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**Resolution No. 14-1 (14-1-7)**

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**DEPARTMENT OF STATISTICS (Semester-IV/V/VI)**

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# Semester 4
# DEPARTMENT OF STATISTICS
# B. Sc. (H) Statistics

## Category I

## DISCIPLINE SPECIFIC CORE COURSE-10: SAMPLING DISTRIBUTIONS

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the Course | | | Eligibility Criteria | Pre-requisite of the Course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Sampling Distributions | 4 | 3 | 0 | 1 | Class XII with Mathematics | Basic knowledge of probability and probability distributions |

### Learning Objectives:

The learning objectives of this course are as follows:

- To introduce the modes of convergence and their relation to limit laws, with a focus on the central limit theorem.
- To introduce the concept of sampling distributions and their applications in statistical inference.
- To describe the statistical ideas behind the procedure of hypothesis testing.
- To explain the assumptions and conditions under which to apply different tests of hypothesis about population parameters and draw appropriate conclusions from the analysis.

### Learning Outcomes:

After successful completion of this course, students will be able to:

- Understand the basics of convergence theory and its importance in limit laws.
- Apply the concept of the central limit theorem and the relevance of the theorem in inferential statistics.
- Analyze data by using suitable hypothesis testing procedures in real-life applications related to large and small samples.
- Apply the knowledge of the idea of sampling distributions and appreciate their importance in the field of statistics.
- Integrate the knowledge of various sampling distributions like chi-square, t, and F distributions in hypothesis testing problems.

### SYLLABUS OF DSC-10

**Theory**

**UNIT I** **(10 Hours)**

**Modes of Convergence and Central Limit Theorem**

Convergence in probability, convergence with probability one, convergence in the mean square, convergence in distribution – definitions and relations between the various modes.

Chebyshev's inequality, Weak Law of Large Numbers (WLLN), and Strong Law of Large Numbers (SLLN) along with examples and applications.

Basic idea and relevance of Central Limit Theorem (CLT), De-Moivre Laplace theorem, Lindeberg Levy theorem, Liapunov Theorem (only statement), and applications of CLT.

**UNIT II** **(4 Hours)**

**Order Statistics**

Basic concept and discussion on the area of applications, probability distribution and cumulative distribution function of a single order statistic, joint probability distribution of two and the general case of all order statistics, distribution of range, and distribution of sample median.

**UNIT III** **(9 Hours)**

**Sampling Distributions and Test of Hypotheses**

Concepts of parameter, statistic, sampling distribution of a statistic, standard error. Sampling distribution of sample mean, standard errors of the sample mean, sample variance, and sample proportion.

Null and alternative hypotheses, level of significance, Type I and Type II errors, their probabilities and critical region, determination of sample size, confidence intervals, and p-value.

Tests of significance and confidence intervals for - single proportion, difference of two proportions, single mean, difference of two means, and difference of two standard deviations.

**UNIT IV** **(10 Hours)**

**Exact Sampling Distribution**

Chi-Square distribution: Definition and derivation of the probability distribution of Chi-square distribution with n degrees of freedom, nature of the curve for different degrees of freedom, mean, mode, variance, moment generating function, cumulant generating function, additive property, and limiting form of the Chi-square distribution, Applications of Chi-Square distribution.

**UNIT V** **(12 Hours)**

**Exact Sampling Distributions (continued)**

Student's t-statistic and Fishers t-statistic: definition and derivation of their sampling distributions, nature and characteristics of graph of t distribution, moments, limiting form and applications of the t distribution.

F-statistic: Definition and derivation of the sampling distribution, the graph of F distribution, moments, and applications of the F distribution. Relationship between t, F, and Chi-square distributions.

