KAVAYITRI BAHINABAI CHAUDHARI
NORTH MAHARASHTRA UNIVERSITY
JALGAON-425001, INDIA

SYLLABUS UNDER
FACULTY OF SCIENCE & TECHNOLOGY

FOR
T.Y.B.Sc.(Statistics)
Semester V and VI of B.Sc. with CBCS

WITH EFFECT FROM ACADEMIC

YEAR 2020-2021

Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon
SYLLABUS FOR T.Y.B.Sc.(Statistics)
B.Sc.(Semester-V and Semester-VI) with effect from June 2020
Course Structure Semester V

Discipline and Course Type	Course Code	Title of Course	Credits	Teaching (Clock Hrs /week)	Total Teaching Hours	Marks Wt	
						INT (CA)	EXT (UA)
Discipline Specific Core Courses (DSC)	ST-501	Distribution Theory-I	3	3	45	40	60
	ST-502	Statistical Inference-I	3	3	45	40	60
	ST-503	Design of Experiments	3	3	45	40	60
	ST-504	Sampling Theory	3	3	45	40	60
DSC-Skill Enhancement	ST-505	Statistical Techniques for Research Methods	3	3	45	40	60
DSC-Elective (Select one)	ST-506(A)	Introduction to Regression Analysis	3	3	45	40	60
	ST-506(B)	Stochastic Processes					
DSC-Practical	ST-507	Statistics Practicals-V	2	4/Batch	60	40	60
	ST-508	Statistics Practicals- VI	2	4/Batch	60	40	60
	ST-509	Statistics Practicals- VII	2	4/Batch	60	40	60
Non Credit Elective Audit Corse (Select one)	AC-501(A)	NSS	--	2	30	100	--
	AC-501(B)	NCC					
	AC-501(C)	Sports					

Course Structure (Semester VI)

Discipline and Course Type	Course Code	Title of Course	Credits	Teaching (Clock Hrs /week)	Total Teaching Hours	Marks Wt	
						INT (CA)	EXT (UA)
Discipline Specific Course(DSC)-Core	ST-601	Distribution Theory-II	3	3	45	40	60
	ST-602	Statistical Inference-II	3	3	45	40	60
	ST-603	Statistical Quality Control	3	3	45	40	60
	ST-604	Official Statistics and Applied Statistics	3	3	45	40	60
DSC-Skill Enhancement	ST-605	C-Programming	3	3	45	40	60
DSC-Elective (Select one)	ST-606(A)	Optimization Techniques	3	3	45	40	60
	ST-606(B)	Actuarial Statistics					
DSC-Practical	ST-607	Statistics Practicals- VIII	2	4/Batch	60	40	60
	ST-608	Statistics Practicals-IX	2	4/Batch	60	40	60
	ST-609	Statistics Practicals-X-Project	2	4/Batch	60	40	60
Non Credit Elective Audit Corse (Select one)	AC-601(A)	Soft skill	--	2	30	100	--
	AC-601(B)	Yoga					
	AC-601(C)	Practicing Cleanliness					

Note: Detail syllabus and process of conducting non-credit elective Audit courses will be given separately (common for all degree programs) by University.

Note:
Distribution of Practical Examination marks will be as below:

Internal (40 Marks):
Internal Practical Exam Paper-30 marks.
Journal -10 marks.
External (60 Marks):
External Practical Exam Paper- 50 marks.
Viva-voce - 10 marks.

Course 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.

General Instructions to Teachers and Paper Setters/ Examiners

1. The medium of instruction is English.
2. Each Theory paper requires 45 Lectures each of one clock hour.
3. Each Practical paper requires 60 laboratory clock hours for each batch.
4. Numbers of Lectures to be devoted for each topic 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.

ST-501: Distribution Theory-I

1. Probability Distributions (6L)

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 HERE.

2. Chebychev's Inequality and Weak Law of Large Numbers (4L)

2.1 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 $P\{g(X) \geq k\} \leq E\{g(X)\}/k^2$.

2.2 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 $\sigma^2 = V(X)$.

