Rayat Shikshan Sanstha's

SADGURU GADAGE MAHARAJ COLLEGE, KARAD

(An Autonomous College)

Revised Syllabus

Bachelor of Science

Part III

STATISTICS

Semester V and VI

Choice Based Credit System (CBCS) as per NEP - 2020

Syllabus Implemented w. e. f. June, 2024

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Rayat Shikshan Sanstha's

Sadguru Gadage Maharaj College, Karad

(An Autonomous College)

B.Sc. III

Structure of the course

To be implemented from June 2024

Theory

Semester V

Paper. No.	Title of the paper	Total Marks
IX	Probability Distributions - I	50
X	Statistical Inference-I	50
XI	Sampling Theory	50
XII	Quality Management	50

Semester VI

Paper. No.	Title of the paper	Total Marks
XIII	Probability Distributions - II	50
XIV	Statistical Inference-II	50
XV	Design of Experiments	50
XVI	Operations Research	50

Practical

Paper No.	Title of the Practical	Marks for Practical	Journal	Oral	Total Marks
IV	Probability Distributions	32	4	4	40
V	Statistical Inference	32	4	4	40
VI	Design of Experiments and Sampling Techniques	32	4	4	40
VII	Quality Management and Operations Research	32	4	4	40
	A Project Report and Viva-voce	40	-	-	40

1. Nature of Project

(i) Identification of problem where statistical techniques can be used.

(ii) Planning and execution of data collection.

(iii) The Marking system for the project work is as follows:

- Data Collection : 8 Marks
- Use of Statistical Tools : 8 Marks
- Analysis of Data : 8 Marks
- Conclusion : 8 Marks
- Viva on Project : 8 marks

Total Marks of Project : 40 marks

(iv) Project will be conducted in a group of 5 to 6 students.

2. Nature of Question papers (Theory)

COMMON NATURE OF THEORY QUESTION PAPER WILL BE MENTIONED SPERATELY:

3. Nature of practical papers:

(i) Each practical question paper must contain **Four** questions.

(ii) Each question should contain **Two** bits from different units.

(iii) Student should attempt **Any Two** questions.

(iv) Each question should carry **16** marks and to be distributed according to followingpoints:

(a) Aim of the Experiment : 2 Marks

(b) Statistical formulae : 4 Marks

(c) Observation Tables : 4 Marks

(d) Calculations : 4 Marks

(e) Conclusion/ result of the experiment : 2 Marks.

(v) In each practical paper, four marks are reserved for journal and four marks are reservedfor oral.

4. Instructions:

i) While attempting questions based on R-software students have to write the commands of R-software on their Answer-book. Final result should be shown to the examiner online or the printout may be attached.

ii) Duration of each practical paper should be of four hours.

iii) Student can use MS-Excel or electronic calculators for other practical.

5. Requirements:

(i) There should be two subject experts at the time of practical examination.

(ii) Laboratory should be well equipped with 20 scientific calculators, 20 computers,2 printers with sufficient backup facility (UPS/Inverter /Generator).

EQUIVALENCE FOR THEORY PAPERS

(From June 2024)

Old Syllabus		**Revised Syllabus**	
Paper No.	**Title of the Paper**	**Paper No.**	**Title of the Paper**
Sem. V / P. IX	Probability Distributions-I	Sem. V / P. IX	Probability Distributions-I
Sem. V/ P.X	Statistical Inference - I	Sem. V/ P.X	Statistical Inference – I
Sem. V / P XI	Design of Experiments	Sem. VI / P XV	Design of Experiments
Sem. V / P XII	Industrial Statistics	Sem. V / P XII	QualityManagement
Sem. VI / P XIII	Probability Distributions-II	Sem. VI / P XIII	Probability Distributions-II
Sem. VI / P XIV	Statistical Inference - II	Sem. VI / P XIV	Statistical Inference – II
Sem. VI / P XV	Sampling Theory	Sem. V / P XI	Sampling Theory
Sem. VI / P XVI	Operations Research	Sem. VI / P XVI	Operations Research

EQUIVALENCE FOR PRACTICAL PAPERS

(From June 2024)

Old Syllabus		**Revised Syllabus**	
Paper No.	**Title of the Practical Paper**	**Paper No.**	**Title of the Practical Paper**
IV	Probability Distributions	IV	Probability Distributions
V	Statistical Inference	V	Statistical Inference
VI	Design of Experiments and Sampling Methods	VI	Design of Experiments and Sampling Techniques
VII	Quality Management and Operations Research	VII	Quality Management and Operations Research

Paper- IX
NBST22- 501 : Probability Distributions - I
(Credit 02)

Marks-50

Course Outcomes: The students will acquire

a) knowledge of important univariate distributions such as Laplace, Cauchy, Lognormal, Weibull, Logistic, Pareto, Power Series Distribution.

b) knowledge of Multinomial and Bivariate Normal Distribution.

c) knowledge of Truncated Distributions.

d) information of various measures of these probability distributions.

e) acumen to apply standard continuous probability distributions to different situations.

Unit-1: Univariate and Multinomial Probability Distributions (1 credit)

1.1 Laplace (Double Exponential) Distribution:

Laplace distribution with parameters μ and θ (- $\infty <$ μ $< \infty$ $and\ \theta > 0$) :

$$f(x;\theta,\mu) = \begin{cases} \frac{\theta}{2} e^{-\theta|x-\mu|} & if -\infty < x < \infty \\ 0 & if\ otherwise \end{cases}$$

Nature of the probability curve, Distribution function, quartiles, moment generating function, mean, variance, moments,β_1, β_2, γ_1, γ_2 coefficients.