**PRACTICAL / LAB WORK – 30 Hours**

**List of Practicals:**

1. Large Sample Tests:
   a) Testing of significance and confidence intervals for single proportion and difference of two proportions.
   b) Testing of significance and confidence intervals for single mean and difference of two means.
   c) Testing of significance and confidence intervals for the difference of two standard deviations.
2. Tests based on Chi-Square Distribution:
   a) Testing of significance and confidence intervals for the population variance has a specific value.
   b) Testing for the goodness of fit.
   c) Testing of significance for the independence of attributes.
   d) Testing based on a 2 x 2 contingency table without and with Yates' corrections.
3. Tests based on t- Distribution and F- Distribution:
   a) Testing of significance and confidence intervals for single mean and difference of two means and paired t-test.
   b) Testing of significance and confidence intervals of an observed sample correlation coefficient.
   c) Testing and confidence intervals of equality of two population variances.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**


- Gupta, S. C. and Kapoor, V. K. (2020). Fundamentals of Mathematical Statistics, Twelfth Edition, S. Chand and Sons. Delhi.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2016). An Outline of Statistical Theory, Volume I, The World Press, Kolkata.
- Mukhopadhyay, P. (2016). Mathematical Statistics, Books and Allied, India.
- Hogg, R.V., Tanis, E.A. and Rao, J.M. (2009). Probability and Statistical Inference, Seventh Edition, Pearson Education, New Delhi.
- Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, Eight Edition, Pearson Education, Asia.
- Johnson, R.A. and Bhattacharya, G.K. (2001). Statistics-Principles and Methods, Fourth Edition, John Wiley and Sons.


**SUGGESTED READINGS**


- Bhat, B.R. (2016). Modern Probability Theory- An Introductory Textbook, Fourth Edition, New Age International Publishers.
- Rohatgi, V. K and Saleh M. E. (2015). An Introduction to Probability and Statistics, Third Edition, John Wiley and Sons, Inc., New Jersey.
- Mood, A.M. Graybill, F.A. and Boes, D.C. (2007). Introduction to the Theory of Statistics, Third Edition, (Reprint), Tata McGraw-Hill Pub. Co. Ltd.

**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC CORE COURSE-11: TOTAL QUALITY MANAGEMENT

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the Course | | | Eligibility Criteria | Pre-requisite of the Course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Total Quality Management | 4 | 3 | 0 | 1 | Class XII with Mathematics | Introductory statistics and familiarity probability distributions |

### Learning Objectives:

The learning objectives of this course are as follows:

- To introduce statistical and management techniques,
- To explain the approach of Quality control being used in industry to manufacture goods and services of high quality at low cost.
- To introduce Six-sigma, TQM which is in high demand in the market both in the manufacturing as well as the service sector

### Learning Outcomes:

After completing this course, students will be able to:

- Understand the concept of quality, its historical background, and ISO standards.
- Apply the statistical process control tools and product control tools.
- Understand the idea of Six sigma- Lean manufacturing, TQM
- Comprehend the Six sigma training plans, Voice of customers (VOC), Critical to Quality (CTQ)
- Analyze the data to find the root cause of defects through DMAIC (Define-Measure-Analyze-Improve-Control).

### SYLLABUS OF DSC-11

**Theory**

**UNIT I** **(9 Hours)**

**Basics of Quality Management**

Quality: Definition, dimensions of quality, its concept, application, and importance. Brief historical perspective of quality control and improvements, Quality Gurus, and Quality Hall of Fame. Quality system and standards: Introduction to ISO quality standards, Quality registration.

Introduction to Process and Product Control, Statistical Process Control - Seven tools of SPC, Chance and Assignable causes of quality variation.

**UNIT II** **(12 Hours)**

**Statistical Control Charts**

Statistical Control Charts- Construction and Statistical basis of 3-σ Control charts,. Control charts for variables: X-bar & R-chart, X-bar & s-chart. Rational Sub-grouping, Revised and Modified Control Limits. Control charts for attributes: np-chart, p-chart, c-chart and u-chart. Comparison between control charts for variables and control charts for attributes. Analysis of patterns on a control chart, estimation of process capability.

**UNIT III** **(12 Hours)**

**Sampling Plans**

Acceptance sampling plan: Principle of acceptance sampling plans. Single and Double sampling plans, their Operating Characteristic (OC), Acceptance Quality Level (AQL), Lot Tolerance Percent Defective (LTPD), Average Outgoing Quality (AOQ), Average Outgoing Quality Limit (AOQL), Average Sample Number (ASN), and Average Total Inspection (ATI) functions with graphical interpretation, use, and interpretation of Dodge and Romig's sampling inspection plan tables.