2.3 Concept of convergence in probability.

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

2.5 Examples and problems.

3. Central Limit Theorem (3L)

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

3.2 Examples and problems.

4. Poisson Distribution (7L)

4. 1 Probability mass function

$$P(X = x) = \begin{cases} \dfrac{e^{-\lambda}\lambda^x}{x!}, & x = 0, 1, 2, 3, \ldots\ldots\ldots\ldots, \lambda > 0 \\ 0, & otherwise \end{cases}$$

Notation: $X \sim P(\lambda)$

4.2 Mean, variance, mode.

4.3 Recurrence relation for probabilities.

4.4 Real life situations.

4.5 *Mgf*, *cgf* , *pgf*

4.6 Additive property for two independent Poisson variables.

4.7 Poisson Approximation to binomial distribution.

4.8 Recurrence relation for raw and central moments.

4.9 Conditional distribution of X given that X+Y=n (n positive integer), when X and Y be independent Poisson random variables with parameters λ_1 *and* λ_2 respectively.

4.10 Examples and Problems.

5. Geometric Distribution (5L)

5.1 Probability mass function of the form

$$P(X = x) = \begin{cases} pq^{x-1} & x = 1, 2, 3, \ldots \ldots \\ 0 & otherwise \end{cases}$$

5.2 Recurrence relation for probabilities.

5.3 Real life situations.

5.4 Distribution function.

5.5 Mean, variance, *mgf*, *cgf*,*pgf*and hence moments.

5.6 Geometric distribution as a waiting time distribution.

5.7 Lack of memory property.

5.8 Examples andproblems.

6. Negative Binomial Distribution (NBD) (6L)

6.1 P.m.f :

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

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

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

6.3 Additive property.

6.4 NB distribution as a waiting time distribution.

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

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

6.7 Poisson approximation to NB distribution.

6.8 Examples and problems.

7. Truncated Distributions (6L)

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

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

7.3 Poisson distribution P(λ) left truncated at X = 0 (value zero not observable), its p.m.f, mean, variance.

7.4 Normal distribution N(μ, σ^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.

7.5 Examples and problems.

8. Order Statistics **(7L)**

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

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

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

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

8.5 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.

8.6 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.).
6. Biswas D.(2009) Probability and Statistics (Vol-I) New Central Book Agency Ltd.
7. Biswas S. and Sriwastav G. L. (2011) Mathematical Statistics; Narosa Pub.

ST-502: Statistical Inference-I

1. Point Estimation **(12L)**

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(θ) give rise to infinitely many unbiased estimators of f(θ).

(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: (3L)

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: (6L)

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 (4L)

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 (6L)

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 ϕ 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 (14L)

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) ($-\theta$, 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 (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.).
5. Siegel S.: Non Parametric Methods for the Behavioral Sciences. International Student Ed. McGraw Hill Kogakusha Ltd.
6. Daniel: Applied Non Parametric Statistics, Houghton Mifflin Company Roston.
7. Kale, B.K. and K. Muraridharan (2015) Parametric Inference: An Introduction,Alpha Science Intl Ltd.
8. Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics, (Wiley Sons).
9. Biswas S. and Sriwastav G. L. (2011) Mathematical Statistics; Narosa Pub.

ST-503: Design of Experiments

1. Introduction (4L)

1.1 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.

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

1.3 Uniformity trials.

1.4 Choice of size and shape of a plot.

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

1.6 Examples and problems

2. Standard Designs of Experiments (15L)

2.1 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.

2.2 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.

2.3 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.

2.4 Linear treatment contrasts, orthogonal contrasts. Scheffe's method for comparing contrasts, Tuckey's procedure for comparing pairs of treatment means(applicable to C.R.D., R.B.D. and L.S.D.)

2.5 Identification of real life situations where the above designs are useful.

2.6 Applications of principles of Design of Experiments in CRD, RBD and LSD.
2.7 Simple algebraic and numerical problems.

3. Efficiency of a Design (4L)

3.1 Concept and definition of efficiency of a design.
3.2 Comparison of efficiencies between CRD and RBD.
3.3 Comparison of efficiencies between LSD and RBD, LSD and CRD.
3.4 Simple numerical problems.

