Estd. 1962
"A++" Accredited by
NAAC (2021)
With CGPA 3.52

SHIVAJI UNIVERSITY, KOLHAPUR - 416004, MAHARASHTRA

PHONE:EPABX-2609000, www.unishivaji.ac.in, bos@unishivaji.ac.in

शिवाजी विद्यापीठ, कोल्हापूर -४१६००४,महाराष्ट्र

दुरध्वनी-ईपीएबीएक्स -२६०९०००, अभ्यासमंडळे विभाग दुरध्वनी ०२३१—२६०९०९४
०२३१—२६०९४८७

SU/BOS/Science/06 **Date: 01/01/2024**

To,

The Principal, All Concerned Affiliated Colleges/Institutions Shivaji University, Kolhapur	The Head/Co-ordinator/Director All Concerned Department (Science) Shivaji University, Kolhapur.

Subject: Regarding syllabi of B.Sc. Part-III (Sem. V & VI) as per NEP-2020 (1.0) degree programme under the Faculty of Science and Technology.

Sir/Madam,

With reference to the subject mentioned above, I am directed to inform you that the university authorities have accepted and granted approval to the revised syllabi, nature of question paper and equivalence of B.Sc. Part-III (Sem. V & VI) as per NEP-2020 (1.0) degree programme under the Faculty of Science and Technology.

B.Sc.-III (Sem. V & VI) as per NEP-2020 (1.0)			
1.	Mathematics	12.	Computer Science (Opt)
2.	Statistics	13.	Computer Science (Entire)
3.	Physics	14.	Information Technology (Entire)
4.	Microbiology	15.	Food Science and Technology (Entire)
5.	Industrial Microbiology	16.	Food Science
6.	Electronics	17.	Food Science and Quality Control (Entire)
7.	Chemistry	18.	Food Technology &Management (Entire)
8.	Sugar Technology (Entire)	19.	Biochemistry
9.	Geology	20.	Biotechnology (Optional/Vocational)
10.	Zoology	21.	Biotechnology (Entire)
11.	Botany	22.	Environmental Science (Entire)

This syllabus, nature of question and equivalence shall be implemented from the academic year 2024-2025 onwards. A soft copy containing the syllabus is attached herewith and it is also available on university website www.unishivaji.ac.in NEP-2020(Online Syllabus)

The question papers on the pre-revised syllabi of above-mentioned course will be set for the examinations to be held in October /November 2024 & March/April 2025. These chances are available for repeater students, if any.

You are, therefore, requested to bring this to the notice of all students and teachers concerned.

Thanking you,

Dy Registrar
Dr. S. M. Kubal

Copy to:

SHIVAJI UNIVERSITY, KOLHAPUR.

Accredited By NAAC With 'A' Grade

CHOICE BASED CREDIT SYSTEM

Syllabus For

Bachelor of Science (Part III) Statistics

SEMESTER V AND VI

AS PER NEP 2020

Syllabus to be implemented from June 2024 onwards

Shivaji University, Kolhapur
B. Sc. III Statistics
Structure of the course
To be implemented from June 2024
Theory

Semester V

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

Semester VI

Paper. No.	Title of the paper	Total Marks
XIII	Probability Theory and Applications	50
XIV	Statistical Inference - II	50
XV	Design of Experiments	50
XVI	Operations Research and Decision Theory	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	Designs of Experiments and Sampling Techniques	32	4	4	40
VII	R-Programming, Quality Management and Operations Research	32	4	4	40
	A Project Report & 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 following points:

(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 reserved for 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	Sem.V / P. IX DSE-E13	Probability Distributions
Sem. V/ P.X	Statistical Inference - I	Sem. V/ P.X DSE-E14	Statistical Inference – I
Sem. V / P XI	Design of Experiments	Sem. VI / P XV DSE-F15	Design of Experiments
Sem. V / P XII	R-Programming and Quality Management	Sem. V / P XII DSE-E16	R-Programming and Quality Management
Sem. VI / P XIII	Probability Theory	Sem. VI / P XIII DSE-F13	Probability Theory and Applications
Sem. VI / P XIV	Statistical Inference - II	Sem. VI / P XIV DSE-F14	Statistical Inference – II
Sem. VI / P XV	Sampling Theory	Sem. V / P XI DSE-E15	Sampling Theory
Sem. VI / P XVI	Operations Research	Sem. VI / P XVI DSE-F16	Operations Research and Decision Theory