**UNIT IV** **(12 Hours)**

**Six-Sigma**

Overview of Six Sigma, Lean Manufacturing, and Total Quality Management (TQM). Organizational Structure and Six Sigma training plans- Selection Criteria for Six Sigma roles and training plans. Voice of customers (VOC): Importance and VOC data collection. Critical to Quality (CTQ), Introduction to DMAIC (Define-Measure-Analyze-Improve-Control).

**PRACTICAL / LAB WORK – 30 Hours**

**List of Practical:**

1. Construction and interpretation of statistical control charts for
   a) $\bar{X}$ and R-chart for known parameters.
   b) $\bar{X}$ and R-chart with revised control limits for unknown parameters.
   c) $\bar{X}$ $and$ s-chart
   d) np-chart
   e) p-chart with fixed sample size
   f) p-chart with variable sample size.
   g) c-chart
   h) u-chart
2. Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, and AOQL curves under a Single sample inspection plan
3. Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, and AOQL curves under a Single sample inspection plan for varying acceptance numbers.
4. Calculation of process capability and comparison of 3-sigma control limits with specification limits.

5. Plan a single sampling plan using Dodge and Romig sampling inspection tables.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Goon A M, Gupta M K and Dasgupta B (2018): Fundamentals of Statistics, Volume I & II, 9th Edition and 4th reprint.
- Montogomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.
- Ehrlich, B. Harris (2002): Transactional Six Sigma and Lean Servicing, 2nd Edition, St. Lucie Press.


**SUGGESTED READING:**


- Gupta S.C., Kapoor V.K.(2007): Fundamentals of Applied Statistics. 4th Edition, Sultan Chand and Sons., New Delhi.
- Hoyle, David (1995): ISO Quality Systems Handbook, 2nd Edition, Butterworth Heinemann Publication.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC CORE COURSE-12: TIME SERIES ANALYSIS

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the Course | | | Eligibility Criteria | Pre-requisite of the Course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical / Practice | | |
| Time Series Analysis | 4 | 3 | 0 | 1 | Class XII with Mathematics | Introductory probability theory and statistics, Calculus, and matrix algebra |

### Learning Objectives:

The learning objectives of this course are as follows:

- To introduce basic time series analysis, trend, and seasonality,
- To understand spectral analysis,
- To familiarise students with stationary processes,
- To understand various time series models,

- To use nonstationary and seasonal time series models,
- To introduce forecasting techniques and forecasting methods.

## Learning Outcomes:

After successful completion of this course, students will be able to:

- Understand the important time series models and their applications in various fields.
- Formulate real-life problems using time series models.
- Use statistical software to estimate the models from real data, and draw conclusions and develop solutions from the estimated models.
- Use visual and numerical diagnostics to assess the soundness of their models.
- Communicate the statistical analyses of substantial data sets through explanatory text, tables, and graphs.
- Combine and adapt different statistical models to analyze larger and more complex data.
- Possess skills to understand the components and forecast values of a time series at future time points.

## SYLLABUS OF DSC-12

**Theory**

**UNIT I** **(6 Hours)**

**Time Series Data and its Components**

Introduction to times series data and its applications; Components of a time series and its decomposition; Estimation of trend and the seasonal component.

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**UNIT II** **(9 Hours)**

**Spectral Analysis and Stationarity**

Simple sinusoidal model; Periodogram, and Harmonic Analysis; Variate-difference method; Time series, and Stochastic process; Stationarity; Autocorrelation; meaning, definition, causes, the consequence, and test for autocorrelation.

**UNIT III** **(15 Hours)**

**Time Series Models**

Stochastic Models: White noise Process, Random walk, Moving Average (MA), Auto-Regressive (AR), Auto-Regressive Moving Average (ARMA) models, and their properties using correlogram, ACF, and PACF, Yule walker equations; Fitting of AR(1), AR(2), MA(1), MA(2), and ARMA(1,1) processes. Non-Stationary models: Auto-Regressive Integrated Moving Average (ARIMA) and Seasonal Auto-Regressive Integrated Moving Average (SARIMA) models; Dicky Fuller test, Augmented Dickey-Fuller test. Wold's Decomposition Theorem; Non-linear time series models: Auto-Regressive Conditional Heteroskedasticity (ARCH) and Generalized Auto-Regressive Conditional Heteroskedasticity (GARCH) Process.