4. Missing Plot Technique (6L)

4.1 Situations where missing plot technique is applicable.
4.2 Estimation of missing plots by minimizing error sum of squares in RBD and LSD with one or two observations are missing.
4.3 Derivation of exact treatments sum of squares, preparing analysis of variance table and writing report.
4.4 Iterative procedure in case of missing observations.
4.5 t-test for comparing any two treatment effects.

5. Balanced Incomplete Block Design (B.I.B.D.) (9L)

5.1 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) $r \geq k$

5.2 Model, estimation of parameters (derivation are not expected)
5.3 Analysis of variance table (intra-block analysis only) for testing significance of treatment effects and block effects.
5.4 Tests for comparing two treatment effects.
5.5 Symmetric BIBD: definition, theorems on symmetric BIBD

6. Factorial Experiments (7L)

6.1 General description of factorial experiments, 2^2, 2^3 factorial experiments arranged in RBD.
6.2 Definitions of main effects and interactions in 2^2, 2^3 factorial experiments.
6.3 Preparation of ANOVA table by Yates procedure, test for main effects and interactions, estimation of main effects and interaction effects.
6.4 General idea of confounding in factorial experiments, total confounding, analysis of variance table, testing main effects and interactions (confounding only one interaction).

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

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

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-504: Sampling Theory

1. Sample Survey (6L)

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 (12L)

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) (3L)

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 (12L)

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 **(6L)**

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.

6 .Ratio and Regression Methods of Estimation for SRSWOR **(6L)**

6.1 Rationale behind using auxiliary variates in estimation.

6.2 Situations where (i) ratio method is appropriate, (ii) regression method is appropriate.

6.3 Ratio and regression estimators of the population mean and population total.

6.4 Comments regarding bias, statement of standard errors of ratio and regression estimators relative efficiency of these estimators, with respect to SRSWOR

(Derivations are not expected).

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-505: Statistical Techniques for Research Methods

UNIT I **(15L)**

Introduction: Meaning, objectives and motivation in research, types of research, research approach, significance of research. Research problems: definition, selection and necessity of research problems.

Introduction to research, meaning of research, role of research in important areas, process of research, types of research, Unit of analysis, characteristics of interest. Research problem as a hypothesis testing

UNIT II **(10L)**

Survey Methodology and Data Collection.

Sampling Techniques: Introduction to sampling, advantage of sampling over census, simple random sampling, sampling frame, probabilistic aspects of sampling, stratified random sampling, other methods of sampling, sampling design, non probability sampling methods.

Inference and error in surveys, the target populations, sampling frames and coverage error, methods of data collection, non-response, questions and answers in surveys.

UNIT III **(10L)**

Processing, Data Analysis and Interpretation: Review of various techniques for data analysis covered in core statistics papers, techniques of interpretation, precaution in interpretation. Examples based on some case studies.

UNIT IV **(10L)**

Develop a questionnaire, collect survey data pertaining to a research problem (such as gender discriminations in private v/s government sector, unemployment rates, removal of subsidy, impact on service class v/s unorganized sectors), interpret the results and draw inferences.

Books Recommended:

1. Kothari, C.R. (2009): Research Methodology: Methods and Techniques, 2nd Edition, New Age International Publishers.
2. Krishnaswamy O.R. and M. Rangnatham (2005) Methodology of Research in Social Sciences by Himalaya publication House.
3. Kumar, R (2011): Research Methodology: A Step - by - Step Guide for Beginners, SAGE publications.

ST- 506(A): Introduction to Regression Analysis

1. Simple linear regression model **(14L)**

1.1 Review of simple linear regression model: $Y = \beta 0 + \beta 1X + \varepsilon$, where ε is a continuous random variable with $E(\varepsilon) = 0$, $V(\varepsilon) = \sigma^2$. Estimation of $\beta 0$ and $\beta 1$, by the method of least squares.

1.2 Properties of estimators of $\beta 0$,and $\beta 1$

1.3 Estimation of σ^2

1.4 Assumption of normality of ε .Tests of hypothesis of $\beta 1$

1.5 Interval estimation in simple linear regression model

1.6 Coefficient of determination

1.7 Residual analysis : Standardized residuals, Studentized residuals, residual plots

1.8 Detection and treatment of outliers

1.9 Interpretation of four plots produced by lm command in R

2. Multiple linear regression model **(16L)**

2.1 Review of multiple linear regression model $Y = \beta 0 + \beta 1X1 + \ldots + \beta pXp + \varepsilon$, where ε is a continuous random variable with $E(\varepsilon) = 0$, $V(\varepsilon) = \sigma 2$. Estimation of regression parameters $\beta 0, \beta 1, \ldots$ and βp by the method of least squares, obtaining normal equations, solutions of normal equations.

