SCIENCE FACULTY

# FOR

# T.Y.B.Sc. STATISTICS
# (Semester I and II)

# WITH EFFECT FROM ACADEMIC YEAR 2014-2015

# NORTH MAHARASHTRA UNIVERSITY, JALGAON
# Syllabus for T.Y.B.Sc.(Statistics)
## (With effect from Academic Year 2014-2015)
## Syllabus Structure

## Semester-I

| Course Code | Title of the Course | Contact Periods/week | | | Distribution of Marks for Examination | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Internal | | External | | Total | |
| | | Th(L) | Pr # | Total | Th | Pr | Th | Pr | Th | Pr |
| ST-351 | Distribution Theory-I | 04 | -- | 04 | 10 | -- | 40 | -- | 50 | -- |
| ST-352 | Statistical Inference-I | 04 | -- | 04 | 10 | -- | 40 | -- | 50 | -- |
| ST-353 | Design of Experiments-I | 04 | -- | 04 | 10 | -- | 40 | -- | 50 | -- |
| ST-354 | Sampling Theory | 04 | -- | 04 | 10 | -- | 40 | -- | 50 | -- |
| ST-355 | Financial Mathematics | 04 | -- | 04 | 10 | -- | 40 | -- | 50 | -- |
| ST-356 | Statistical Computing Using R-Software | 04 | -- | 04 | 10 | -- | 40 | -- | 50 | -- |
| ST-301 | Practicals- I | -- | 04 | 04 | -- | 20 | -- | 80* | -- | 100 |
| ST-302 | Practicals- II | -- | 04 | 04 | -- | 20 | -- | 80* | -- | 100 |
| ST-303 | Practicals- III and Project | -- | 04 | 04 | -- | 20 | -- | 80* | -- | 100 |

## Semester-II

| Course Code | Title of the Course | Contact Periods/week | | | Distribution of Marks for Examination | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Internal | | External | | Total | |
| | | Th(L) | Pr # | Total | Th | Pr | Th | Pr | Th | Pr |
| ST-361 | Distribution Theory-II | 04 | -- | 04 | 10 | -- | 40 | -- | 50 | -- |
| ST-362 | Statistical Inference-II | 04 | -- | 04 | 10 | -- | 40 | -- | 50 | -- |
| ST-363 | Design of Experiments-II | 04 | -- | 04 | 10 | -- | 40 | -- | 50 | -- |
| ST-364 | Statistical Quality Control | 04 | -- | 04 | 10 | -- | 40 | -- | 50 | -- |
| ST-365 | Applied Statistics | 04 | -- | 04 | 10 | -- | 40 | -- | 50 | -- |
| ST-366 | Optimization Techniques | 04 | -- | 04 | 10 | -- | 40 | -- | 50 | -- |
| ST-301 | Practicals- I | -- | 04 | 04 | -- | 20 | -- | 80* | -- | 100 |
| ST-302 | Practicals- II | -- | 04 | 04 | -- | 20 | -- | 80* | -- | 100 |
| ST-303 | Practicals- III and Project | -- | 04 | 04 | -- | 20 | -- | 80* | -- | 100 |

**Th: Theory Pr: Practicals L: Lectures**
***: Annual Practical Examination**
**#: Per Batch**

## General Instructions to Teachers and Paper Setters/ Examiners

1. The medium of instruction is English.
2. Each Theory paper requires 60 Periods(Lectures).
3. Each Practical paper requires 60 laboratory periods for each batch.
4. Numbers of Lectures/periods to be devoted for each topic and minimum number of marks to be allotted out of 40 for main topics are mentioned in parentheses in the detailed syllabi.
5. Teacher should follow syllabus as well as time schedule given in the syllabus for all topics.
6. Question paper should generally be uniformly distributed over the syllabus.

## Objectives and Job Opportunities

1. To develop balanced Statisticians with theoretical, practical and computational skills required to formulate mathematical, scientific, societal and industrial problems and offer proper solutions to the formulated problems through the tools learned under subject Statistics during B.Sc. along with other science subjects.
2. The student who has thoroughly studied this syllabus of T.Y.B.Sc.(Statistics) can join for higher education at PG level towards M.Sc.(Statistics)
3. Students with B.Sc.(Statistics) degree are expected to served as Statisticians/ Administrators/Investigators in the private as well as government sections.
4. Students with B.Sc.(Statistics) degree under this syllabus will find better opportunities of Statistician/Analyst in Manufacturing(SQC unit), Pharmaceutical Industries, Service Industries such as Banking and Insurance, Railway, Forest, Telecom, Transports, Hotel etc services.

# ST-351: Distribution Theory-I

**1. Concept of Probability (Review)** **(5L, 3M)**

Random experiment: trial, sample point and sample space, event. Operations on events, concepts of mutually exclusive and exhaustive events.

Definition of probability: classical, relative frequency and axiomatic approach. Discrete probability space, Properties of probability, Independence of events, Conditional probability, total and compound probability rules, Bayes' theorem and its applications.

**NOTE:** DERIVATIONS ARE NOT EXPECTED.

**2. Probability Distributions** **(12L, 7M)**

Random variable, its probability function and cumulative distribution function (cdf). Joint probability functions of bivariate r.v.s. Marginal and conditional distributions. Independence of r.v.s. Expectation of a r.v. and its properties. Moments, measures of location and dispersion of a r.v. Probability generating function (pgf) and moment generating function (mgf), cgf, fmgf, characteristic function of a r.v., their properties and uses. Indicator r.v. Degenerate, discrete uniform, binomial, Poisson, Geometric, Exponential and Normal distributions. Reproductive (additive) property of standard distributions.

**NOTE:** DERIVATIONS ARE NOT EXPECTED.

**3. Chebychev's Inequality and Weak Law of Large Numbers** **(9L, 6M)**

3.1 Chebychev's theorem: If g(X) is a non-negative function of a r.v. X , $E\{g(X)\} < \infty$ and if $k > 0$ then $P\{g(X) \geq k\} \leq E\{g(X)\}/k$.

3.2 Chebychev's inequality for discrete & continuous distribution in the forms

$P\{|X - \mu| \geq k\sigma\} \leq 1/k^2$ and

$P\{|X - \mu| < k\sigma\} \geq 1 - 1/k^2$, where $\mu = E(X)$ and $\sigma^2 = V(X)$.

3.3 Concept of convergence in probability.

3.4 Statement and proof of WLLN based on Chebychev's theorem.

3.5 Examples and problems.

**4. Central Limit Theorem** **(4L,3M)**

4.1 Statement and proof of the central limit theorem for i.i.d.r.v.s. based on mgf.

4.2 Examples and problems.

**5. Rectangular (Uniform) Distribution** **(10L,7M)**

5.1 p.d.f.

$$f(x) = \frac{1}{b-a} \qquad -\infty < a < x < b < \infty$$

$$= 0 \qquad \text{Otherwise}$$

5.2 Distribution function, mean, variance, mgf, $r^{th}$ raw moment.

5.3 Standard form: U(0,1).

5.4 U(0,1) as the distribution of F(X), where X is a continuous type r.v. with d.f. F(.) applicable to model sampling, Use of U(0,1) to generate integer valued random numbers.