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	R-Programming, Quality Management and Operations Research	VII	R-Programming, Quality Management and Operations Research

B. Sc. Part-III Semester V

SUBJECT – STATISTICS - IX

DSE-E13: Probability Distributions

Theory: 36 hours. Marks-50 (Credit 02)

Course Outcomes: The students will acquire

a) Knowledge of important univariate distributions such as Rayleigh, Weibull, Linear failure rate, Cauchy, Lognormal, 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 Multivariate Probability Distributions (18 hours)

1.1: Lifetime Distributions:

Rayleigh distribution: Probability density function (p.d.f.) with parameter (λ = scale)

$$f(x) = 2\lambda x e^{-\lambda x^2}\ ;\ x, \lambda > 0$$

Cumulative distribution function (c.d.f.), mean and variance.

Weibull Distribution: Probability density function (p.d.f.) with parameters α and λ (α = shape, λ = scale)

$$f(x) = \alpha\lambda x^{\alpha-1} e^{-\lambda x^{\alpha}};\ x, \lambda, \alpha > 0$$

Cumulative distribution function (c.d.f.), nature of the probability curve for different values of α *and* λ quartiles, mean and variance, coefficient of variation, relation with gamma, exponential and Rayleigh distribution.

Linear Failure Rate Distribution: Probability density function (p.d.f.) with parameters (λ_1, λ_2)

$$f(x) = (\lambda_1 + 2\lambda_2 x) e^{-(\lambda_1 x + \lambda_2 x^2)}\ ;\ x, \lambda_1, \lambda_2 > 0$$

Cumulative distribution function (c.d.f.). Proof of,

if X$\sim$ exp(λ_1), Y$\sim$Rayleigh(λ_2) and if X and Y are independent then,

$Z = \min(X, Y) \sim \text{Linear Failure Rate Distribution}(\lambda_1, \lambda_2)$

1.2: **Lognormal Distribution:** Probability density function (p.d.f.) with parameters (μ, σ^2)

$$f(x) = \frac{e^{-\left[\frac{(\ln(x)-\mu)}{\sigma}\right]^2}}{x\sigma\sqrt{2\pi}} \; ; -\infty < \mu < \infty, x > 0, \sigma > 0$$

First four raw Moments, variance.

Show that, if X~**Lognormal Distribution** (μ, σ^2), Then log(X)~N(μ, σ^2). Examples and problems.

1.3: Cauchy Distribution: Probability density function (p.d.f.) with parameters (μ, λ),

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

Nature of the probability curve, Cumulative distribution function (c.d.f.), 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 Students'-t distribution, distribution of X/Y where X and Y are i. i. d. N(0, 1). Examples and problems.

1.4: Logistic distribution: Probability density function (p.d.f.) with parameters (μ, σ),

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

Cumulative distribution function (c.d.f.), mean, mode, variance, skewness using mode, applications.

1.5: Pareto distribution: Probability density function (p.d.f.) with parameters (α, β)

$$f(x) = \frac{\alpha\beta^{\alpha}}{x^{\alpha+1}} \; ; x \geq \beta, \alpha, \beta > 0$$

c.d.f., mean, variance, mode, skewness using mode, applications.

1.6: Power series distribution: Probability mass function (p.m.f.),

$$p(x) = \frac{a_x \theta^x}{\sum_0^\infty a_x \theta^x} \; ; \; x = 0,1,2, \ldots$$

mean mode, variance and Binomial, Poisson, Geometric, Negative Binomial distributions as a particular case of a power series distribution.

1.7: Multinomial distribution: Probability mass function (p.m.f.), moment generating function, marginal distribution, mean, variance, covariance, variance covariance matrix, correlation coefficient, additive property, Trinomial distribution as a particular case of multinomial distribution.