2.2 Estimation of σ^2

2.3 Assumption of normality of ε .Tests of hypothesis of regression parameters

2.4 Interval estimation in simple linear regression model

2.5 Variable selection and model building

2.6 Residual diagnostics and corrective measures such as transformation of response variable, weighted least squares method

2.7 Polynomial regression models

3. Logistic regression model **(15L)**

3.1 Binary response variable, Logit transform, estimation of parameters, interpretation of parameters.

3.2 Tests of hypotheses of model parameters, model deviance, LR test.

3.3 AIC and BIC criteria for model selection

3.4 Interpretation of output produced by glm command in R

3.5 Multiple logistic regression

Books Recommended

1. Draper, N. R. and Smith, H. (1998). Applied Regression Analysis (John Wiley) 3rd Ed.
2. Hosmer, D. W. and Lemeshow, S. (1989). Applied Logistic Regression (Wiley).
3. Montgomery, D. C., Peck, E. A. and Vining, G. G. (2003). Introduction to Linear Regression Analysis (Wiley).
4. Neter, J., W., Kutner, M. H. ;Nachtsheim, C.J. and Wasserman, W.(1996). Applied Linear Statistical Models, fourth edition, Irwin USA.

ST-506(B): Introduction to Stochastic Processes

UNIT I **(10L)**

Probability Distributions: Generating functions, Bivariate probability generating function.

Stochastic Process: Introduction, Stationary Process. Examples of Stochastic Processes.

UNIT II **(20L)**

Markov Chains: Definition of Markov Chain, transition probability matrix, order of Markov chain, Markov chain as graphs, higher transition probabilities. Generalization of independent Bernoulli trials, classification of states and chains, stability of Markov system, graph theoretic approach.

UNIT III **(15L)**

Counting Process: Definition, examples and properties

Poisson Process: postulates of Poisson process, properties of Poisson process, inter-arrival time, pure birth process, Yule Furry process, birth and death process, pure death process.

Books Recommended:

1. Medhi, J. (2009): Stochastic Processes, New Age International Publishers.
2. Basu, A.K. (2005): Introduction to Stochastic Processes, Narosa Publishing.
3. Bhat,B.R.(2000): Stochastic Models: Analysis and Applications, New Age International Publishers.
5. Feller, William (1968): Introduction to probability Theory and Its Applications, Vol I, 3rd Edition, Wiley International.
6. Ross S. M.(2012) Stochastic Processes, Wiley India Pub.

ST-507: Statistics Practicals-V

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

1. Fitting of Poisson, Geometric and Negative binomial Distribution
2. Fitting of Truncated binomial Distribution (Parameter should be estimate by using Newton Raphson Method)
3. Fitting of Truncated Poisson Distribution(Parameter should be estimate by using Newton Raphson Method)
4. Model sampling from Poisson, Geometric and Negative binomial Distribution
5. Applications of Poisson, Geometric, Negative binomial and multinomial Distribution
6. Estimation of parameters and their functions for standard probability distributions by the method of Maximum Likelihood Estimation.
7. Estimation of parameters of standard probability distributions by method of moments
8. Sampling distribution of order statistics
9. Verification of consistency of estimators

ST-508: Statistics Practicals-VI

Note: All Practicals must be conducted by using R/MS-Excel/MINITAB software

1. Analysis of CRD.
2. Analysis of RBD.
3. Analysis of LSD.
4. Efficiency of Designs.
5. Missing Plot Technique in RBD.
6. Missing Plot Technique in LSD.
7. Analysis of BIBD.
8. Analysis of 2^3 factorial experiment arranged in RBD.
9. Analysis of 2^3 factorial experiment with total & partial confounding.