5.5 Distributions of X+Y, X-Y, XY, X/Y for X and Y are independent U(0,1) random variables.

5.6 Real life situations.

5.7 Examples and problems.

**6. Multinomial Distribution** **(10L, 7M)**

6.1 Joint p.m.f.

$$P(X_1 = x_1, X_2 = x_2, \ldots X_k = x_k) = \frac{n!\, p_1^{x_1} p_2^{x_2} \ldots p_k^{x_k}}{x_1!\, x_2! \ldots x_k!} \qquad x_i = 0,1,2,\ldots n$$

$$i = 1,2\ldots k,$$

$$x_1+x_2+\ldots+x_k = n,$$

$$p_1+p_2+\ldots+p_k = 1$$

$$0<p_i<1, i = 1,2,..k$$

$$= 0 \qquad \text{otherwise}$$

Notation $(X_1,X_2,\ldots X_k)' \sim MD(n,p_1, p_2,\ldots p_k)$

6.2 Joint mgf of $X_1\, X_2 \ldots X_k$

6.3 Use of joint mgf to obtain means, variances, covariances, total correlation coefficients, multiple and partial correlation coefficients for k = 3, univariate marginal distributions.

6.4 Variance covariance matrix, Rank of Variance-Covariance matrix and its interpretation.

6.5 Real life situations.

6.6 Examples and problems.

**7. Order Statistics** **(10L, 7M)**

7.1 Order statistics for a random sample from a continuous distribution.

7.2 Distribution of the $i^{th}$ order statistics $X_{(i)}$ ( distribution function and probability density function).

7.3 Joint distribution of $(X_{(i)},X_{(j)})$.

7.4 Distribution of the smallest order statistics $X_{(1)}$, distribution of largest order statistics $X_{(n)}$

7.5 Distribution of the sample median, distribution of the sample range $X_{(n)} - X_{(1)}$ distribution of $X_{(1)}$ and $X_{(n)}$ for uniform and exponential distributions.

7.6 Examples and problems.

**Books Recommended:**

1. Bhat B.R. : Modern Probability Theory ($3^{rd}$ Ed.), 1999.
2. Mood A. M, Graybill F. Bose D. C. : Introduction to theory of Statistics (III Edn.) Mc- Graw Hill Series, 1974.
3. Hogg R.V. and Graig A. T.: Introduction to Mathematical Statistics ($5^{th}$Edn.)
4. S.C. Gupta and V.K. Kapoor : Fundamentals of Mathematical Statistics Sultan Chand and Sons, 88 Daryaganj New Delhi 2
5. Rohatgi V.K. and Ehsanes Saleh A. K. MD. (2003). An Introduction to Probability Theory and Mathematical Statistics, (Wiley Eastern, $2^{nd}$ Ed.).

# ST-352: Statistical Inference-I

**1. Point Estimation** **(14L, 9M)**

1.1 Concept of random sample from a distribution, Notion of a Parameter, Parameter space, general problem of estimation, Types of estimation: Point estimation and interval estimation.

Point estimation: Definition of estimator, distinction between estimator and estimate, illustrative examples.

1.2 Unbiasedness :

Definition of unbiased estimator, biased estimator, positive and negative biases. Illustrative examples (These should include unbiased and biased estimators for the same parameters)

Proofs of the results regarding unbiased estimator:

(a) Two distinct unbiased estimators of $f(\theta)$ give rise to infinitely many unbiased estimators of $f(\theta)$.

(b) If T is an unbiased estimator of θ, then f (T) is an unbiased estimator f(θ), provided f(T ) is linear function of T.

Discussion of the following results:-

(a) If T is an unbiased estimator of θ, then f(T) need not be an unbiased estimator of f(θ), illustrative examples.

(b) Sample standard deviation is a biased estimator of population standard deviation.

1.3 Examples and Problems.

**2. Relative Efficiency: (4L, 3M)**

2.1 Relative efficiency of unbiased estimator $T_1$ with respect to another unbiased estimator $T_2$, use of mean square error to define relative efficiency of biased estimators.

2.2 Notion of uniformly minimum variance unbiased estimator (UMVUE), uniqueness of UMVUE whenever it exists, Examples and problems.

2.3 Examples and Problems.

**3. Sufficiency: (8L, 5M)**

3.1 Concept and definition of sufficiency

3.2 Statement of Neyman's factorization theorem (proof for discrete case only).

3.3 Proofs of the following properties of sufficient statistics:

i) If T is sufficient for θ, f (T) is also sufficient for f(θ) provided f is one to one and onto function.

ii) If T is sufficient for θ then T also sufficient for f (θ).

3.4 Definition of likelihood as a function of the parameter for a random sample from (i) discrete, (ii) continuous distribution, Definition of Fisher's information function. Amount of information regarding parameter contained in a statistic T and a sufficient statistic T.

3.5 Examples and problems.

**4. Asymptotic Behavior of an Estimator (6L, 4M)**

4.1 Consistency: Definition of consistent estimator, proof of the following theorems:

(a) Biased estimator is consistent if its bias and variance both tend to zero as the sample size tends to infinity.

(b) If T is consistent estimator of θ then f(T) is also consistent estimator of f(θ) provided f is continuous function of T. (Invariance property of consistent estimator).

4.2 Examples and problems.

**5. Cramer – Rao Inequality (9L, 6M)**

5.1 Statement and proof of Cramer-Rao inequality.

Definition of minimum variance bound unbiased estimator (MVBUE) of f (θ)

Proofs of the following results:

i) If MVBUE exists for θ, then MVBUE exists for $\phi(\theta)$, provided $\phi$ is linear function.

ii) If T is MVBUE for θ then T is sufficient for θ.

5.2 Examples and problems.

**6. Methods of Estimation (19L, 13M)**

6.1 Method of maximum likelihood, derivation of maximum likelihood estimators (m.l.e.) for parameters of only standard distributions: binomial, normal, Invariance property of m.l.e., relation between m.l.e. and sufficient statistics.

6.2 (a) m.l.e. of uniform distribution over (i) (a, b), (ii) (-θ, θ).

(b) m.l.e. of θ in $f(x,\theta) = \exp[-(x-\theta)]$ $x \geq \theta$ .

6.3 Method of moments: Derivation of moment estimators for standard distributions: binomial, Poisson, normal, exponential and uniform, illustration of situations where m.l.e. and moment estimators are distinct and their comparison using mean square error.

6.4 Examples and problems.

**Books Recommended:**

1. Mood A. M, Graybill F. Bose D. C.: Introduction to theory of Statistics (III Edn.) Mc- Graw Hill Series, 1974.
2. Hogg R.V. and Graig A. T.: Introduction to Mathematical Statistics ($5^{th}$Edn.)3. S.C. Gupta and V.K. Kapoor : Fundamentals of Mathematical Statistics Sultan Chand and Sons, 88 Daryaganj New Delhi 2.
4. Rohatgi V.K. and Ehsanes Saleh A. K. MD. (2003). An Introduction to Probability Theory and Mathematical Statistics, (Wiley Eastern, $2^{nd}$ Ed.).
5. Siegel S.: Non Parametric Methods for the Behavioral Sciences. International Student Ed. McGraw Hill Kogakusha Ltd.
7. Daniel: Applied Non Parametric Statistics, Houghton Mifflin Company Roston.
8. Kale B.K. (2005). A First Course on Parametric Inference, ($2^{nd}$ Narosa Publishing House)

# ST-353: Design of Experiments-I

**1. Analysis of variance (Random Effect Model) (10L, 7M)**

1.1 ANOVA for random effect model for one way classified data with equal classes: assumptions and interpretation, Expectation of various sum of squares

1.2 ANOVA for random effect model for one way classified data with unequal classes: assumptions and interpretation, Expectation of various sum of squares

1.3 ANOVA for random effect model for two way classified data: assumptions and interpretation, Expectation of various sum of squares

1.4 Examples and problems

**2. Analysis of Two way classified with m observations per cell (12L, 8M)**

2.1 (Fixed effect Model) Layout, Model, derivation of least square estimators of parameters.