Laplace distribution as a distribution of the difference of two i.i.d. exponential variates with parameter θ. Examples and problems.

1.2 Lognormal Distribution: P.d.f. with parameters(μ, σ^2), Nature of the probability curve, mean, variance, median, mode, moments, β_1, β_2, γ_1 and γ**2** coefficients, Relation with N(μ, σ^2),examples and problems.

1.3 Cauchy Distribution: P. d. f. with parameters (μ, λ), nature of the probability curve, distribution function, quartiles, non-existence of moments, additive property for two independent Cauchy variates (statement only), statement of distribution of the sample mean, relationship with uniform and Student's 't' distribution, distribution of X/Y where X and Y are i. i. d. N(0, 1), examples and problems.

1.4 Weibull Distribution: p.d. f. with parameters (α, β), distribution function, quartiles, mean and variance, coefficient of variation, relation with gamma and exponential distribution, examples and problems.

1.5 Logistic distribution: P.d.f. with parameters (μ, σ), c.d.f., mean, mode, variance, skewness using mode, applications.

1.6 Pareto distribution: P.d.f. with parameters (α,β),mean, variance, mode, skewness using mode, applications.

1.7 Power series distribution: P.m.f. mean, mode, variance, Binomial, Poisson, Geometric and negative binomial distribution as particular cases of power series distribution.

1.7 Multinomial distribution: P.m.f, m.g.f.,marginal distribution, mean, variance, covariance, variance and covariance matrix, correlation coefficient, additive property, Trinomial distribution as particular case of multinomial distribution.

Unit-2: Truncated Distributions **(1 credit)**

2.1 Truncated Distributions: Truncated distribution as conditional distribution, truncation to the right, left and on both sides. **a)** Binomial distribution B(n, p) left truncated at X = 0(value zero not observable), its p.m.f, mean, variance. **b)** Poisson distribution P(λ), left truncated at X = 0 (value zero not observable), its p.m.f., mean and variance. **c)** Normal distribution $N(\mu, \sigma^2)$ truncated i) to the left below a ii) to the right above b iii) to the left below a and to the right above b, its p.d.f. and mean.
d) Exponential distribution with parameter θ left truncated below a, its p.d.f., mean and variance. Examples and problems.

Books Recommended

1. Cramer H.: Mathematical Methods of Statistics, Asia Publishing House, Mumbai.
2. Mood, A. M., Graybill K, Bose. D. C. : Introduction to Theory of Statistics. (Third edition) Mc-GrawHiil Series.
3. Lindgren B. W.: Statistical Theory (Third Edition), Collier Macmillan International Edition, Macmillan Publishing Co. Inc. New York.
4. Hogg, R. V. and Craig A. T. :Introduction to Mathematical Statistics (Third Edition),Macmillan Publishing Company, Inc. 866, 34d Avenue, New York, 10022.
5. Sanjay Arora and BansiLal : New Mathematical Statistics (First Edition),Satya Prakashan, 16/17698, New Market, New Delhi, 5 (1989).
6. Gupta S. C and Kapoor V. K. : Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 88, Daryaganj, New Delhi 2.
7. Rohatgi V. K.: An Introduction to Probability Theory and MathematicalStatistics, Wiley Eastern Ltd., New Delhi.
8. Feller. W. : An Introduction of Probability Theory and its Applications, Wiley Eastern Ltd.. Mumbai.
9. Jhonson and Kotz: Continuous Univariate Distributions I and II
10. Bhat B. R.: Modern Probability Theory. New Age International.
11. Morgan.B.J.T.(1984) Elements of simulation.
12. Robert. C.P and Casella.G. Monte Carlo statistics method,(Sprinnger)
13. Ross.S.M.(2006) Simulation, (Academic press).
14. Elements of Simulation: Byron.J.T. Morgan

Paper X

NBST22- 502: Statistical Inference - I

(Credit 02)

Marks-50

Course Outcomes : The students will acquire

a) knowledge about important inferential aspect of point estimation.

b) concept of random sample from a distribution, sampling distribution of a statistic, standard error of important estimates such as mean and proportions.

c) knowledge of various important properties of estimator

d) knowledge about inference of parameters of standard discrete and continuous distributions.

e) concept of Fisher information and CR inequality.

f) knowledge of different methods of estimation.

Unit - 1: Point Estimation **(1 credit)**

1.1 Introduction: Notion of a parameter, parameter space, general problem of estimation, estimating an unknown parameter by point and interval estimation.

1.2 Point estimation: Definition of an estimator (statistic) & its S.E., distinction between estimator and estimate, illustrative examples.

1.3 Properties of estimator:

1.3.1: Unbiased estimator, biased estimator, positive and negative bias, examples of unbiased and biased estimators. Proofs of the following results regarding the unbiased estimators:

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

b) If T is unbiased estimator of θ then ϕ (T) is an unbiased estimator of ϕ (θ)provided $\phi(.)$ is a linear function.

Sample variance is a biased estimator of the population variance. Illustration of unbiased estimator for the parameter and parametric function.Examples.