Unit-2: Bivariate Normal and Truncated Distributions: (18 hours)

2.1: Bivariate Normal Distribution: Probability density function (p.d.f.) of $BN(\mu_{1,} \mu_2, \sigma_1^2, \sigma_2^2, \rho)$, marginal and conditional distributions, identification of parameters, conditional mean and conditional variance, regression of Y on X and of X on Y., independence and uncorrelatedness imply each other, m. g. f and moments. Distribution of aX + bY + c, where a, b and c are real numbers. Cauchy distribution as a distribution of Z = X/Y where (X, Y) ~ $BN(0, 0, \sigma_1^2, \sigma_2^2, \rho)$. Examples and problems.

2.2: Truncated Distributions: Truncated distribution as a conditional distribution, truncation to the right, left and on both sides. Binomial distribution B(n, p) left truncated at X = 0 (value zero not observable): Probability mass function (p.m.f), mean, variance. Poisson distribution P(λ), left truncated at X = 0 (value zero not observable): p.m.f., mean and variance. 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 Probability density function (p.d.f.) and mean. Exponential distribution with parameter θ left truncated below *a*: Probability density function (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 Mathematical Statistics, 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
: Discrete Distributions
: Multivariate Distributions
10. Bhat B. R.: Modern Probability Theory. New Age International.

B. Sc. Part-III Semester V

SUBJECT – STATISTICS - X

DSE-E14: Statistical Inference-I

Theory: 36 hours. Marks-50 (Credit 02)

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: (18 hours)

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) and its Standard Error, distinction between estimator and estimate.

1.3: Properties of estimator:

1.3.1: Unbiased estimator, biased estimator, positive and negative bias, examples of unbiased and biased estimator, Proof of the results:

a) Two distinct unbiased estimators of Ψ(ɵ) give rise to infinitely many unbiased estimators of Ψ(ɵ).

b) If T is an unbiased estimator of ɵ then Ψ(T) is an unbiased estimator of Ψ(ɵ) provided Ψ(.) is a linear function.

Sample variance is a biased estimator of the population variance. Illustrations of unbiased estimators for parameter and parametric functions. Examples.

1.3.2: Relative efficiency of T_1 with respect to T_2, where T_1 and T_2 are unbiased estimators. Use of mean square error (MSE) to modify the above definition for biased estimators. Minimum Variance Unbiased Estimator (MVUE) and Uniformly Minimum Variance Unbiased Estimator (UMVUE), Uniqueness of UMVUE whenever it exists. Examples.

1.3.3: Consistency: Definition, Proof of the results:

a) Sufficient condition for consistency,

b) If T is consistent for ɵ and Ψ (.) is a continuous function, then Ψ (T) is consistent for Ψ (ɵ).

Likelihood function: Definition of likelihood function as a function of the parameter ɵ based on a random sample from discrete and continuous distributions.

1.3.4: Sufficiency: Concept of sufficiency, Definition of sufficient statistic through conditional distribution of the sample given the statistics. Neyman factorization criterion, Pitman-Koopman form which admits sufficient statistic. Properties of sufficient statistic:

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

b)If T is a sufficient for ɵ then T is sufficient for Ψ (ɵ).

Examples.

Unit 2. Cramer Rao Inequality and Methods of estimation: (18 hours)

2.1: Fisher Information function: Definition of Information function, amount of information contained in a sample, Statement regarding equality of the information in

(x_1, x_2, …, x_n) and in a sufficient statistic T, concept of minimal sufficient statistic with illustrations to exponential family. Examples.

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

a) If MVBUE exists for ɵ then MVBUE exists for Ψ(ɵ), if Ψ(.) is a linear function.

b) If T is MVBUE for ɵ then T is sufficient for ɵ. Examples.

2.3: Methods of Estimation:

2.3.1: Method of Maximum Likelihood: Definition, Derivation of maximum likelihood estimators (mle) for parameters of standard distributions. Properties of mle:

a) Invariance property (With Proof),

b) mle is a function of sufficient statistics,

c) Non-uniqueness property of mle (With counter examples).

d) mle's are asymptotically normally distributed. (Without Proof)

2.3.2: Method of Moments: Derivation of moment estimators for standard distributions. Examples.