2.2 Partitioning of total sum of squares and degrees of freedom (d.f.), expectations of mean sum of squares.

2.3 Statement of the distributions of different sum of squares, preparing ANOVA

2.4 Two way classification with m observations per cell (random effect Model) Layout, Model, derivation of least square estimators of parameters.

2.5 Partitioning of total sum of squares and degrees of freedom (d.f.), expectations of mean sum of squares.

2.6 Statement of the distributions of different sum of squares, preparing ANOVA

2.7 Examples and problems

**3. Design of experiments (8L, 5M)**

3.1 Concept of Design of Experiment (DOE), Introduction to basic terms of Design of Experiments, Experimental unit, treatments, layout of an experiment, factor, level, run of experiment, control experiment, test experiment.

3.2 Basic principles of Design of Experiments, Randomization, Replication and Local control.

3.3 Uniformity trials.

3.4 Choice of size and shape of a plot.

3.5 The empirical formula for the variance per unit area of plots.

3.6 Examples and problems

## 4. Standard Designs of Experiments (22L, 15M)

4.1 Completely Randomized Design (CRD).

Definition and model, Preparation of Analysis of Variance (ANOVA) table, testing of equality of treatment effects, testing equality of two specified treatment means, critical differences. Merits and demerits of CRD.

4.2 Randomized Block Design (RBD).

Definition and model, Preparation of ANOVA table, testing of equality of treatment effects and block effects, testing for equality of two specific treatment means, critical differences. Merits and demerits of RBD.

4.3 Latin Square Design (LSD) : definition, model:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \varepsilon_{ijk} \qquad i = 1,2,,....,m;$$
$$j = 1,2,,....,m; \qquad (i,j,k)\varepsilon S$$
$$k= 1,2,,....,m$$

Assumptions and interpretation, Estimation of parameters, Expected value of Mean sum of squares, components of variance.

Hypothesis for the model:

$H_{01} : \alpha_1 = \alpha_2 =...= \alpha_m$

$H_{02} : \beta_1 = \beta_2 =...= \beta_m$

$H_{02} : \gamma_1 = \gamma_2 =...= \gamma_m$

and its interpretation. Justification of use of F-test for $H_{01}$, $H_{02}$ and $H_{03,}$ (independence of Chi-squares is to be assumed), Preparation of ANOVA table and F-test for $H_{01}$, $H_{02}$ and $H_{03}$. Testing for equality of two specified treatments effects, use of critical difference, testing for equality of two row effects, two column effects and treatment effects. Merits and demerits of LSD.

4.4 Identification of real life situation where the above designs are useful.

4.5 Applications of principles of Design of Experiments in CRD, RBD and LSD.

4.6 Simple algebraic and numerical problems.

## 5. Efficiency of a Design (8L, 5M)

5.1 Concept and definition of efficiency of a design.

5.2 Comparison of efficiencies between CRD and RBD.

5.3 Comparison of efficiencies between LSD and RBD, LSD and CRD.

5.4 Simple numerical problems.

**Books Recommended:**

1. Federer W.T. : Experimental Designs, Oxford & IDH Publishing Co., New Delhi.
2. Cochren W.G. & Cox G,M.: Experimental Designs, John Wiley & Sons Inc., New Delhi.
3. Montgomery D.C. : Design & Analysis of Experiments, John Wiley & Sons Inc., New Delhi,2001.
4. Dass M.N. & Giri N.C. : Design & Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
5. Snedecor G.W.& Cochren W.G. : Statistical Methods, Affiliated East West Press, New Delhi.
6. Goon, Gupta, Dasgupta : Fundamentals of Statistics, Vol-II, The World Press Pvt. Ltd., Calcutta 1986.
7. Gupta S.C. & Kapoor V.K. : Fundamentals of Applied Statistics, S. Chand Sons, New Delhi.
8. Parimal Mukhopadhyay : Applied Statistics, Books and Allied (P) Ltd, Kolkata,2005.

# ST-354: Sampling Theory

**1. Sample Survey** **(12L, 8M)**

1.1 Concept of distinguishable elementary units, sampling units, sampling frame.

1.2 Objective of a sample survey.

1.3 Designing questionnaire, characteristics of good questionnaire.

1.4 Planning, execution and analysis of a sample survey. Practical problems in planning, execution and analysis of a sample survey.

1.5 Sampling and non-sampling errors with illustrations.

1.6 Study of some surveys illustrating the above ideas.

**2. Simple Random Sampling** **(15L, 10M)**

2.1 Simple random sampling with and without replacement: Definition, inclusion probabilities. Definitions of population mean, population total and population variance.

2.2 Proof of the following results:

1) Sample mean as an unbiased estimator of population mean.

2) $N\bar{y}$ is an unbiased estimator of population total.

3) Sample mean square is an unbiased estimator of population mean square for SRSWOR

4) Var($\bar{y}$)= $\frac{N-n}{Nn}$ $S^2$ and SE($\bar{y}$) in case of SRSWOR.

5) Var($\bar{y}$)=$\frac{N-1}{Nn}S^2$ and SE($\bar{y}$) in case of SRSWR.

2.3 Simple random sampling without replacement for proportions.

2.4 Proof of the following results:

1) Sample proportion is an unbiased estimator of Population proportion

2) Np is an unbiased estimator of NP.

3) Var(p) = $\frac{(N-n)}{N-1}\frac{P(1-P)}{n}$ and SE(p)

**3. Determination of Sample Size (in case of SRS) (6L, 4M)**

3.1 Determination of sample size for estimating population mean and population proportion when

(i) Margin of error and confidence coefficient is given.

(ii) Coefficient of variation and confidence coefficient is given.

3.2 Examples and problems.

**4. Stratified Random Sampling (18L, 12M)**

4.1 Introduction

4.2 Real life situations.

4.3 Stratified random sampling as a sample drawn from individual stratum using SRSWOR in each stratum.

4.4 Construction of strata

4.5 Proof of the following results.

a) $\bar{y}_{st}$ as an unbiased estimator of population mean $\bar{Y}$.

b) N $\bar{y}_{st}$ as an unbiased estimator of population total.

4.5 Standard error of $\bar{y}_{st}$ & N $\bar{y}_{st}$ and their estimation.

4.6 Problem of allocation, proportional allocation, Neyman's allocation, derivation of the expressions for the standard errors of the above estimators when these allocations are used.

4.7 Gain in precision due to stratification, comparison amongst SRSWOR, stratification with proportional allocation & stratification with Neyman's allocation.

4.8 Cost & variance analysis in stratified random sampling, minimization of variance for fixed cost, minimization of cost for fixed variance, optimum allocation, Neyman's allocation as a particular case of optimum allocation in cost and variance analysis.

4.9 Examples and problems.

**5. Systematic Sampling** **(9L, 6M)**

5.1 Real life situation where systematic sampling is appropriate. Technique of drawing a sample using systematic sampling.