1.3.2: Relative efficiency of T1 with respect to T2, where T1 and T2 are unbiased estimators. Use of mean square error to modify the above definition for biased estimator. Minimum Variance Unbiased Estimator (MVUE) and Uniformly Minimum Variance Unbiased Estimator (UMVUE), uniqueness of UMVUE whenever it exists.Illustrative examples.

1.3.3: Consistency : Definition, proof of the following :

(a) Sufficient condition for consistency,

(b) If T is consistent for θ and ϕ (.) is a continuous function then ϕ (T) is consistent for$\phi(\theta)$Illustrative examples.

Likelihood Function: Definition of likelihood function as a function of the parameter θ for a random sample from discrete and continuous distributions. Illustrative examples.

1.3.4: Sufficiency: Concept of sufficiency, definition of sufficient statistic through (i) conditional distribution (ii) Neyman factorization criterion. Pitman Koopman form and sufficient statistic. Proof of the following properties of sufficient statistic:

(a) If T is sufficient for θ then ϕ (T) is also sufficient for θ provided ϕ (.) is a one-to-one function.

(b) If T is sufficient for θ then T is sufficient for ϕ (θ).

Examples.

Unit – 2 : Cramer-Rao Inequality **(1 credit)**

2.1: Fisher information function: Definition of information function, amount of information contained in a sample. Statement regarding equality of the information in (x1, x2,...,xn) and in a sufficient statistic T, concept of minimal sufficient statistic. With illustrations to exponential family. Illustrative examples.

2.2: Cramer Rao Inequality: Statement and proof of Cramer Rao inequality. Definition of Minimum Variance Bound Unbiased Estimator (MVBUE) of ϕ (θ). Proof of the following results:

i) If MVBUE exists for θ then MVBUE exists for ϕ (θ), if $\phi(.)$ is a linear function.

ii) If T is MVBUE for θ then T is sufficient for θ. Examples and problems.

2.3: Methods of Estimation

2.3.1: Method of maximum likelihood, derivation of maximum likelihood estimators for parameters of standard distributions. Use of iterative procedure to derive MLE of location parameter μ of Cauchy distribution, invariance property of MLE, relation between MLE and sufficient statistic. Illustrative examples.

2.3.2 : Method of moments: Derivation of moment estimators for standard distributions. Illustrations of situations where MLE and moment estimators are distinct and their

comparison using mean square error (for uniform distribution). Illustrative examples.

2.3.3: Method of minimum chi-square: Definition, derivation of minimum chi-square estimator for the parameter. Illustrative examples.

Books Recommended

1. Kale, B. K.: A first Course on Parametric Inference
2. Rohatgi, V. K.: Statistical Inference
3. Rohatgi, V. K.: An introduction to Probability Theory and Mathematical Statistics
4. Saxena H. C. and Surenderan : Statistical Inference
5. Kendall M. G. and Stuart A.: An advanced Theory of Statistics
6. Lindgren, B. W.: Statistical Theory
7. Lehmann, E. L.: Theory of Point Estimation
8. Rao, C. R.: Linear Statistical Inference
9. Dudewicz C. J. and Mishra S. N. : Modern Mathematical Statistics
10. Fergusson, T. S.: Mathematical statistics.
11. Zacks, S.: Theory of Statistical Inference.
12. Cramer, H.: Mathematical Methods of Statistics.
13. Cassela G. and Berger R. L.: Statistical Inference

Paper XI
NBST22- 503 : Sampling Theory
(Credit 02)

Marks-50

Course Outcomes: The students shall get

a) basic knowledge of complete enumeration and sample, sampling frame sampling distribution, sampling and non-sampling errors, principle steps in sample surveys, sample size determination, limitations of sampling etc.

b) concept of various sampling methods such as simple random sampling, stratified random sampling, systematic sampling and cluster sampling.

c) an idea of conducting sample surveys and selecting appropriate sampling techniques.

d) knowledge of comparing various sampling techniques.

e) knowledge of ratio and regression estimators.

Unit – 1: Simple and Stratified Random Sampling (1 credit)

1.1: Introduction: Concept of distinguishable elementary units, sampling units, sampling frame, random sampling and non-random sampling. Advantages of sampling method over census method, objectives of a sample survey, Designing a questionnaire, Characteristics of a good questionnaire, Concept of sampling and non-sampling errors. Handling of nonresponse cases.

1.2: Simple random sampling:

i) Simple random sampling from finite population of size N with replacement (SRSWR) and without replacement (SRSWOR): Definitions, population mean and population total as parameters, inclusion probabilities.

ii) Sample mean y as an estimator of population mean, derivation of its expectation, standard error and estimator of standard error.

iii) $N\,y$ as an estimator of population total, derivation of its expectation, standard error and estimator of standard error.

iv) Sampling for dichotomous attributes. Estimation of population proportion Sample proportion (p) as an estimator of population proportion (P), derivation of its expectation, standard error and estimator of standard error using SRSWOR..Np as an estimator of total number of units in the population possessing the attribute of interest, derivation of its expectation, standard error

and estimator of standard error.

1.3: Determination of the sample size.

Determination of the sample size (n) for the given:

i) Margin of error and confidence coefficient.

ii) Coefficient of variation of the estimator and confidence coefficient.

1.4: Stratified Sampling

i) Real life situations where stratification can be used.

ii) Description of stratified sampling method where sample is drawn from individual stratum using SRSWOR method.

iii) (a) *st y* as an estimator of population mean $\bar{Y}$, derivation of its expectation, standard error and estimator of standard error.