Books Recommended:

1. Kale B. K. : A first course in 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 Surendreran: Statistical Inference
5. Lehmann E. L.: Theory of Point Estimation
6. Dudewicz C. J. and Mishtra S. N. : Modern Mathematical Statistcs
7. Cassela G. and Berger R. L. Statistical Inference
8. Dixit P. G. Patil S.M. Prayag V. R. and Sunde N. J.: Inference: Theory of Estimation.
9. A. Santhakumaran: Fundamentals of Testing of Statistical Hypothesis
10. Manojkumar Srivastava, Namita Srivastava: Statistical Inference

B. Sc. Part-III Semester V

SUBJECT – STATISTICS - XI

DSE-E15: Sampling Theory

Theory: 36 hours. Marks-50 (Credit 02)

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: (18 hours)

1.1: Introduction: Meaning of population, census, sample, sampling frame. Advantages of sampling over census, random and non-random sampling, purposive, convenient, quota and snowball sampling (concepts and real life examples).

i) Revision of Simple random sampling, Procedure of drawing SRSWOR and SRSWR using (a) random number table (b) software.

ii) Sample mean ($\bar{y}$) as an estimator of population mean, derivation of its expectation, standard error and estimator of standard error under SRSWOR and SRSWR

iii) N$\bar{y}$ as an estimator of population total, derivation of its expectation, standard error and estimator of standard error under SRSWOR and SRSWR

iv) Sampling of dichotomous attributes. Estimation of population proportion, Sample proportion (p) as an estimator of population proportion (P), derivation of its expectation, 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.

1.2: Determination of the sample size:

Determination of the sample size (n) under SRSWOR for variables and attributes when

i) Margin of error and confidence coefficient is known.

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

1.3: Stratified Sampling:

i) Real life situations where stratification is appropriate.

ii) Procedure of drawing stratified sample using (a) random number table (b) software given the sampling frame.

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

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

(b) N$\bar{y}$ 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. Gain in precision due to stratification.

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.

Unit2: Other Sampling Methods: (18 hours)

2.1: Systematic Sampling:

i) Real life situations where systematic sampling is appropriate. Techniques of drawing a sample using systematic sampling (when the population size is multiple of sample size).

ii) Estimation of the 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. Techniques of drawing a sample using cluster sampling.

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

iii) Variance in terms of intra class correlation.

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 and rationale 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, IndianSociety 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 EasternLtd., New Delhi.

5. Murthy, M.N: Sampling Methods, Indian Statistical Institute, Kolkata.

6. ParimalMukhopadhyay (2008):Sampling theory and methods of survey sampling, Prentice Hall of India.

B. Sc. Part-III Semester V

SUBJECT – STATISTICS - XII

DSE-E16: R-Programming and Quality Management

Theory: 36 hours. Marks-50 (Credit 02)

Course outcomes: The students will acquire

a) importance of R- programming
b) knowledge of identifiers and operators used in R.
c) knowledge of conditional statements and Loops used in R.
d) knowledge of quality tools used in Quality management.
e) knowledge of process and product control used in Quality management.

Unit-1: R Programming: (18 hours)

1.1: Introduction: History, Feathers of R**,** Introduction to R Studio, Getting help in R. Objects/Variable, **Data Types**: numeric, integer, character, complex, logical. **Operators**: Arithmetic, relational, logical, assignment, special operators. **Data Structures**: vector, matrix, data frame. Indexing and slicing of data structure.

Input and output functions, R-packages, R-datasets, Data Import and Export, Basic built-in functions (Mathematical and Statistical). Functions for diagrammatic and graphical representations of data.

1.2: Programming:

Conditional Statements: If, if else, **Loops:** for, while.

Simple programs:

1) Finding Area of circle.
2) To check whether the given integer is positive or negative.
3) Reverse a given number.
4) To find greatest of three numbers.
5) Find Prime numbers in a given range.
6) To check if number is odd or even.
7) To check leap year.
8) To find sum of first n natural numbers.
9) To find AM, GM, and HM for ungrouped data.
10) To find Mean deviation, Variance, Standard deviation for ungrouped data.