5.2 Estimation of population mean and population total, standard errors of these estimators.

5.3 Distinguishing between stratification and systematic sampling, between SRSWOR and systematic sampling through real life situations.

5.4 Examples and problems.

**Books Recommended:**

1. Cochran W.G. : Sampling Techniques, Wiley Eastern Ltd.,New Delhi.
2. Sukhatme P.V. & B.V. : Sampling Theory of Surveys with Application, Indian Society of Agricultural Statistics, New Delhi Pub.
3. Murty M.N. : Sampling Methods, ISI, Kolkata,1977.
4. Daroga, Singh & Chaudhary F.S. : Theory & Analysis of Sample Survey Designs, Wiley Eastern Ltd., New Delhi.
5. Gupta S.C. & Kapoor V.K. : Fundamentals of Applied Statistics, S. Chand Sons, New Delhi.
6. Mukhopadhay P. (2002). Theory and Method of Sample Survey, (Chapman and Hall)

# ST-355: Financial Mathematics

1. **The measurement of interest:** **(12L, 8M)**
   Introduction, The accumulation and amount functions, The effective rate of interest, Simple interest, Compound interest, Present value, The effective rate of discount, Nominal rates of interest and discount, Forces of interest and discount, Varying interest, Summary of results.
2. **Solution of problems in interest:** **(9L, 6M)**
   Introduction, The basic problem, Equation of value, Unknown time, Unknown rate of interest, Determining time periods, Practical examples.

3. **Basic annuities:** **(12L. 8M)**
   Introduction, Annuity-immediate, Annuity-due, Annuity values on any date, Perpetuities, Unknown time, Unknown rate of interest, Varying interest, Annuities not involving compound interest.
4. **More general annuities:** **(15L,10M)**
   Introduction, Differing payment and interest conversion periods, Annuities payable less frequently than interest convertible, Annuities payable more frequently than interest convertible, Continuous annuities, Payments varying in arithmetic progression, Payments varying in geometric progression, More general varying annuities, Continuous varying annuities, Summary of results,
5. **Amortization schedules and sinking funds:** **(12L, 8M)**
   Introduction, Finding the outstanding loan balance, Amortization schedules, Sinking funds, Differing payment periods and interest conversion periods, Varying series of payments, Amortization with continuous payments, Step-rate amounts of principal.

**References**

1. Kellison Stephen G., The Theory of Interest, 3rd Edition. McGraw-Hill International Edition (2009).
2. UK Institute of Actuaries core leading for the subject CT1-Financial Mathematics.
3. Elliott R.J. and Kopp P.E. Mathematics of Financial Markets. Springer.1999

# ST 356: Statistical Computing Using R-Software

**1. Introduction to R** **(5L, 3M)**

1.1 Downloading and installation of R

1.2 Features of R, to start R and exit from R, Introduction to R screen.

1.3 Meaning of package, base(standard package) package, to install a package, to load a package, to delete a package, learning about a package, getting help.

1.4 Meaning of workspace, saving a workspace, loading a workspace, deleting a workspace.

**2. Basics of R** **(4L, 4M)**

2.1 Data Types (Modes) in R: numeric, character, logical.

2.2 Meaning of object, function. Types of function: built-in function and user defined function

2.3 Naming an object.

2.4 Functions.

2.5 Data objects, Types of data object: scalar, vector, factor, data frame, list, array, matrix

2.6Functions for working with objects: mode(), length(), cbind(), rbind(), names(), ls(), rm()

**3. Operators in R (3L, 3M)**

3.1 Types of operators: arithmetic operators, relational operators, logical operators.

3.2 Expression: arithmetic expression, relational expression, logical expression.

3.3 Precedence rule of arithmetic operators and logical operators.

**4. Working with data objects and using functions (7L, 6M)**

4.1 Vectors: creating a vector, modifying a vector, deleting a vector.

4.2 Working with vectors: the functions to be discussed-c(), rep(), rev(), sort(), diff(), max(), min(), colon operator(:), seq(), scan(), cut(), cat(), table(), which(), unique(), is.vector(), as.vector().

4.3 Mathematical functions: abs(), sqrt(), ceiling(), floor(), trunk(), log(), log10(), exp(), sin(), cos(), tan(), atan(), sign(), round().

4.4 Character functions: nchar(), substr(), grep(), sub(), paste(), strsplit(), toupper(), tolower().

4.5 Meaning of data frame, creation of data frame, modifying a data frame, deleting data frame, extracting elements from a data frame, use of $ sign. Functions to be discussed: subset(), transform(), attach(), detach(), with(), data.entry(), edit(), is.data.frame(), as.data.frame().

**5. Working with matrices: (4L, 3M)**

5.1 Creating a matrix, scalar multiplication of matrix, matrix addition, subtraction and multiplication, transpose of a matrix, inverse of a matrix, solving system of linear equations, finding row and column sums and means.

5.2 The functions to be discussed: matrix(), colMeans(), colSums(), rowMeans(), rowSums(), solve(), t(), diag(), is.matrix(), as.matrix()..

**6. Array (3L, 2M)**

6.1 Creating an array, accessing the elements of an array.

6.2 Functions to be discussed: array().

6.3 Working with factors, creation of factor, extracting elements of a factor, the function to be discussed factor(), levels, ordered(), is.factor(), as.factor().

**7. Working with lists** **(2L, 2M)**

7.1 Creating a list, extracting elements from a list, splitting vectors and data frames into lists, the functions to be discussed: list(), split()..

**8. Graphics** **(3L, 3M)**

8.1 Low level and high level functions.

8.2 Functions to be discussed: plot(), lines(), points(), smooth.spline(), curve(), barplot(), pie(), hist(), mtext(), legend().

**9. Statistical applications** **(25L, 14M)**

9.1. Sampling: Simple Random Sampling with and without replacement, Stratified Random Sampling, proportional allocation and optimum allocation in stratified random sampling, Systematic Sampling.

Functions to be discussed: sample()

Simulation of simple random experiments

9.2 Diagrams and Graphs: Bar Chart (Subdivided, multiple), Pie diagram, Stem and Leaf diagram, Rod, Spike diagram, Histogram (equal as well as unequal class intervals), Empirical distribution function, Ogive curve, Frequency polygon superimposed.

9.3. Measures of Central Tendency, Dispersion, Skewness, Kurtosis: Mean, Mode, Median, G.M., H.M., Quartiles, Deciles, Percentiles, Box Plot, Moments, Skewness, Kurtosis.

9.4 Probability: Permutation and combination $\binom{n}{r}$, $\left({}^{n}P_{r}\right)$, Computation of probabilities.

9.5 Probability Distributions: Hypergeometric distribution, Binomial distribution, Poisson distribution, Normal distribution.

In all the above distributions, simulations as well as computation of probabilities are expected.

9.6 Correlation and Regression Analysis: Scatter diagram, computation of Karl Pearson's correlation coefficient and Spearman's rank correlation coefficient, simple and multiple linear regression, computation of regression coefficients, residuals, estimated values, multiple and partial correlation coefficient. Examples and problems.

9.7 Functions to be discussed: sum(), cumsum(), mean(), median(), var(), sd(), quantile(), cov(), cor(), lm(), abline(), coef(), residuals(), predict(), qqnorm().