(b) *st N y* as an estimator of population total, derivation of its expectation, standard error and estimator of standard error.

iv) Problem of allocation: Proportional allocation, Neyman's allocation and optimum allocation, derivation of the expressions for the standard errors of the above estimators when these allocations are used.

v) Comparison amongst SRSWOR, stratification with proportional allocation and stratification with optimum allocation.

vi) Cost and variance analysis in stratified random sampling, minimization of variance for fixed cost, minimization of cost for fixed variance, optimum allocation as a particular case of optimization in cost and variance analysis.

Unit-2 Other Sampling Methods: (1 credit)

2.1: Systematic Sampling:

i) Real life situations where systematic sampling is appropriate. Technique of drawing a sample using systematic sampling.

ii) Estimation of population mean and population total, standard error of these estimators.

iii) Comparison of systematic sampling with SRSWOR.

iv) Comparison of systematic sampling with SRSWOR and stratified sampling in the presence of linear trend.

v) Idea of Circular Systematic Sampling.

2.2: Cluster Sampling:

i) Real life situations where cluster sampling is appropriate. Technique of drawing a sample using cluster sampling.

ii) Estimation of population mean and population total (with equal size clusters), standard error of these estimators

iii) Systematic sampling as a particular case of cluster sampling.

2.3: Two Stage and Multi Stage Sampling

Idea of two-stage and multistage sampling.

2.4: Ratio Method:

i) Concept of auxiliary variable and its use in estimation

ii) Situations where Ratio method is appropriate.

iii) Ratio estimators of the population mean and population total and their standard errors (without derivations), estimators of these standard errors.

iv) Relative efficiency of ratio estimators with that of SRSWOR

2.5: Regression Method:

i) Situations where Regression method is appropriate.

ii) Regression estimators of the population mean and population total and their standard errors (without derivations), estimators of these standard errors.

iii) Comments regarding bias in estimation

iv) Relative efficiency of regression estimators with that of

a) SRSWOR b) Ratio estimator.

Books Recommended

1. Cochran, W.G: Sampling Techniques, Wiley Eastern Ltd., New Delhi.
2. Sukhatme, P.V. and Sukhatme, B.V. : Sampling Theory of Surveys with Applications, Indian Society of Agricultural Statistics, New Delhi.
3. Des Raj : Sampling Theory.
4. Daroga Singh and Choudhary F.S.; Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd., New Delhi.
5. Murthy, M.N: Sampling Methods, Indian Statistical Institute, Kolkata.
6. Mukhopadhay, Parimal: Theory and Methods of Survey Sampling, Prentice Hall.

Paper XII

NBST22- 504 : Quality Management

(Credit 02)

Marks-50

Course Outcomes:

a) Knowledge of quality tools used in Quality Management.
b) Knowledge of process used in Quality Management.
c) Knowledge of product control used in Quality Management.
d) Knowledge of lean and six sigma used in Quality Management.

Unit.1: Quality Tools and Process Control (1 credit)

1.1: Quality Tools: Meaning and dimensions of quality, quality philosophy, Magnificent tools of quality: Histogram, Check sheet, Pareto diagram, cause and effect diagram, scatter diagram, control chart, flow chart. Deming's PDCA cycle for continuous improvements and its applications.

1.2: Process Control: CUSUM chart, tabular form, use of these charts for monitoring process mean. Moving average and exponentially weighted moving average charts. Introduction to six-sigma methodology, DMAIC cycle and case studies.

Unit 2: Product Control and Lean and Six Sigma (1 credit)

2.1: Product Control: Sampling Inspection plans for attribute inspection: Concept AQL, LTPD, Consumer's risk, producer's risk, AOQ, AOQL, OC, ASN and ATI. Description of Single and double sampling plans with determination of above constants.

2.2: Lean and Six Sigma: Overview of Lean and Six Sigma with principles. Methodologies – Introduction to SCORE, DMAIC, Six Sigma Roles and Responsibilities. Tools used in Define Phase. Tools used in Measure Phase. Spaghetti diagram. Tools used in Analyze Phase. Various Statistical Techniques used in analyze Phase (Revision), Tools used in Improve/Design Phase. Tools used in Control/Verify Phase.

Books Recommended

1. Introduction to quality Control – Montgomery D. C.
2. Quality Control and Industrial statistics Duncan A J
3.Statistical Quality Control by E L Grant

B. Sc. III Statistics: Semester VI
Paper XIII
NBST22 -601 : Probability Distributions - II
(Credit 02)

Marks-50

Course Outcomes: The students will acquire

a) knowledge about order statistics and associated distributions
b) concept of convergence and Chebychev'sinequality and its uses
c) concept of law large numbers and central limit theorem and its uses.
d) knowledge of terms involved in reliability theory as well as concepts and measures.

Unit-1: Convergence and Central Limit Theorem (1 credit)

1.1: Convergence

Definition of convergence of sequence of random variables (a) in probability, (b) in distribution, (c) in quadratic mean.

If $X_n \xrightarrow{P} X$ then $g(X_n) \xrightarrow{P} g(x)$ Where g is continuous function without proof.

Examples and problems.