**UNIT IV** **(12 Hours)**

**Univariate Forecasting Procedures**

Principles of Forecasting; Performance Evaluation; Extrapolation of Trend Curves; Exponential smoothing; Holt-Winter's; Box- Jenkins' Methodology.

**PRACTICAL / LAB WORK – 30 hours**

**List of Practicals:**

1. Fitting and plotting of modified exponential curves by different methods.
2. Fitting and plotting of Gompertz curve by different methods.
3. Fitting and plotting of logistic curves by different methods.
4. Fitting of the trend by the Moving Average Method for a given extent and for an estimated extent.
5. Measurement of Seasonal indices: a) Fixed and b) Changing Patterns
6. Construction of Periodogram and Harmonic Analysis
7. Estimation of variance of the random component
8. Construction of Correlogram for given AR(1), AR(2), MA(1), MA(2), and ARMA(1,1) processes.
9. Fitting of AR(1), AR(2), MA(1), MA(2), and ARMA(1,1) processes for given datasets.
10. Forecasting by various exponential smoothing procedures.
11. Forecasting by Box-Jenkins methodology.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Goon A M, Gupta M K and Dasgupta B (2018): Fundamentals of Statistics, Volume II, 9th Edition and 4th reprint.
- Galit Shmueli and Kenneth C. Lichtendahl Jr (2016): Practical Time Series Forecasting with R: A Hands-On Guide, 2nd Edition, Axelrod Schnall Publishers
- James D. Hamilton (2012): Time Series Analysis, 1st Indian Edition, Princeton University Press, Levant Books Kolkata.
- Chatfield, C. (1996): The Analysis of Time Series, 5th Edition, Chapman and Hall, New York.


**SUGGESTED READING:**


- Shumway and Stoffer (2011): Time Series Analysis and its applications, with examples in R, 3rd Edition, Springer.
- Brockwell, Peter J., and Davis, Richard A. (2002). Introduction to Time Series and Forecasting, 2nd edition. Springer-Verlag, New York.
- Montgomery D. C. and Johnson, L A. and (1967): Introduction to Time Series Analysis And Forecasting, 2nd ed. McGraw-Hill, New York.
- Kendall M.G. (1976): Time Series, Charles Griffin.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

# B.Sc. (P)/B.A(P) with Statistics as Major

## Category II

**DISCIPLINE SPECIFIC CORE COURSE-7: ELEMENTS OF STATISTICAL INFERENCE**

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the Course | | | Eligibility Criteria | Pre-requisite of the Course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Elements of Statistical Inference | 4 | 3 | 0 | 1 | Class XII with Mathematics | Basic probability, probability distributions and sampling distributions |

### Learning Objectives:

The learning objectives of this course are as follows:

- To understand the concept of estimation theory and testing of hypothesis.
- To draw inferences about the unknown population parameters based on random samples.
- To validate the estimation/ inference about the population using hypothesis testing.

### Learning Outcomes:

After successful completion of this course, students will be able to:

- Understanding of estimation theory, Point and interval estimations.
- Characteristics of a good estimator and different methods of estimation.
- Demonstrate the use of these techniques in data analysis.
- Develop the best/most powerful statistical tests to test the hypotheses regarding unknown population parameters by using Neyman-Pearson theory.

### SYLLABUS OF DSC-7

**Theory**

**UNIT I** **(15 hours)**

**Estimation Theory**

Parameter space, sample space, point estimation, requirement of a good estimator, consistency, unbiasedness, efficiency, sufficiency, Minimum variance unbiased estimators, Factorization theorem, Fisher- Neyman Criterion: statement and applications, Cramer- Rao inequality:

statement and application, MVB estimators and their applications, Statement of Rao-Blackwell theorem and Lehmann-Scheffe theorem..