**Books Recommended:**

1. Venables, W.N., and Smith, D.M. and the R Development Core Team: An Introduction to R, Notes on R.
2. Purohit S.G., Gore S.D. and Deshmukh S.R.(2008): Statistics Using R., Narosa Pub.

# ST-361: Distribution Theory-II

**1. Negative Binomial Distribution (NBD) (10L, 7M)**

1.1 P.m.f :

$$P(X = x) = \binom{x+k-1}{x} p^k q^x \qquad x = 0,1,2,\ldots \qquad 0< p < 1, q = 1-p.$$

Notation X~ NB(k, p), $k \geq 1$.

1.2 Probability Generating function (pgf), mgf, cgf, fmgf, first four moments and cumulants, factorial moments, recurrence relation for probabilities.

1.3 Additive property.

1.4 NB distribution as a waiting time distribution.

1.5 NB (k,p) as the distribution of sum of k i.i.d. geometric r.v.s. with common parameter p.

1.6 NB distribution obtained form Poisson distribution with gamma distributed parameter.

1.7 Poisson approximation to NB distribution.

1.8 Examples and problems.

**2. Truncated Distributions (10L,7M)**

2.1 Truncated distribution as conditional distribution, truncation to the right, left and on both sides.

2.2 Binomial distribution B(n p) left truncated at X = 0 (value zero not observable), its p.m.f, mean, variance.

2.3 Poisson distribution P($\lambda$) left truncated at X = 0 (value zero not observable), its p.m.f, mean, variance.

2.4 Normal distribution N($\mu$, $\sigma^2$) truncated

(i) to the left of X = a

(ii) to the right of X = b

(iii) to the left of X = a and to the right of X = b, its p.d.f and mean.

2.5 Examples and problems.

**3. Log-Normal Distribution (7L, 5M)**

3.1 P.d.f :

$$f(x) = \frac{1}{(x-a)\sigma\sqrt{2\pi}} \exp\left\{-\frac{1}{2\sigma^2}\left(\log(x-a)-\mu\right)^2 \right\}; \quad a < x < \infty, \ a < \mu < \infty, \ \sigma > 0$$

$= 0$ *otherwise.*

Notation : X~LN (a, $\mu$, $\sigma^2$)

3.2 Nature of the probability curve.

3.3 Moments ($r^{th}$ moment about x=a ), first four moments, $\beta_1$ and $\gamma_1$ coefficients, quartiles.

3.4 Relation with $N(\mu, \sigma^2)$ distribution.

3.5 Examples and problems.

**4. Weibull Distribution** **(7L, 4M)**

4.1 p.d.f.:

$$f(x) = \frac{\beta}{\alpha}\left(\frac{x-\gamma}{\alpha}\right)^{\beta-1} \exp\left\{-\left(\frac{x-\gamma}{\alpha}\right)^{\beta}\right\};\ \gamma \le x < \infty,\ -\infty < \gamma < \infty,\ \alpha, \beta > 0$$

$$= 0 \qquad \textit{otherwise.}$$

Notation : $X \sim W(\gamma, \alpha, \beta)$

4.2 Distribution function, quartiles.

4.3 $r^{th}$ Moment about $x = \gamma$, mean and variance.

4.4 Relation with exponential distribution.

4.5 Examples and problems.

**5. Cauchy Distribution** **(8L, 6M)**

5.1 p.d.f.:

$$f(x) = \frac{\lambda}{\pi}\,\frac{1}{1+\left(\frac{x-\mu}{\lambda}\right)^2};\ -\infty < x < \infty,\ -\infty < \mu < \infty,\ \lambda > 0$$

$$= 0 \qquad \textit{otherwise.}$$

Notation : $X \sim C(\mu, \lambda)$

5.2 Nature of probability curve.

5.3 Distribution function, quartiles, non-existence of moments.

5.4 Additive property for two independent Cauchy variates (Statement only), Statement of distribution of the sample mean.

5.5 Relationship with uniform and Student's 't' distribution.

5.6 Examples and problems.

**6. Laplace Distribution (Double Exponential Distribution)** **(8L, 4M)**

6.1 P.d.f :

$$f(x) = \frac{\lambda}{2}\exp\left[-\lambda\left|x-\mu\ \right|\right] \quad -\infty < x < \infty,\ -\infty < \mu < \infty,\ \lambda > 0$$

$= \quad 0 \quad$ *otherwise.*

Notation : X ~ L (μ, λ)

6.2 Nature of probability curve.

6.3 Distribution function, quartiles.0

6.4 mgf, cgf, moments and cumulants, $\beta_1$, $\beta_2$, $\gamma_1$, $\gamma_2$.

6.5 Laplace distribution as the distribution of the difference of two i.i.d exponential variates with mean θ.

6.6 Examples and problems.

**7. Bivariate Normal Distribution (BND) (10L, 7M)**

7.1 P.d.f :

$$f(x) = \frac{1}{2\pi\sigma_1\sigma_2\ \sqrt{1-\rho^2}}\exp\left\{-\frac{1}{2\left(1-\rho^2\right)}\left[\left(\frac{x-\mu_1}{\sigma_1}\right)^2 + \left(\frac{y-\mu_2}{\sigma_2}\right)^2 - 2\rho\left(\frac{x-\mu_1}{\sigma_1}\right)\left(\frac{y-\mu_2}{\sigma_2}\right)\right]\right\}$$

$$-\infty < x, y, \mu_1, \mu_2 < \infty \quad \sigma_1, \sigma_2 > 0 \quad , -1 < \rho < 1$$

$= \quad 0 \quad$ *otherwise.*

Notation : (X,Y) ~ BN ($\mu_1$, $\mu_2$, $\sigma_1^2$, $\sigma_2^2$, ρ)

Marginal and conditional distributions, identification of parameters, regression of Y on X and X on Y, independence and uncorrelatedness, mgf and moments

7.2 Cauchy distribution as the distribution of Z = X/Y where

(X ,Y) ~ BN (0,0,$\sigma_1^2$, $\sigma_2^2$, $\rho$ )

7.3 Example and problems.

**Books Recommended:**

1. Mood A. M, Graybill F. Bose D. C.: Introduction to theory of Statistics (III Edn.) McGraw Hill Series, 1974.
2. Hogg R.V. and Graig A. T.: Introduction to Mathematical Statistics (5thEdn.)
3. S.C. Gupta and V.K. Kapoor : Fundamentals of Mathematical Statistics Sultan Chand and Sons, 88 Daryaganj New Delhi 2
4. Rohatgi V.K. and Ehsanes Saleh A. K. MD. (2003). An Introduction to Probability Theory and Mathematical Statistics, (Wiley Eastern, 2nd Ed.).

# ST-362: Statistical Inference-II

**1. Parametric Tests** **(18L, 12M)**

1.1 (a) Statistical hypothesis, problem of testing of hypothesis, Definition and Illustrations of (i) simple hypothesis, (ii) composite hypothesis, (iii) Two types of errors in testing of hypothesis (iv) sizes of two types of errors.

Problem of controlling the sizes of two types of errors.

(b) Definition and illustrations of (i) level of significance (ii) observed level of significance (p value) (iii) power function of the test (iv) size of test (v) power of test.

1.2 Definition of Most Powerful (MP) and Uniformly Most Powerful (UMP) tests of size $\alpha$. Neyman-Pearson's (NP) lemma with proof for the construction of MP test, construction of UMP test for one sided alternative.