1.2: Weak Law of Large Numbers and Central Limit Theorem

i) Weak law of large numbers (WLLN) statement and proof for i. i. d. random variables with finite variance.
ii) Central limit theorem: Statement and proof for i. i. d. random variables with finite variance, proof based on m. g. f..
iii) Simple examples based on Bernoulli, binomial, Poisson and chi-square distribution

1.3: Markov Chain

a) Definition of Stochastic process, state space ,parameter space, types of stochastic processes ,first order Markov property, Markov chains (MC), finite MC, time homogeneous M.C. one step transition probabilities, and transition probability matrix (t.p.m.),stochastic matrix, Chapman Kolmogorov equation, n step transition probabilitiy matrix , n- step tpm of two state M.C. and some typical t. p. m. initial distribution, finited imensional distribution functions, partial sum (and functions) of independent and identically distributed random variables as Markov chain, illustrations such as random walk,Gambler'sruin problem, Ehresfest chain.

b) Communicating states , first return probability, probability of ever return Classification of states , as persistent and transient states , irreducible MC.

Unit 2: Stochastic Processes, Order Statistics and Queuing Theory (1 credit)

2.1: Stochastic Processes:

Definition of stochastic process, Postulates and difference differential equations for : Poisson process, Pure death process, Birth and death process.

2.2:Order Statistics: Order statistics for a random sample of size n from a continuous distribution, Joint distribution, definition, derivation of distribution function and density function of the i^{th} order statistic, particular cases for i=1 and i= n, Derivation of joint p.d. f. of i^{th} and j^{th} order statistics, statement of distribution of the sample range, Distribution of the sample median when n is odd. Examples and problems.

2.3: Queuing Theory:

Introduction, essential features of queuing system, input source, queue configuration, queue discipline, service mechanism, Operating characteristics of queuing system, transient- state and steady state, queue length, general relationship among system characteristics. Probability distribution in queuing system: Distribution of arrival, distribution of inter arrival time, distribution of departure and distribution of service

time (Derivations are not expected).Types of queuing models, Solution of queuing Model: M/M/1, using FCFS queue discipline. Problems and examples.

Books Recommended

1. Cramer H.: Mathematical Methods of Statistics, Asia Publishing House, Mumbai.
3. Lindgren B. W.: Statistical Theory (Third Edition), Collier Macmillan International Edition, Macmillan Publishing Co. Inc. New York. .. . .
4. Hogg, R. V. and Craig A. T. : Introduction to Mathematical Statistics (Third Edition), Macmillan Publishing Company, Inc. 866, 34d Avenue, New York, 10022.
5. Sanjay Arora and BansiLal : New Mathematical Statistics (First Edition), Satya Prakashan, 16/17698, New Market, New Delhi, 5 (1989).
6. Gupta S. C and Kapoor V. K. : Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 88, Daryaganj, New Delhi 2.
7. Rohatgi V. K.: An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd., New Delhi.
8. MedhiJ : Stochastic Processes. Wiley Eastern Ltd. New Delhi.
9. Hoel, Port and Stone: Introduction to Stochastic Processes, Houghton Mifflin.
10. Feller. W. : An Introduction of Probability Theory and its Applications.Wiley Eastern Ltd.. Mumbai.
11.Bhat B. R.: Modern Probability Theory.
12. Karlin and Taylor: Stochastic Process. 14.Ross S: Probability Theory.
13..Bhat B. R.: Stochastic Models : Analysis and Applications. New Age International.
14.Zacks S. : Introduction to Reliability Analysis, Probability Models and Statistical Methods, Springer Verlag.
15.Taha H. A.: Operation research – An Introduction, Fifth edition, Prentice Hall of India, New Delhi
16. Barlow R. E. and ProschanFrank : Statistical Theory of Reliability and Life Testing. Holt Rinebart and Winston Inc., New Yark.
17. Sinha S. K. : Reliability and Life Testing, Second Edition, Wiley Eastern Publishers, New Delhi.
18.Trivedi R. S. : Probability and Statistics with Reliability and Computer Science Application, Prentice – Hall of India Pvt. Ltd., New Delhi.
19. Parimal Mukhopadhyaya : An Introduction to the Theory of Probability. World Scientific Publishing.

Paper XIV
NBST22- 602 : Statistical Inference – II
(Credit 02)

Marks-50

Course Outcomes: The students will acquire

a) concept of interval estimation.
b) knowledge of interval estimation of mean, variance and population proportion.
c) knowledge of important aspect of test of hypothesis and associated concept.
d) concept about parametric and non-parametric methods.
e) Knowledge of some important parametric as well as non–parametric tests.

Unit - 1: Interval Estimation and Parametric Tests (1 credit)

1.1: Interval Estimation

1.1.1: Notion of interval estimation, definition of confidence interval, length of confidence interval, confidence bounds. Definition of Pivotal quantity and its us in obtaining confidence intervals and bounds.

1.1.2: Interval estimation for the following cases:

i) Mean μ of normal distribution (σ^2 known and σ^2 unknown).

ii) Variance σ^2 of normal distribution (μknown and μ unknown).

iii) Difference between two means $\mu_1 - \mu_2$,

a) for a sample from bivariate normal population,

b) for samples from two independent normal populations.

iv) Ratio of variances for samples from two independent normal populations.

v) Mean of exponenential distribution.

vi) Population proportion and difference of two population Proportion of two independent large samples.

vii) Population median using order statistics. Illustrative example.

1.2: Parametric Tests

1.2.1: Statistical hypothesis, problems of testing of hypothesis, definitions and illustrations of (i) simple hypothesis (ii) composite hypothesis, critical region, type I and type II error, probabilities of type I & type II errors. Power of a test, p-value, size of a test, level of significance, problem of controlling probabilities of type I & type II errors.