ST-509: Statistics Practicals-VII

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

1. Estimation of population mean and population proportion under Simple Random Sampling.
2. Determination of sample size under simple random sampling while estimating population mean and population proportion..
3. Stratified Random Sampling-I.
4. Stratified Random Sampling-II.
5. Systematic sampling..
6. Ratio and Regression methods of estimation
7. Simple regression analysis and dignostics by graphical method
8. Multiple regression analysis and dignostics by graphical method
9. Logistic regression
10. Calculation of transition probability matrix
11. Identification of characteristics of reducible and irreducible chains.
12. Identification of types of classes of Markov chain
13. Identification of ergodic transition probability matrix

    (Note: Consider practical No. 7,8 and 9 for ST-506(A) and 10,11,12 and 13 for ST-506(B))

ST-601: Distribution Theory-II

1. Rectangular (Uniform) Distribution (8L)

1.1 p.d.f.

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

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

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

1.3 Standard form: U(0,1).

1.4 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.

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

1.6 Real life situations.

1.7 Examples and problems.

2. Log-Normal Distribution (5L)

2.1 P.d.f :

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

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

Notation : X~LN (a, μ, σ^2)

2.2 Nature of the probability curve.

2.3 Moments (r^{th} moment about x=a), first four moments, β_1 and γ_1 coefficients, quartiles.

2.4 Relation with N(μ, σ^2) distribution.

2.5 Examples and problems.

3. Weibull Distribution (5L)

3.1 p.d.f.:

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

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

Notation : X ~ W (γ,α,β)

3.2 Distribution function, quartiles.

3.3 r^{th} Moment about x = γ, mean and variance.

3.4 Relation with exponential distribution.

3.5 Examples and problems.

4. Laplace Distribution (Double Exponential Distribution) (6L)

4.1 P.d.f :

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

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

Notation : X ~ L (μ, λ)

4.2 Nature of probability curve.

4.3 Distribution function, quartiles.

4.4 mgf, cgf, moments and cumulants, β_1, β_2, γ_1, γ_2.

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

4.6 Examples and problems.

5. Cauchy Distribution (6L)

5.1 p.d.f.:

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

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

Notation : X~ C(μ, λ)

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. Multinomial Distribution (8L)

6.1 Joint p.m.f.

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

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

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

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

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

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

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. Bivariate Normal Distribution (BND) (7L)

7.1 P.d.f :

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

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

$= 0$ *otherwise.*

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

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

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

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.).
5. Biswas D.(2009) Probability and Statistics (Vol-I) New Central Book Agency Ltd.
6. Biswas S. and Sriwastav G. L. (2011) Mathematical Statistics; Narosa Pub.

ST-602: Statistical Inference-II

1. Parametric Tests (15L)

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 α. 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 (8L)

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 (μ) of normal distribution (when σ known and σ unknown)

(ii) Variance (σ^2) of normal distribution (when μ known and μ unknown)

(iii) Difference of two means μ_1 - μ_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 (14L)

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 **(8L)**

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 (α, β).

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 (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.).
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. and K. Muraridharan (2015) Parametric Inference: An Introduction,Alpha Science Intl Ltd.
9. Dudewicz, E.J.and Mishra, S.N. (1988). Modern Mathematical Statistics, (Wiley Sons).
10. Biswas S. and Sriwastav G. L. (2011) Mathematical Statistics; Narosa Pub.

ST-603: Statistical Quality Control

1. Indian Standards and International Standards **(4L)**

Introduction to IS series and ISO 9000: 2015 Series with reference to process Control and statistical techniques (History, Organization Structure and different Clauses), role of statistical methods.

2. Statistical Process Control (SPC) **(20L)**

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 (σ) is not given. Control limits, drawing of Control Chart, Plotting sample range values, revision of control limits if necessary, estimate of σ for future use. Construction of $\overline{X}$ chart when the process standard deviation (σ) is not given: Control limits based on σ, 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: (8L)

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 (13L)

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.

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 (6^{th} Ed.)
4. Hand Book of SQC: Bureau of Indian Standards.
5. ISO 9001-2015 Standards, 2015.