1.3 Examples and problems.

**2. Interval Estimation** **(12L, 8M)**

2.1 Notion of interval estimation, definition of confidence interval, confidence bounds.

2.2 Relation between confidence interval and testing of hypothesis, definition of pivotal quantity and its use in obtaining confidence interval and bounds.

2.3 Interval estimation for the following cases:

(i) Mean ($\mu$) of normal distribution (when $\sigma$ known and $\sigma$ unknown)

(ii) Variance ($\sigma^2$) of normal distribution (when $\mu$ known and $\mu$ unknown)

(iii) Difference of two means $\mu_1$ - $\mu_2$ (a) for a sample from bivariate normal population (b) for samples from two independent normal populations.

(iv) Mean of exponential distribution.

(v) Population proportion (P) and difference of two population proportions $(P_1 - P_2)$ in case of two independent large samples.

(vi) Population quantiles using order statistics.

2.4 Examples and problems.

**3. Non Parametric Tests** **(20L, 14M)**

3.1 Meaning of ordinal and nominal data.

Meaning of non-parametric problems, Distinction between parametric and Non-parametric methods. Concept of distribution free statistic, advantages and disadvantages of non parametric methods.

Procedure of:

(i) sign test for one and two samples problem

(ii) Wilcoxon signed rank T-test for paired observations.

(iii) Mann-Whitney U-test for two independent samples.

(iv) Run test for randomness of given observations.

(v) Kolmogorov-Smirnov test for completely specified univariate distribution (only one sample problem)

3.2 Examples and problems.

**4. Sequential Tests** **(10L, 6M)**

4.1 Sequential test procedure for simple null hypothesis against simple alternative hypothesis and its comparison with fixed sample size test procedure. Definition of Wald's sequential probability ratio test (SPRT) of strength ($\alpha$, $\beta$).

Illustration for standard distributions: Bernoulli, Poisson, normal and exponential distribution, graphical and tabular procedures for carrying out the test.

4.2 Examples and problems.

**Books Recommended:**

1. Mood A. M, Graybill F. Bose D. C. : Introduction to theory of Statistics (III Edn.) Mc- Graw Hill Series, 1974.
2. Hogg R.V. and Graig A. T.: Introduction to Mathematical Statistics ($5^{th}$Edn.)
3. S.C. Gupta and V.K. Kapoor : Fundamentals of Mathematical Statistics Sultan Chand and Sons, 88 Daryaganj New Delhi 2
4. Rohatgi V.K. and Ehsanes Saleh A. K. MD. (2003). An Introduction to Probability Theory and Mathematical Statistics, (Wiley Eastern, $2^{nd}$ Ed.).
5. Siegel S.: Non Parametric Methods for the Behavioral Sciences. International Student Ed. McGraw Hill Kogakusha Ltd.
6. J.D. Gibbons : Non Parametric Statistical Inference, McGraw Hill Book Company, New York.
7. Daniel : Applied Non Parametric Statistics, Houghton Mifflin Company Roston.
8. Kale B.K. (2005). A First Course on Parametric Inference, ($2^{nd}$ Narosa Publishing House)

# ST-363: Design of Experiments-II

**1. Missing Plot Technique (10L, 6M)**

1.1 Situations where missing plot technique is applicable.

1.2 Estimation of missing plots by minimizing error sum of squares in RBD and LSD with one or two observations are missing.

1.3 Derivation of exact treatments sum of squares, preparing analysis of variance table and writing report.

1.4 Iterative procedure in case of missing observations.

1.5 t-test for comparing any two treatment effects.

**2. Analysis of Covariance (With One Concomitant Variable) (12L, 8M)**

2.1 Situations where analysis of covariance is applicable.

2.2 Analysis of covariance in CRD model, estimation of parameters, Partition of total sum of squares and for sums of product, ANCOVA table

2.3 Analysis of covariance in RBD model, estimation of parameters, Partition of total sum of squares and for sums of product, ANCOVA table

2.4 Analysis of covariance in LSD model, estimation of parameters, Partition of total sum of squares and for sums of product, ANCOVA table

**3. Balanced Incomplete Block Design (B.I.B.D.) (15L, 10M)**

3.1 Definition and simple relations between parameters:

(i) $bk = rv$

(ii) $\lambda(v - 1) = r(k-1)$

(iii) $b \geq v$

(iv) $b \geq v + r - k$

(v) $r \geq k$

3.2 Model, estimation of parameters (derivation are not expected )

3.3 Analysis of variance table (intra-block analysis only) for testing significance of treatment effects and block effects.

3.4 Tests for comparing two treatment effects.

3.5 Symmetric BIBD: definition, theorems on symmetric BIBD

**4. Factorial Experiments (16L, 12M)**

4.1 General description of factorial experiments, $2^2$, $2^3$ factorial experiments arranged in RBD.

4.2 Definitions of main effects and interactions in $2^2$, $2^3$ factorial experiments.

4.3 Preparation of ANOVA table by Yates procedure, test for main effects and interactions, estimation of main effects and interaction effects.

4.4 General idea of confounding in factorial experiments, total confounding, analysis of variance table, testing main effects and interactions (confounding only one interaction).

4.5 Partial confounding (confounding only one interaction per replicate), ANOVA table, testing of main effects and interactions.

4.6 Construction of layouts in total confounding and partial confounding for $2^2$, $2^3$ factorial experiments.

**5. Split Plot Design (7L, 4M)**

6.1 General description of a split plot design.

6.2 Layout & model.

6.3 Analysis of variance table for testing significance of main effects & interactions.

**Books Recommended:**

1. Federer W.T. : Experimental Designs, Oxford & IDH Publishing Co., New Delhi.
2. Cochren W.G. & Cox G,M.: Experimental Designs, John Wiley & Sons Inc., New Delhi.
3. Montgomery D.C. : Design & Analysis of Experiments, John Wiley & Sons Inc., New Delhi,2001.
4. Dass M.N. & Giri N.C. : Design & Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
5. Snedecor G.W.& Cochren W.G. : Statistical Methods, Affiliated East West Press, New Delhi.
6. Goon, Gupta, Dasgupta : Fundamentals of Statistics, Vol-II, The World Press Pvt. Ltd., Calcutta 1986.
7. Gupta S.C. & Kapoor V.K. : Fundamentals of Applied Statistics, S. Chand Sons, New Delhi.
8. Parimal Mukhopadhyay : Applied Statistics, Books and Allied (P) Ltd, Kolkata,2005.

# ST-364: Statistical Quality Control

**1. Indian Standards and International Standards (6L, 3M)**

Introduction to IS series and ISO 9000: 2008 Series with reference to process Control and statistical techniques (History, Organization Structure and different Clauses), role of statistical methods.

**2. Statistical Process Control (SPC) (24L, 17M)**

2.1 Introduction

2.2 Seven Process Control (PC) Tools of SPC

(i) Check sheet (ii) Cause and Effect Diagram (CFD)

(iii) Pareto Diagram (iv) Histogram

(v) Control chart. (vi) Scatter diagram

(vii) Designs of Experiment (DOE).

2.3 Control Charts: Chance Causes and assignable causes of variation, statistical basis of control charts, exact probability limits, k-Sigma limits. Justification for the use of 3-sigma limits for normal distribution and using Chebychev's inequality for non normal distributions. Criteria for detecting lack of Control Situations:

i. A point outside the control limits.

ii. Non random pattern of variation of the following type.