1. 2.2: Definition of Most Powerful (MP) test. Statement and proof (sufficient part) of Neyman-Pearson (NP) lemma for simple null hypothesis against simple alternative hypothesis for construction of MP test. Examples of construction of MP test of level α.

1.2.3: Power function of a test, power curve, definition of uniformly most powerful (UMP) level α test. Use of NP lemma for constructing UMP level α test for one-sided alternative. Illustrative examples .

1.2.4: Likelihood Ratio Test: Procedure of likelihood ratio test, statement of its properties, Likelihood Ratio test involving mean and variance of normal population.

Unit - 2: SPRT and Non- parametric Tests (1 credit)

2.1: Sequential Tests: General theory of sequential analysis and its comparison with fixed sample procedure. Wald's SPRT of strength (α, β), for simple null hypothesis against simple alternative hypothesis. Illustrations for standard distributions like binomial, Poisson, exponential and normal. Graphical and tabular procedure for carrying out the test. Illustrative examples.

2.2: Non- parametric Tests: Notion of non-parametric statistical inference (test) and its comparison with parametric statistical inference. Concept of distribution free statistic. Test procedure of:

(i) Run test for one sample (i.e. test for randomness) and run test for two independent sample problems.

(ii) Sign test for one sample and two sample paired observations

(iii) Wilcoxon's signed rank test for one sample and two sample paired observations.

(iv) Mann-Whitney U - test (two independent samples)

(v) Median test

(vi) Kolmogorov Smirnov test for one and for two independent samples.

Books Recommended

1. Kale, B. K.: A first Course on Parametric Inference
2. Rohatgi, V. K.: Statistical Inference
3. Rohatgi, V. K.: An introduction to Probability Theory andMathematical Statistics
4. Saxena H. C. and Surenderan : Statistical Inference
5. Kendall M. G. and Stuart A.: An advanced Theory of Statistics
6. Lindgren, B. W.: Statistical Theory
7. Cassela G. and Berger R. L.: Statistical Inference

8. Lehmann, E. L: Testing of Statistical Hypothesis
9. Rao, C. R.: Linear Statistical Inference
10. Dudewicz C. J. and Mishra S. N. : Modern Mathematical Statistics
11. Fergusson, T. S.: Mathematical statistics.
12. Zacks, S.: Theory of Statistical Inference.
13. Cramer, H.: Mathematical Methods of Statistics.
14. Gibbons, J. D.: Non-parametric Statistical Inference.
15. Doniel: Applied Non-parametric Statistics
16. Siegel, S.: Non-parametric Methods for the behavioral sciences.
17. Kunte, S. ;Purohit, S. G. and Wanjale, S.K.: Lecture notes on Non-parametric Tests.

Paper XV

NBST22- 603 : Designs of Experiments

(Credit 02)

Marks-50

Course Outcomes: The students will acquire:

a) knowledge of basic terms used in design of experiments.
b) concept of one-way and two-way analysis of variance.
c) knowledge of various designs of experiments such as CRD, RBD, LSD and factorial experiments.
d) knowledge of using an appropriate experimental design to analyze the experimental data.

Unit – 1: Simple Designs of Experiments: **(1 credit)**

1.1: Basic Concepts:

i) Basic terms in design of experiments: Experimental unit, treatment, layout of an experiment.
ii) Basic principles of design of experiments: Replication, randomization and local control.
iii) Choice of size and shape of a plot for uniformity trials, the empirical formula for the variance per unit area of plots.
Concept and definition of efficiency of a design.

1. 2 : Completely Randomized Design (CRD):

i) Application of the principles of design of experiments in CRD, layout, model, assumptions and interpretations:
ii)Estimation of parameters, expected values of mean sum of squares, components of variance.
iii) Breakup of total sum of squares in to components.
iv) Technique of one way analysis of variance (ANOVA) and its applications to CRD.
v) Testing for equality for treatment effects and its interpretation. F-test for testing H0, test for equality of two specified treatment effects.

1.3: Randomized Block Design(RBD):

i)Application of the principles of design of experiments in RBD, layout, model , assumptions and interpretations:
ii) Estimation of parameters, expected values of mean sum of squares, components of variance.
iii) Breakup of total sum of squares into components.
iv) Technique of two way analysis of variance (ANOVA) and its applications to RBD.
v) Tests and their interpretations , test for equality of two specified treatment effects, comparison of treatment effects using critical difference (C.D.).
vi) Idea of missing plot technique.

vii) Situations where missing plot technique is applicable.

viii) Analysis of RBD with single missing observation.

ix) Efficiency of RBD over CRD.

1.4: Latin Square Design (LSD):

i) Application of the principles of design of experiments in LSD, layout, model, assumptions and interpretations:

ii) Breakup of total sum squares into components.

iii)Estimation of parameters, expected values of mean sum of squares, components of variance. preparation of analysis of variance (ANOVA) table.

iv) Tests and their interpretations, test for equality of two specified treatment effects, comparison of treatment effects using critical difference (C.D.).

v) Analysis of LSD with single missing observation.

vi) Identification of real life situations where CRD, RBD AND LSD are used. vii.Efficiency of LSD over CRD and LSD over RBD.