Unit-2: Quality Management: (18 hours)

2.1: Quality Tools: Meaning and importance of S.Q.C. dimensions of quality, magnificent tools of quality: Histogram, Check sheet, Pareto diagram, cause and effect diagram, Defect concentration diagram, scatter diagram, control chart, Deming's PDCA cycle.

2.2: Process Control: CUSUM chart, tabular form. Moving average and exponentially weighted moving average charts. Use of these charts for monitoring process mean. Introduction to six-sigma methodology.

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

Books Recommended:

1. Crawley, M. J. (2006): Statistics - An introduction using R. John Wiley, London 32
2. Purohit, S.G.; Gore, S.D. and Deshmukh, S.R. (2015): Statistics using R, second edition. Narosa Publishing House, New Delhi.
3. Shahababa, B. (2011): Biostatistics with R, Springer, New York
4. Verzani, J. (2005): Using R for Introductory Statistics, Chapman and Hall /CRC Press, New York
5. Montgomery D. C.: Introduction to quality Control
6. Duncan A. J.:Quality Control and Industrial statistics
7. GrantE. . L: Statistical Quality Control

B. Sc. Part-III Semester VI

SUBJECT – STATISTICS - XIII

DSE-F13: Probability Theory and Applications

Theory: 36 hours. Marks-50 (Credit 02)

Course Outcomes: The students will acquire

a) knowledge about order statistics and associated distributions
b) concept of convergence and Chebychev's inequality 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: Order Statistics and Convergence: **(18 hours)**

1.1: 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.

1.2: Convergence and Limit Theorem: 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.

1.3: Chebycheve's Inequality: Chebycheve's inequality for discrete and continuous distributions. Examples.

1.4: Weak Law of Large Numbers and Central Limit Theorem: Weak law of large numbers (WLLN)- statement and proof for i. i. d. random variables with finite variance.

1.5 Central Limit Theorem: Statement and proof for i. i. d. random variables with finite variance, proof based on m. g. f., simple examples based on Bernoulli, binomial, Poisson and chi-square distribution.

Unit-2: Reliability Theory: **(18 hours)**

2.1: Binary System: Block diagrams, definition of binary coherent structure and illustrations. Coherent system of components at most three, (a) Series, (b) Parallel, (c) 2 out of 3: Minimal cut and minimal path representation of system.

2.2: Reliability of binary System: Reliability of systems h(p), when components are independent and identically distributed with common probability p of operating.

2.3: Ageing Properties: Definitions of hazard rate, hazard function, survival function. Concept of distributions with increasing and decreasing failure rate (IFR, DFR). Relationship between survival function and hazard function, density function and hazard rate. Derivations of results: (1) Hazard rate of a series system of components having independent life times is summation of component hazard rates.(2) Life time of series system of independent components with independent IFR life times is IFR,

2.4: Examples on exponential distribution.

Books Recommended:

1. Barlow R. E. and Proschan Frank: Statistical Theory of Reliability and Life Testing. Holt Rinebartand Winston Inc., New Yark.
2. 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. Hoel, Port and Stone: Introduction to Stochastic Processes, Houghton Mifflin.
9. Feller. W. : An Introduction of Probability Theory and its Applications. Wiley Eastern Ltd.. Mumbai.
10. Bhat B. R.: Modern Probability Theory.
11 Ross S: Probability Theory.
12. Sinha S. K. : Reliability and Life Testing, Second Edition, Wiley Eastern Publishers, New Delhi.
13.Trivedi R. S. : Probability and Statistics with Reliability and Computer Science Application, Prentice – Hall of India Pvt. Ltd., New Delhi.
14. Parimal Mukhopadhyaya: An Introduction to the Theory of Probability. World Scientific Publishing.

B. Sc. Part-III Semester VI

SUBJECT – STATISTICS - XIV

DSE-F14: Statistical Inference-II

Theory: 36 hours. Marks-50 (Credit 02)

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: (18 hours)

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 use in obtaining confidence intervals and bounds.