(a) Seven or more points above or below central line.

(b) Presence of cycle or linear trends.

Note: Mathematical justification for (ii) is not expected.

Use of control charts when (i) standards are given (ii) standards are not given.

2.4 Control charts for continuous variables

Decisions preparatory to control charts:

(i) Choice of the variable

(ii) Basis of subgroups.

(iii) Size of subgroups.

(iv) Frequency of subgroups (Periodicity)

2.5 R Chart and $\overline{X}$ chart:

Purpose of R and $\overline{X}$ chart. Construction of R chart when the Process Standard deviation ($\sigma$) is not given. Control limits, drawing of Control Chart, Plotting sample range values, revision of control limits if necessary, estimate of $\sigma$ for future use. Construction of $\overline{X}$ chart when

the process standard deviation ($\sigma$) is not given: Control limits based on $\sigma$, drawing of control chart. Plotting sample means, revision of control limits of $\overline{X}$ chart, if necessary.

2.6 Control charts for Attributes:

Decision preparatory to control charts:

(i) size of subgroups:

(ii) frequency of subgroups (Periodicity).

p-chart (for fixed and variable sample size),

np-chart, c-chart and u-chart (for fixed sample size)

2.7 X chart, MR chart.

2.8 CUSUM chart (tabular method).

**3. Capability Studies: (12L, 8M)**

3.1 Specification Limits, natural tolerance limits and their comparisons.

3.2 Decisions based on these comparisons, estimate of percent defective.

3.3 Catching the shift on average, evaluation of probability of catching shift of the first sample or on the subsequent samples after the shift (when process standard deviation is fixed).

3.4 Shift in the process fraction defective, Evaluation of probability (using normal approximation only) of catching the shift on the first sample or on the subsequent samples after the shift.

3.5 Process Capability Indices $C_p$, $C_{pk}$ .

**4. Acceptance Sampling for Attributes (18L, 12M)**

4.1 Introduction.

Concept of sampling inspection plan, comparison between 100% inspection and sampling inspection .Rectification of single and double sampling plans.

Explanation of the terms: Producer's risk, Consumer's risk, Acceptance Quality Level (AQL), LTFD, Average Outgoing Quality (AOQ), AOQL, Average Sample Number (ASN), Average Total inspection (ATI), Operating characteristic (OC) curve ,AOQ curve, ATI curve.

**Note:** Distinction between type-A OC Curve and type-B OC curve is not expected.

4.2 Single Sampling Plan:

Evaluation of probability of acceptance using

(i) Hypergeometric (ii) Binomial (iii) Poisson and (iv) Normal distributions.

Derivation of AOQ and ATI. Graphical determination of AOQL, Determination of a single sampling plans by lot quality and average quality approaches (numerical problems are not expected). Description of Dodge and

Romig tables (numerical problems are not expected)

4.3 Double Sampling Plan.

Evaluation of probability acceptance using Poisson approximation, derivation of ASN and ATI (With complete inspection of second sample). Derivation of the approximate formula of AOQ. Description of Dodge Romig Tables.

4.4 comparisons of single sampling plan and double sampling plan.

4.5 Example and problems.

**Books Recommended:**

1. Duncan A.J.: Quality Control & Industrial Statistics, D.B. Taraporevale Sons & Co. Pvt. Ltd., Bombay.
2. Grant E.L. & Leavenworth: Statistical Quality Control, Mc-Graw Hill Kogakusha, Ltd., New Delhi.
3. Montgomery: Statistical Quality Control, John Wiley & Sons Inc. New York (3rd Ed.),1996
4. Hand Book of SQC: Bureau of Indian Standards.
5. ISO 9000-2000 Standards, 2008.

# ST-365: Official Statistics and Applied Statistics

**1. Indian official statistics (18L, 12M)**

1.1 Introduction to Indian Statistical system,

1.2 National and State level Statistical Offices

1.3 Methods of collection of official statistics, their reliability and limitations.

1.4 Introduction of Nationwide Censuses and Surveys

1.5 Agencies responsible for collection of data on Official Statistics on Agriculture, Industrial production, Trade, Price (Retail and Wholesale) and their important publications

1.6 The principal publications containing such statistics on the topics- population, agriculture, industry, trade, price, labour and employment, transport and communications, banking and finance.

**2. Index Number** **(12L, 8M)**

2.1 Meaning and utility of Index number.

2.2 Limitations of index number

2.3 Weighted and unweighted index number

2.4 Selection of base. Shifting of base, splicing, deflating, purchasing power of money.

2.5 Fixed and chain base index numbers.

2.6 Types of index number: Laspeyre's, Passche's, Fisher, Kelly, Walsh Marshall-Edgeworth's, Dorbish-Bowely, Value index number, wholesale Price index number, Industrial product index number.

2.7 Testing for Adequacy of all index number using time reversal test, factor Reversal test, Circular test,

2.8 Construction of consumer price index, steps to be followed in construction. Problems in construction, family-budget method, aggregate expenditure method.

2.9 Examples and problems.

**3. Demography** **(12L, 8M)**

3.1 Vital Statistics, uses, measurement of population.

3.2 Measures of mortality: crude death rate, specific death rates (age wise, sex wise). Standardized death rates (based on age-specific death rates) direct and indirect method comparative study of these measures, infant morality rate.

3.3 Measures of fertility, Crude birth rate, specific rate (age and sex), total fertility rate, comparative study of these measures.

3.4 Reproduction rates: G.R.R., N.R.R., comparison and interpretation.

3.5 Simple numerical problems.

**4. Life Tables** **(6L, 4M)**

4.1 Introduction and meaning.

4.2 Construction. Functions and their interrelations Complete life table

4.3 Expectation of life.

4.4 Numerical examples and problems.

**5. Elements of Actuarial Statistics** **(12L, 8M)**

5.1 Concept of risk, types of risk, characteristics of insurable risk.

5.2 Annuities: annuity certain, annuity due, annuity immediate, Life annuity.

5.3 A whole life annuity, present value r.v. of the annuity, its actuarial present value.

5.4 n-year temporary life annuity, its present value and actuarial present value.

5.5 Simple numerical problems.

**Books Recommended:**

1. Gupta S.C. & Kapoor V.K. : Fundamentals of Applied Statistics, S. Chand Sons, New Delhi.
2. Goon, Gupta, Dasgupta : Fundamentals of Statistics, Vol-II, The World Press Pvt. Ltd., Calcutta 1986.
3. Parimal Mukhopadhyay : Applied Statistics, Books and Allied (P) Ltd, Kolkata,2005.
4. Bowers N.L., Jr. H.S. Gerber, Hickan J.C.,Jons D.A., Nesbitt C.J.: Actuarial Mathematics, The Society of Actuaries, 1997.
5. Lecture Notes on Statistics in Insurance: An Introduction, Dr. Mrs. S.R.Deshmukh.

# ST-366: Optimization Techniques

**1. Linear Programming Problems** **(20L, 14M)**

1.1 Statement of the linear programming problems. Simple examples and formulation of problems.

1.2 Definitions of i) A Slack variable ii) Surplus variable iii) Unrestricted variable iv) Decision variable.

1.3 Definition of i) a solution ii) feasible solution iii) a basic feasible solution (b.f.s. degenerate and non-degenerate solution) iv) Optimal solution v) basic and non basic variables vi) objective function vii) non- negativity conditions.