Unit – 2 SP Design, ANOCOVA and Factorial Experiments (1 credit)

2.1: Split Plot Design:

i) Application of the principles of design of experiments in layout, model , assumptions and interpretations:

ii) Estimation of parameters, expected values of mean sum of squares, components of variance.

3.2 Strip Plot Design:

i) Application of the principles of design of experiments, layout, model, assumptions and interpretations:

ii)Estimation of parameters, expected values of mean sum of squares, components of variance.

2.2: Analysis of Covariance (ANOCOVA) with one concomitant variable

i) Purpose of analysis of covariance.

ii) Practical situations where analysis of covariance is applicable.

iii)Model for analysis of covariance in CRD and RBD. Estimation of parameters (derivations are not expected).

iv)Preparation of analysis of covariance (ANOCOVA) table, test for $\beta = 0$, test for equality of treatment effects (computational technique only).

Note :- For given data, irrespective of the outcome of the test of regression coefficient (β), ANOCOVA should be carried out.

2.3: Factorial Experiments

i) General description of factorial experiments, 2^2 and 2^3 factorial experiments arranged in RBD.

ii) Definitions of main effects and interaction effects in 2^2 and 2^3factorialexperiments.

iii)Model , assumptions and its interpretation.

iv)Preparation of ANOVA table by Yate's procedure, test for main effects and interaction effects.

v) General idea and purpose of confounding in factorial experiments.

vi)Total confounding (Confounding only one interaction) : ANOVA table, testing main effects and interaction effects.

vii)Partial Confounding (Confounding only one interaction per replicate): ANOVA table, testing main effects and interaction effects.

viii)Construction of layout in total confounding and partial confounding in 2^3 factorial experiment.

Books Recommended

1. Federer, W.T. : Experimental Design, Oxford and IBH publishing Company, New Delhi.
2. Cochran, W.G. and Cox, G.M. : Experimental Design, John Wiley and Sons, Inc., New York.
3. Montgomery, D.C.: Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi. 12
4. Das, M.N. and Giri, N.C. : Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
5. Goulden, G.H. : Methods of Statistical Analysis, Asia Publishing House, Mumbai.
6. Kempthrone, O. : Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
7. Snedecor, G.W. and Cochran, W.G. : Statistical Methods, Affiliated East- West Press, New Delhi.
8. Goon, Gupta, Dasgupta : Fundamental of Statistics, Vol. I and II, The World Press Pvt. Ltd. Kolkata.
9. Gupta, S.C. and Kapoor, V.K. : Fundamentals of Applied Statistics, S. Chand & Sons, New Delhi.
10. C.F. Jeff Wu, Michael Hamada : Experiments, Planning Analysis and Parameter Design Optimization.

Paper XVI

NBST22- 604 : Operations Research

(Credit 02)

Marks-50

Course Outcomes: The students will acquire

a) Concept of Linear programming problem.

b) Knowledge of solving LPP by graphical and Simplex method.

c) Knowledge of Transportation, Assignment and Sequencing problems.

d) Concept of queuing theory.

Knowledge of simulation technique and Monte Carlo technique of simulation

Unit-1: Linear programming **(1 credit)**

1.1 Basic concepts: Statement of the Linear Programming Problem (LPP), formulation of problem as .L.P. problem. Definition of (i) a slack variable, (ii) a surplus variable.L.P. problem in (i) canonical form, (ii) standard form. Definition of (i) a solution, (ii) a feasible solution,(i)basic variable and non-basic variable, (iv) a basic feasible solution, (v) a degenerate and a non-generate solution, (vi) an optimal solution.

Solution of L.P.P.: i) Graphical Method: Solution space, obtaining an optimal solution, unique and nonunique optimal solutions.ii) Simplex Method: a)Initial basic feasible solution (IBFS) is readily available: obtaining an IBFS, criteria for deciding whether obtained solution is optimal, criteria for unbounded solution, , more than one optimal solutions. B) IBFS not readily available: introduction of artificial variable, Big- M method, modified objective function, modifications and applications of simplex method to L.P.P., criterion for no solution.

Duality Theory: Writing dual of a primal problem, solution of L.P.P. with artificial variable. Examples and problems.

1.2: Transportation, Assignment and Sequencing Problem

Transportation problem (T. P.): statement of T. P., balanced and unbalance T. P., Methods of obtaining initial basic feasible solution of T.P. (a) North West corner rule (b)Method of matrix minima (least cost method), (c) Vogel's approximation(VAM)., MODI method of obtaining Optimal solution of T. P, uniqueness and non- uniqueness of optimal solutions, degenerate solution.Examples and problems.

Assignment Problem: Statement of an assignment problem, balanced and unbalanced assignment

problem,relation with T.P, optimal solution of an assignment problem using Hungarian method. Examples and problems.

Unit-2: **(1 credit)**

2.1 Sequencing Problem: Introduction. Statement of problem.**,**Procedure of processing n jobs on two machines.**,**Procedure of processing n jobs on three machines and m machines. Computations of elapsed time and idle times. Examples and problems.

2.2 Decision Theory: Introduction, steps in decision theory approach **,**Type of decision making environments **,**Decision making under uncertainty: Criteria of optimism, criteria of pessimism, equally likely decision criterion, criterion of regret **,**Decision making under risk: Expected monetary value, expected opportunity loss, expected value of perfect information. Examples **a**nd problems.