1.1.2: Interval estimation for the following cases:

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

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

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

a. For a sample from bi-variate normal population

b. For samples from two independent normal populations.

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

v) Mean of exponential distribution

vi) Population proportion and difference of two population proportions

vii) Population median (using order statistics and limiting distribution of median).

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 and Type II errors. Power of a test, p-value, size of a test, level of significance, problem of controlling probabilities of type I and 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. Computation of powers for standard probability distributions.

1.2.4:Likelihood Ratio (LR) Test: Procedure of LR test, statement of its properties, LR test involving mean and variance of normal population for two sided alternative hypothesis only.(i.e. H_o: $\mu=\mu_o$ v/s $H_1 : \mu \neq \mu_0$ and H_o: $\sigma^2= \sigma_0^2$ v/s $H_1 : \sigma^2 \neq \sigma_0^2$)

Unit 2. SPRT and Non-parametric Tests: (18 hours)

2.1: Sequential Test: 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 binomial, Poisson, exponential and normal distributions, Graphical and tabular procedure for carrying out the test.

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 randomness and run test for equality of distributions.

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

iii) Wilcoxon's signed rank test for one sample and two samples pairedobservations

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

v) Median test

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

Books Recommended:

1. Kale B. K. : A first course in 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 Surendreran: Statistical Inference
5. Lehmann E. L.: Theory of Point Estimation
6. Dudewicz C. J. and Mishtra S. N. : Modern Mathematical Statistics
7. Cassela G. and Berger R. L. Statistical Inference
8. Gibbons J. D.: Non-parametric Statistical Inference
9. Doniel : Applied Non-parametric Statistics
10. Siegel S.: Non-parametric Methods for the behavioral sciences.
11. Kunte S, Purohit S. G and Wanjale S.K: Lecture notes on Non-parametric Tests.
12. Dixit P. G. Patil S.M. Prayag V. R. and Sunbandh N. J.: Inference: Theory of Estimation.
13. Bhuyan K. C.: Probability Distribution Theory and Statistical Inference
14. A. Santhakumaran: Fundamentals of Testing of Statistical Hypothesis
15. Manojkumar Srivastava, Namita Srivastava: Statistical Inference

B. Sc. Part-III Semester VI

SUBJECT – STATISTICS - XV

DSE-F15: Design of Experiments

Theory: 36 hours. Marks-50 (Credit 02)

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: (18 hours)

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.

1.2: Completely Randomized Design (CRD):

i) Application of the principles of design of experiments in CRD, layout, mathematical model assumptions and interpretations.

ii) Estimation of parameters, Standard Error (SE), estimate of σ as square root of Mean Error Sum of Squares. Expected values of mean sum of squares, components of variance.

iii) Breakup of total sum of squares into components.

iv) Visual inspection of treatment effects using treatment wise BOX-PLOT's.

v) Technique of one-way analysis of variance (ANOVA) and its applications to CRD.

vi) Statement of Chochran's theorem (without proof) for justification of F-test. Tests for equality for treatment effects and its interpretation. Test for equality of two specified treatment effects using Critical Difference (CD)

vii) Model adequacy check using residual analysis.

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) Visual inspection of treatment effects, block effects using BOX-PLOT's.

v) Technique of Two way analysis of variance (ANOVA) and its applications to RBD. Residual analysis for model adequacy checking.

vi) Related testing procedures and their interpretations, test for equality of two specified treatment effects, comparison of treatment effects using critical difference (C.D.).

vii) Idea of missing plot technique.

viii) Situations where missing plot technique is applicable.

ix) Analysis of RBD with single missing observation.

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 of squares into components.

iii) Estimation of parameters, Standard Error (SE), expected values of mean sum of squares, components of variance. Preparation of analysis of variance (ANOVA) table.

iv) Visual inspection of treatment effects, row and column effects using BOX-PLOT's.

v) Related tests and their interpretations, test for equality of two specified treatment effects, comparison of treatment effects using critical difference (C.D.).Residual analysis for model adequacy checking.

vi) Analysis of LSD with single missing observation.