1.4 Solutions of L.P.P. by i) graphical method: Solution space unique and non-unique solutions. Obtaining on optimum solution ii) Simplex method: initial b.f.s. is readily available, obtaining the initial basic feasible solution. Criterion for deciding whether obtained solution is optimal, method of improving a solution.

1.5 Initial b.f.s. is not readily available, introduction to artificial variable. Big M. method (or penalty method) modified objective function. Modification and applications of simplex method L.P.P. with artificial variable.

1.6 Examples and problems.

**2. Theory of Duality** **(6L, 4M)**

2.1 Writing a dual of primal problem.

2.2 Solution of L.P.P. by using its dual

2.3 Conversion of primal to dual and dual to primal

2.4 Examples and problems.

**3. Transportation Problem** **(12L, 8M)**

3.1 Definition of i) a feasible solution, ii) a basic feasible solution and iii) optimal solution.

3.2 Statement of transportation problem, balanced and unbalanced transportation problem.

3.3 Methods of obtaining initial basic feasible solution:

1) North west corner method.

2) Method of matrix minima (least cost method)

3) Vogel's Approximation Method (VAM).

3.4 Optimal solution of transportation problem using *uv*-method (MODI), uniqueness and non uniqueness of optimal solution. Degeneracy and method of resolving degeneracy.

3.5 Variants in transportation problem: No allocation in a particular cell, maximization problem.

**4. Assignment Problem** **(6L, 4M)**

4.1 Assignment problem: Statement of assignment problem, relation to transportation problem and solution of assignment problem using Hungarian method.

4.2 Special cases in the assignment problem: Unbalanced assignment problem, maximization problem, restrictions on assignments and alternate optimal solution.

4.3 Examples and problems.

**5. C.P.M. And Networking Analysis** **(16L, 10M)**

5.1 Definition i) Event or node ii) Activity iii) critical activity iv) Project function v) Predecessor and successor activity vi) Predecessor and successor event vii) properties of network viii) numbering by Fulkerson's rule.

5.2 Critical path method, constructions of a network

5.3 Definition i) Earliest start time ii) Earliest finish time iii) latest start time iv) Latest finish time v) Critical path

5.4 Float, Total float, Independent float & Free float, their significance.

5.5 PERT : Definition of PERT, i) Pessimistic time ii) Optimistic time iii) Most likely time iv) Forward Pass Calculation v) Backward Pass calculation vi) Slack vii) Critical Path viii) Probability of meeting scheduled date.

5.6 Calculation of expected time, S.D. of project duration.

5.7 Distinguish between PERT and C.P.M.

5.8 Examples and problems.

**Books Recommended:**

1. Gauss E.: Linear Programming Method & Applications, Narosa Pub. House, New Delhi.
2. Taha R.A.: Operations Research an Introduction, 5th Ed.
3. Gupta P.K. & Hira D.S. : Operations Research, S. Chand & Co. ltd., New Delhi.
4. Shrinath L.S. : PERT-CPM Principles & Applications, Affiliated East West Press Pvt. Ltd., New Delhi.
5. Kapoor V.K.: Operations Research, S. Chand & Sons, New Delhi.
6. Sharma S.D.: Operations Research, Kedarnath Ramnath & Co., Meerut.

# ST-301: Practicals-I

**Note:** All Practicals in this paper are to be carried out either by using Computer with R/MS-Excel/MINITAB software.

**Section-I**

1. Estimation of parameters of standard probability distributions by the method of Maximum Likelihood Estimation.
2. Plotting of likelihood function.
3. Estimation of parameters of standard probability distributions by method of moments
4. Sampling distribution of estimators.
5. Estimation of population mean and population proportion under Simple Random Sampling.
6. Determination of sample size under simple random sampling while estimating population mean and population proportion..
7. Stratified Random Sampling-I.
8. Stratified Random Sampling-II.
9. Systematic sampling.

**Section-II**

1. Fitting of truncated Binomial, Poisson and Negative Binomial Distribution.
2. Fitting of Log-normal Distribution.
3. Model Sampling from Negative Binomial & Cauchy Distribution.
4. Testing of hypothesis – I ( Prob. Type I & II errors, MP test, Power of test)
5. Testing of hypothesis – II (UMP test for simple Vs. composite for Binomial, Poisson, Normal & Exponential Distributions)
6. Confidence Interval estimation
7. Non – parametric test – I (Sign test, Wilcoxon's Signed Rank test, Run test.)
8. Non – parametric test – II (Mann-Whitney test, Kolmogorov-Smirnov test.)
9. SPRT – I (Binomial & Poisson Distributions.)
10. SPRT – II (Normal & Exponential Distributions.)

**Marks Distribution:**

| Nature of the Examination | Marks | Time |
|---|---|---|
| External Practical Examination | 60 | 3 Hrs |
| Viva | 10 | |
| Verification of Journal | 10 | |
| Internal Examination based on Section I and II | 20 | During whole year |

# ST-302: Practicals-II

**Note:** Practicals in this paper are to be carried out by using Computer with R/MS-Excel/ MINITAB software.

**Section-I**

1. Analysis of CRD.
2. Analysis of RBD.
3. Analysis of LSD.
4. Efficiency of Designs.
5. Analysis of Two way Classification ( with $m > 1$)

**Practicals must be conducted by using R software**

6. Diagrammatic representation, Graphical representation of data.
7. Model sampling from different probability distributions learned during B.Sc.
8. Fitting of normal distribution.
9. Regression up to three variables.

**Section – II**

1. Missing Plot Technique in RBD.
2. Missing Plot Technique in LSD.
3. Analysis of covariance in CRD & RBD.
4. Analysis of BIBD.
5. Analysis of $2^3$ factorial experiment arranged in RBD.
6. Analysis of $2^3$ factorial experiment with total & partial confounding.
7. $\overline{X}$ -R charts,
6. p-charts
7. c and u-charts
8. X & MR charts.
9. CUSUM charts.
10. Single Sampling Plans ( with OC, AOQ, AOQL, ATI, ASN curves )
11. Double Sampling Plans ( with OC, AOQ, AOQL, ATI, ASN curves )

**Marks Distribution:**

| Nature of the Examination | Marks | Time |
|---|---|---|
| External Practical Examination | 60 | 3 Hrs |
| Viva | 10 | |
| Verification of Journal | 10 | |
| Internal Examination based on Section I and II | 20 | During whole year |

# ST-303: Practicals-III and Project

**Section-I**

**Practicals to be conducted by using MS-Excel/MINITAB/R software**

1. Calculation Present and accumulated value under simple and compound interest.
2. Relation between nominal, effective and force of interest.
3. Problems based on equation of value.
4. Calculation of present and accumulated value of annuities.
5. Problems based on more general annuities.
6. Amortization schedules and sinking funds.
7. Life Tables
8. Demography

**Section-II: Project:**

A separate Project may be assigned to individual student or a group of students (group of at most three students). Project work should be based on real life data related to social/ industrial/medical/ banking etc fields. Students may also use primary, secondary or simulated data sets for their project work. Students are supposed to write the project report on project work and submit a copy of project report at department before practical examinations.

**Marks Distribution:**

| Nature of the Examination | Marks | Time |
|---|---|---|
| External Practical Examination | 30 | 3 Hrs |
| Project Report Evaluation and Project Viva | 40 | |
| Verification of Journal | 10 | |
| Internal Examination | 20 | During whole year |