2.3 Network Analysis: Scope and definition of network model, minimal spanning tree algorithm, shortest route problem. CPM, PERT: Network Representation, critical path computation, construction of time schedule, linear programming formulation of CPM. PERT calculations.

Book Recommended:

1. Taha H. A.: Operation research – An Introduction, Fifth Edition, Prentice Hall of India, New Delhi.
2. Shrinath, L. S. : Linear Programming, Affiliated East-West Press Pvt. Ltd., New Delhi. 3.Sharma, J. K. : Mathematical Models in Operations Research, Tau McGraw Hill Publishing Company Ltd., New Delhi.
5. Kapoor, V. K. ; Operations Research, Sultan Chand and Sons, New Delhi.
6. Gupta, P. K. and Hira, D. S. : Operations Research, S. Chand and Company Ltd., New Delhi.

B.Sc. III (Statistics) : Semester VI : Practicals

Practical - IV (NBSP22-605) - Probability Distributions

1. Model sampling from Laplace, Cauchy and Pareto distribution.
2. Model sampling from truncated binomial and poison distributions.
3. Model sampling from truncated normal and exponential distributions.
4. Fitting of Weibull distribution.
5. Fitting of truncated Binomial distribution.
6. Fitting of truncated Poisson distribution.
7. Applications of multinomial distribution.
8. Applications of Laplace, Weibull and Pareto distribution.
9. Model sampling from Log-normal, Weibull, and Logistic distributions using R-Software.
10. Fitting of Binomial and Poisson distributions using R-Software.
11. Fitting of Normal distribution using R-Software.
12. Fitting of Log-normal distribution using R-Software.
13. Analysis of Completely Randomized Design (CRD) and Randomized Block Design (RBD) using R.
14. Classification of TPM, States and computation of higher transition probabilities and Applications of Queuing Systems.
15. Application of Order Statistics.

Practical –V (NBSP22-606) - Statistical Inference

1. Point estimation by method of moments for discrete distributions.
2. Point estimation by method of moment for continuous distributions.
3. Point estimation by method of maximum likelihood (one parameter).
4. Point estimation by method of maximum likelihood (two parameters).
5. Point estimation by method of minimum chi-square.
6. Interval estimation of location and scale parameters of normal distribution (single sample).
7. Interval estimation of difference of location and ratio of scale parameters of normal distribution (two samples).
8. Interval estimation for population median using order statistics.
9. Construction of MP and UMP test.
10. Construction of SPRT for binomial, Poisson distributions, graphical representation of procedure.
11. Construction of SPRT for exponential and normal distribution, graphical representation of procedure.
12. NP test –Sign test and Wilcoxon's signed rank test (for one and two samples paired observation) and Run Test.
13. NP test-- Mann-whitney U- test (for two independent samples).
14. NP test –Median test (for two large independent samples)
15. NP test—Kolmogorov - smirnov test (for one and two independent samples).

Practical - VI (NBSP22-607) - Design of Experiments and Sampling Techniques

1. Analysis of CRD and RBD.
2. Analysis of Latin Square Design (LSD).
3. Missing Plot Technique for RBD and LSD with one missing observation.
4. Efficiency of i) RBD over CRD and ii) LSD over CRD and RBD.
5. Analysis of Covariance in CRD and Covariance in RBD
6. Analysis of 2^2 and 2^3 Factorial Experiment
7. Total and partial Confounding
8. Simple Random Sampling for Variables.
9. Simple Random Sampling for Attributes.
10. Determination of Sample Size in SRS for Variables and Attributes.
11. Stratified Random Sampling – I
12. Stratified Random Sampling – II
13. Ratio Method and Regression Method of Estimation.
14. Systematic Sampling.
15. Cluster Sampling

Practical – VII (NBSP22-608) - Quality Management and Operations Research

1. L.P.P. by simplex method I (Slack variable)
2. L.P.P. by simplex method II (Big M method)
3. Transformation problem-I
4. Transformation problem-II. (Degeneracy)
5. Assignment problem.
6. Sequencing Problem.
7. Decision Theory.
8. Construction of CPM and PERT.
9. EWMA-Chart.
10. CUSUM chart.
11. Six sigma limits for mean.
12. Single sampling plan-I (Small sample).
13. Single sampling plan-II (Large sample).
14. Double sampling plan-I (Small sample.
15. Double sampling plan-II (Large sample).

Nature of Question Paper:-

B.Sc. Part III Semester-V

Statistics (Paper-IX,X,XI,XII)

Total Marks – 40 Marks

Q.1.	Multiple choice-type questions–	8 marks
Q.2.	Attempt any two out of three.	16marks
Q.3.	Solve any four out of six	16marks

1) **Criteria of Passing:-**
   Minimum 04 out of 10 in Internal Evaluation
   Minimum 16 out of 40 in Theory Examination

B.Sc. Part III Semester-VI

Statistics(PaperXIII,XIV,XV,XVI)

Total Marks – 40 Marks

Q.1. Multiple choice-type questions– 8 marks

Q.2. Attempt any two out of three. 16marks

Q.3. Solve any four out of six 16marks

2) **Criteria of Passing:-**
3) Minimum 04 out of 10 in Internal Evaluation
4) Minimum 16 out of 40 in Theory Examination

B.Sc. Part III Semester-VI

Statistics (Practical IV,V,VI,VII)

Total Marks – 40 Marks

Q.1. Attempt any two out of four. 32 marks

Journal : 04 marks

Oral : 04 marks