ST-604: Official Statistics and Applied Statistics

1. Indian Official Statistics (15L)

1.1 Introduction to Indian Statistical system,
Present official statistical system in India, Methods of collection of official statistics, their reliability and limitations. Role of Ministry of Statistics & Program Implementation (MoSPI), National Statistical Office(NSO) including Central Statistical Office (CSO), National Sample Survey Office (NSSO), and National Statistical Commission. Government of India's Principal publications containing data on the topics such as population, industry and finance.

1.2 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. Life Tables (8L)

2.1 Introduction and meaning.

2.2 Construction. Functions and their interrelations Complete life table

2.3 Expectation of life.

2.4 Numerical examples and problems.

3. Economic Time Series: (11L)

3.1 Components of time series

3.2 Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series.

3.3 Measurement of trend by method of free-hand curve, method of semi-averages and method of least squares (linear, quadratic and modified exponential).

3.4 Measurement of seasonal variations by methods of ratio to trend

3.5 Link relative method

3.5 Examples and problem

4. Demand and Supply Analysis (11L)

4.1 Demand: meaning, statement of law, assumptions, exceptions and determinants of demand, individual and market demand..

4.2 Supply: meaning, statement of law, assumptions, exceptions and determinants of supply, individual and market supply

4.3 Elasticity of demand: definition : i) price elasticity of demand ii) income elasticity of demand iii) cross elasticity of demand
4.4 Method of measuring elasticity of demand: i) percentage method, ii) point method iii) total outlay method iv) ARC Method
4.5 Demand forecasting: meaning need and methods of forecasting
4.6 Examples and 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. Biswas D.(2009) Probability and Statistics (Vol-I) New Central Book Agency Ltd.
5. Guide to current Indian Official Statistics, Central Statistical Office, GOI, New Delhi.(Refer website-http://mospi.nic.in/)

ST-605: C PROGRAMMING

1. Introduction (10L)

1.1 Algorithms and flowcharts.
1.2 Introduction to procedural language, middle level language, higher level language, general language structure, character set, keywords, identifiers.
1.3 Data types: Numeric and character data types, Numeric and character constants, string constants, symbolic constants.
1.4 Operators: Numeric, logical, arithmetic, unary, relational, equality, decrement, increment, conditional assignments, precedence of operator expressions and their evaluation.
1.5 Data input/output, numeric and character data, printf ( ), scanf ( ), getchar ( ), putchar ( ), gets ( ), puts ( ).
1.6 Formatted output

2. Control Structures (10L)

If, if else, while, do....while, for, switch, goto, break, continue, nested loops, programs using control structures.

3. Arrays (12L)

3.1 Concept, declaration, definition, initialization of array, problem using arrays, passing to function, arrays and string operations, string functions like strcpy(), strcat(), strlen(), strcmp(), strrev().

List of programs using arrays.
3.2 To find mean, median, variance and coefficient of variation of frequency distribution.
3.3 To find correlation coefficient and least square regression line of Y on X for a given bivariate data.
3.4 To arrange the given data in increasing/decreasing order of magnitude.
3.5 To obtain median of given n observations.
3.6 To obtain addition of two matrices, multiplication of two matrices.

4. Functions **(7L)**

Declaration, definition, recursion, user defined functions, library function, calling a function by reference and by value, local and global variables.
List of writing functions:
1. To find factorial of integer number (both recursive and non-recursive)
2. To find GCD of two integer numbers(both recursive and non-recursive)
3. To find maximum/minimum of n numbers.(non-recursive)

5. Pointers **(6L)**

Basic concept and relation to one dimensional array.

Note: Following programs must be covered under above sections.

List of Simple Programs (short programs)

1. Converting °C temperature to °F.
2. To carry out arithmetic calculations.
3. To check whether given number is odd or even.
4. To check whether given number m is divisible by n or not.
5. To find maximum of 2 numbers or 3 numbers.
6. To find area of triangle and circle.
7. To find roots of quadratic equation.
8. To check whether integer is prime or not.
9. To find mean, Geometric mean and Harmonic Mean of n numbers.
10. To prepare multiplication table.
11. To find sum of digits of a number.
12. To solve simultaneous linear equations.(two equations in two variables)
13. To evaluate simple and compound interest
14. To solve transcendental equations using Newton-Raphson method.
15. To evaluate exp(x), sin (x), log (x) etc. using Taylor‟s series expansion.
16. To convert decimal number to equivalent binary number.
17. To generate Fibonacci series like 0, 1, 1,2,3,5…
18. To test palindrome string using string function.
19. To sort a string using string function.
20. To search string using string function.
21. To combine given two strings using string function.