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

Unit 2: Analysis of Non-Normal Data, Efficiency and Factorial Experiments: (18 hours)

2.1: Analysis of non- normal data using,

i) Square root transformation for counts.

ii) Sin^{-1} (.) transformation for proportions.

iii) Kruskal Wallis test.

2.2: Efficiency of design:

i) Concept and definition of efficiency of a design.

ii) Efficiency of RBD over CRD.

iii) Efficiency of LSD over CRD and LSD over RBD.

2.3: Factorial Experiments:

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

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

iii) Model assumptions and its interpretation.

iv) Preparations 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 experiments.

Books Recommended:

1. Montgomery, D.C. (2001): Design and Analysis of Experiments, John Wiley and sons Inc., New Delhi.

2. Dass, M.N. and Giri,N.C. (1986) Design and Analysis of Experiments, II Edition Wiley Eastern Ltd., New Delhi

3. Snedecor, G.W. and Cochran, W.G. (1994). Statistical Methods, 8th edition, Affiliated East – West Press, New Delhi

4. Goon, A.M., Gupta,M.K. and Dasgupta, B. (1998). Fundamentals of Statistics, Vol.II, The world Press Pvt. Ltd. Kolkatta.

5. Gupta S.C. and Kapoor V.K.(2006). Fundamentals of Applied Statistics, S.Chand Sons, New Delhi

6. Wu, C.F.J. and Hamda, M. (2009). Experiments, Planning, Analysis and Parameter Design Optimization, John Wiley & Sons,Inc.,Hoboken,New Jersey.

B. Sc. Part-III Semester VI

SUBJECT – STATISTICS - XVI

DSE-F16: Operations Research and Decision Theory

Theory: 36 hours. Marks-50 (Credit 02)

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 and decision theory.

e) Knowledge of simulation technique and Monte Carlo technique of simulation.

Unit-1: **(18 hours)**

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

Solution of L.P.P.: i) Graphical Method: Solution space, obtaining an optimal solution, unique and non- unique 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 Problems:

Transportation problem(T.P.): statement, 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, balanced and unbalanced assignment problem, relation with T.P, optimal solution of an assignment problem using Hungarian method, examples and problems.

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 time. Examples and problems.

Unit-2: **(18 hours)**

2.1: 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. Examples and problems.

2.2: Simulation Techniques: Meaning of simulation, Monte Carlo simulation, advantages and disadvantages of simulation, properties of random numbers, generation of pseudo random numbers, Techniques of generating random numbers from uniform distribution.

Decision Theory: Introduction, steps in decision theory approach, Types of decision making environments, Decision making under uncertainty: Criteria of optimism, criteria of pessimism, equally likely decision criterion, criterion of regret. Examples and problems

Book Recommended:

1. Gass E.: Linear Programming Method and Applications, Narosa Publishing House, New Delhi.
2. Shrinath L. S.: Linear Programming.
3. Taha H. A.: Operation research – An Introduction, Fifth Edition, Prentice Hall of India, New Delhi.
4. Saceini, Yaspan, Friedman: Operations Research Method and Problems, Wiley International Edition.
5. Shrinath, L. S.: Linear Programming, Affiliated East-West Press Pvt. Ltd., New Delhi.
6. Phillips, D. T., Ravindra, A., Solberg, J.: Operations Research Principles and Practice, John Wiley and Sons Inc.

7. Sharma, J. K.: Mathematical Models in Operations Research, Tau McGraw Hill Publishing Company Ltd., New Delhi.

8. Sharma, J. K.: Operations Research: Theory and Applications, Trinity Press, Laxmi Publications, New Delhi.

8. Kapoor, V. K.; Operations Research, Sultan Chand and Sons, New Delhi.

9. Gupta, P. K. and Hira, D. S.: Operations Research, S. Chand and Company Ltd., New Delhi.

10. Luc Devroye: Non-Uniform Random Variate Generation, Springer – Verlag, New York.

11. Gentle, J. E.: Random Number Generation and Monte Carlo Methods, Springer- Verlag.

12. Robert, C. P. and Casella, G.: Monte Carlo Statistical methods, Springer-Verlag.

13. Rubinstien, R. Y.: Simulation and Monte Carlo Method, John Wiley, New York.

B.Sc. III (Statistics)