List of programs (long programs)

22. Program in C to prepare a frequency distribution with given class interval from raw data.
23. Program in C to find mean, variance,standard deviation and quartiles for given n observations and frequency distribution.
24. Program in C to fit a Binomial distribution to given data.
25. Program in C to prepare a 2X2 contingency table for chi square test and to find the value of test statistic and to check whether two attributes are independent.

Books Recommended

1. Gottfried, B.S. (1996) Programming with C (Schaum Outline series), McGraw Hill co., London
2. Kanetkar, Y (2008).: Let us C, BFB publishers, New Delhi.
3. Karnighan, B. W. and Ritchi, M.(1988). The C programming language, Second edition ,Prentice Hall.
4. Rajaraman V. (2007). Computer programming in C, Prentice Hall of India.,

ST-606(A): Optimization Techniques

1. Linear Programming Problems (12L)

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 (4L)

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 (9L)

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 (4L)

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 (12L)

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.

6. Simulation (4L)

6.1 Introduction to simulation, merits, demerits, limitations.

6.2 Pseudo random number generates: Linear congruential , mid square method.

6.3 Model sample from normal distribution (using Box- Muller transformation), uniform distribution, exponential distribution.

6.4 Monte Carlo method of simulation: Statistical applications of simulation in numerical integration such as computation of probabilities of events related to gamma, beta and bivariate normal distribution.

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-606(B): Actuarial Statistics

1) Insurance Business (3L)

1.1 Insurance companies as business organizations.

1.2 Role of insurance business in Economy.

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

1.4 Working of insurance business, introduction of terms such as premium, policy, policyholder and benefit.

1.5 Role of Statistics in insurance.

1.6 Insurance business in India.

2) Feasibility of Insurance Business (3L)

2.1 Measurement of adverse financial impact, expected value principle.

2.2 Concept of utility function

2.3 Feasibility of insurance business.

2.4 Illustrative examples.

3) Survival Distribution and Life Tables (12L)

3.1 Time- until death random variable, its d.f. and survival function in actuarial notation.

3.2 Force of mortality.

3.3 Interrelations among d.f., survival function, force of mortality and p.d.f.

3.4 Curtate future life random variable, its p.m.f. and survival function in actuarial notation.

3.5 Construction of life table using random survivorship approach.

4) Models for Life Insurance **(12L)**

4.1 Theory of compound interest, effective rate of interest, discount factor.

4.2 Insurance payable at the end of the year of death, present value random variable, actuarial present value.

4.3 Derivation of actuarial present value for n-year term life insurance, whole life insurance and endowment insurance.

5) Annuities **(8L)**

5.1 Annuities – certain, annuity due, annuity immediate.

5.2 Discrete life annuities: n-year temporary life annuity due and a whole life annuity due, present value random variables of the payment, and their actuarial present values.

6) Benefit Premiums **(7L)**

6.1 Concept of a loss random variable.

6.2 Equivalence principle

6.3 Computation of fully discrete premium for n-year term life insurance, whole life insurance and endowment insurance.

6.4 Variance of loss random variable

References

1. Bowers N.L. Jr., H.S.Gerber, J.C. Hickan, D.A.Jones, C.J.Nesbitt, (1997). Actuarial Mathematics, Society of Actuaries, U.S.
2. Deshmukh, S. R. (2009). Actuarial Statistics, Universities Press, Hyderabad, India.

ST-607: Statistics Practicals-VIII

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

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

ST-608: Statistics Practicals-IX

Note: All Practicals in this paper are to be carried out by using R/MS-Excel/MINITAB software and C-Programming.

1. $\overline{X}$ -R charts, computation of probabilities of detecting shift in process average, Cp and Cpk
2. p-charts, computation of probabilities of detecting shift in process fraction defective
3. c and u-charts
4. X & MR charts, CUSUM charts.
5. Single Sampling Plans (with OC, AOQ, AOQL, ATI, ASN curves)
6. Double Sampling Plans (with OC, AOQ, AOQL, ATI, ASN curves)
7. Construction of life tables and Problems based on life tables

Practicals based on C-Programming

8. A) To find mean, variance and coefficient of variation of n observations.
   B) Arrange the observations in ascending order of magnitude and find median of n observations.
9. To find mean, median, variance and coefficient of variation of frequency distribution when fi and xi are given.
10. To find correlation coefficient for a given bivariate data.
11. To fit a line of regression of Y on X for a given bivariate data.

Practicals based on elective paper: Actuarial Statistics

12. Problems based on simple interest and compound interest.
13. Problems based on annuity immediate and due.
14. Loan repayment calculations.
15. Calculation of Net Single Premium for n-year term life insurance

ST-609: Statistics Practicals-X-Project

Project duration: November to February.

• **Project Guide:** Teachers from the Department of Statistics and/or personnel from organization where student is going to visit for field work or training. Each project group will be guided by concerned teacher (guide)

• **Project Topic**: Students in consultation with the guide will decide Project Topic/Area. Project work may be carried out in a group of students(maximum five) depending upon the depth of fieldwork/problem involved. 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.

• **Project report**: Students are supposed to write the project report on project work and submit a copy of project report to department before practical examinations.

• **Project evaluation:**

Type of assessment	Marks	
College Assessment(CA)	40	Evaluation by guide teacher
University Assessment(UA)	60	Evaluation by Examiners

Reference Websites:

Teachers and students are expected to visit following websites for additional teaching learning material

1. www.freestatistics.tk(National Statistical Agencies)
2. www.psychstat.smsu.edu/sbk00.htm(Online book)
3. www.bmj.bmjournals.com/collections/statsbk/index.shtml
4. www.statweb.calpoly.edu/bchance/stat-stuff.html
5. www.amstat.org/publications/jse/jse-data-archive.html (International journal on teaching and learning of statistics)
6. www.amstat.org/publications/chance (Chance magazine)
7. www.statsci.org/datasets.html (Data sets)
8. www.math.uah.edu/stat (Virtual laboratories in Statistics)
9. www.amstat.org/publications/stats (STATS : the magazine for students of Statistics)
10. www.stat.ucla.edu/cases (Case studies in Statistics).
11. www.statsoft.com
12. www.statistics.com
13. www.indiastat.com
14. www.unstat.un.org
15. www.stat.stanford.edu
16. www.statpages.net
17. www.wto.org
18. www.censusindia.gov.in
19. www.mospi.nic.in
20. www.statisticsofindia.in

Equivalence of old and new papers

Old Syllabus Papers (with effect from June 2017-18)		Equivalent New Syllabus Papers (with effect from June 2020-21)	
Old Code	**Old paper Title**	**New Code**	**New paper Title**
ST-351	Distribution Theory-I	ST-501	Distribution Theory-I
ST-352	Statistical Inference-I	ST-502	Statistical Inference-I
ST-353	Design of Experiments	ST-503	Design of Experiments
ST-354	Sampling Theory	ST-504	Sampling Theory
ST-355	Introduction to Regression Analysis	ST-505(A)	Introduction to Regression Analysis
ST-356	Statistical Computing Using R-Software	--	No Equivalent available
ST-357	Practicals- I	ST-507	Statistics Practicals-V
ST-358	Practicals- II	ST-508	Statistics Practicals- VI
ST-359	Practicals- III	ST-509	Statistics Practicals- VII
ST-361	Distribution Theory-II	ST-601	Distribution Theory-II
ST-362	Statistical Inference-II	ST-602	Statistical Inference-II
ST-363	Statistical Quality Control	ST-603	Statistical Quality Control
ST-364	Official Statistics and Applied Statistics	ST-604	Official Statistics and Applied Statistics
ST-365	Optimization Techniques	ST-606(A)	Optimization Techniques
ST-366(A)	C-Programming	ST-605	C-Programming
ST-366(B)	Actuarial Statistics	ST-606(B)	Actuarial Statistics
ST-367	Practicals- IV	ST-607	Statistics Practicals- VIII
ST-368	Practicals- V	ST-608	Statistics Practicals-IX
ST-369	Practicals- VI-Project	ST-609	Statistics Practicals-X-Project