Practical IV

Probability Distributions

1. Model sampling from Rayleigh and Cauchy distributions.
2. Model sampling from log-normal and Weibull distributions.
3. Model sampling from logistic distribution.
4. Model sampling from Pareto distribution.
5. Model sampling from truncated binomial and Poisson distributions.
6. Model sampling from truncated normal and exponential distributions.
7. Model sampling from bivariate normal distribution.
8. Fitting of log-normal distribution.
9. Fitting of Weibull distribution.
10. Fitting of logistic distribution.
11. Fitting of Pareto distribution.
12. Fitting of truncated binomial distribution.
13. Fitting of truncated Poisson distribution.
14. Applications of multinomial distribution.
15. Applications of bivariate normal distribution.

Practical-V

Statistical Inference

1. Point estimation by Method of Moment for Discrete Distributions.
2. Point estimation by Method of Moment for Continuous Distributions.
3. Point estimation by Method of Maximum Likelihood (for one parameters).
4. Point estimation by Method of Maximum Likelihood (for two parameters).
5. Interval estimation of location and scale parameters of normal distribution(Single Sample).
6. Interval estimation of difference of location and ratio of scale parameters of normal distributions (Two sample).
7. Interval estimation for population proportion and difference between two population proportions.
8. Interval estimation for population median (using order statistics and limiting distribution of median).
9. Construction of MP test.
10. Construction of UMP test.
11. Construction of SPRT for Binomial and Poisson distributions.
12. Construction of SPRT for exponential and normal distributions.
13. Non-Parametric Tests-I : Run test, Sign test and Wilcoxon signed Rank test
14. Non-Parametric Test-II : Mann-Whitney U-test for two independent samples and Median Test for two large independent samples
15. Non-Parametric Tests-III: Kolmogorov-Smirnov test for one and two independent samples.

Practical VI

Design of Experiments and Sampling Techniques

1. Analysis of CRD and RBD, Efficiency of RBD over CRD.
2. Analysis of LSD and efficiency of LSD over CRD and RBD.
3. Missing plot technique for RBD and LSD with single missing observations.
4. Analysis of Variance for non-normal data. (CRD, RBD, LSD)
5. Kruskal - Walli’s test for non-normal data (CRD, RBD, LSD)
6. Analysis of 2^2 and 2^3 factorial experiment.
7. Partial and total confounding
8. Simple Random Sampling for (i) Variables (ii) Attributes.
9. Determination of sample size in SRS for (i) Variables (ii) Attributes.

10. Stratified Random Sampling-I
11. Stratified Random Sampling-II
12. Ratio method of estimation
13. Regression method of estimation
14. Systematic Sampling
15. Cluster Sampling.

Practical VII

R- Programming, Quality Management and Operations Research

R- Programming:

1. Data input/output - Creation of vector using commands: c , rep , seq, scan
   - Data import-export: read.table, read.csv, write. table, write.csv.
   - Creation of data frame using commands: data frame, edit
   - Arithmetic operation on vectors.
2. Diagrammatic and Graphical representation of data- Simple bar diagram, subdivided bar diagram, pie diagram, histogram, frequency polygon, ogive curves, Box plot.
3. R- Programming (Measures of Central Tendency, Dispersion Correlation and Regression)
4. Statistical Analysis: Testing of hypothesis (t-test, paired t-test, χ^2 test for independence and goodness of fit, Wilcox ions sign rank test, K.S. test.)
5. Simulation-I using R (Bernoulli, Binomial, Poisson and Geometric distribution.).
6. Simulation-II using R (Exponential and Normal distribution).

Quality Management:

7. EWMA Chart.
8. CUSUM chart.
9. Moving average control chart.
10. Single sampling plan.

Operations Research:

11. Solution of LPP by Simplex Method
12. Solution of LLP by Big–M method.
13. Transformation problem.
14. Assignment problem.
15. Sequencing and Decision Problems.