**UNIT II** **(15 hours)**

**Method of Estimation**

Maximum likelihood, least squares and minimum variance, Properties of maximum likelihood estimators (illustration), Interval Estimation: confidence interval and confidence limits for the parameters of normal distribution, confidence intervals for large samples.

**UNIT III** **(15 hours)**

**Test of Significance**

Principles of test of significance: Null and alternative hypotheses, simple and composite, Type-I and Type-II errors, critical region, level of significance, power of the test, best critical region, most powerful test, uniformly most powerful test, uniformly most powerful unbiased (UMPU) critical region, Neyman- Pearson Lemma: statement and its applications to construct most powerful test.

**PRACTICAL / LAB WORK – 30 hours**

**List of Practical**

Practical Based on:

1. Unbiased estimators and consistent estimators.
2. Efficient estimators and relative efficiency of estimators.
3. Sufficient estimators and factorization theorem.
4. Cramer- Rao inequality and MVB estimators.
5. Method of maximum likelihood estimation.
6. Method of least squares and minimum variance.
7. Confidence interval and confidence limits for the parameters of normal distribution.
8. Confidence intervals in case of large samples.
9. Type I and Type II errors, power of the test.
10. Most powerful critical region (NP Lemma).

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Gupta, S.C. and Kapoor, V. K. (2020): Fundamentals of Mathematical Statistics, 12th Ed., Sultan Chand and Sons.
- Miller, I. and Miller, M. (2013). John E. Freund's Mathematical Statistics, 8th Ed., Prentice Hall of India.
- Hogg, R. V., Craig, A. T., and Mckean, J. W. (2005): Introduction to Mathematical Statistics, 6th Edition, Pearson Education.
- Goon, A.K., Gupta, M. K. and Das Gupta, B. (2003): An Outline of Statistical Theory (Vol. II), 4th Edition., World Press, Kolkata.


**SUGGESTED READINGS:**

● Rohtagi, V. K. and Md., A. K. Saleh, E. (2009): An Introduction to Probability and Statistics, 2nd Edition, John Wiley and Sons.
● Casella, G. and Berger, R. L. (2002): Statistical Inference, 2nd Edition, Thomson Duxbury.
● Mood A.M., Graybill F.A. and Boes D.C. (1974). Introduction to the Theory of Statistics, McGraw Hill.

**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC CORE COURSE-8: INTRODUCTION TO VITAL STATISTICS AND DEMOGRAPHY

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the Course | | | Eligibility Criteria | Pre-requisite of the Course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Introduction to Vital Statistics and Demography | 4 | 3 | 0 | 1 | Class XII with Mathematics | knowledge of basic statistics |

### Learning Objectives:

The learning objectives of this course are as follows:

- To collect valid Demographic data using different methods.
- To learn basic measures of Mortality, Fertility, and Population Growth.
- To construct life tables.

### Learning Outcomes:

After successful completion of this course, students will be able to:

- Distinguish between Vital Statistics and Demography.
- Understand errors in Demographic data.
- Comprehend sources of data collection on Vital Statistics and errors therein.
- Use methods for measurement of Population.
- Distinguish between Rate and Ratio.
- Understand the basic measures of Mortality.
- Describe and apply the concepts of Stable and Stationary Populations.
- Understand the concept of Life Tables and their construction.
- Understand the basic measures of Fertility.
- Apply measures of Population Growth.

## SYLLABUS OF DSC-8

**Theory**

**UNIT I** **(10 Hours)**

**Introduction to Vital Statistics**

Introduction and sources of collecting data on vital statistics, errors in the census, and registration data. Measurement of population, rate, and the ratio of vital events.

**UNIT II** **(12 Hours)**

**Measurements of Mortality**

Crude Death Rate (CDR), Specific Death Rate (SDR), Infant Mortality Rate (IMR), and Standardized Death Rates. Stationary and Stable population, Central Mortality Rates, and Force of Mortality.

**UNIT III** **(10 Hours)**

**Life Tables**

Life(Mortality) Tables: Assumption, description, construction of Life Tables, and Uses of Life Tables.

**UNIT IV** **(13 Hours)**

**Measurements of Fertility**

Crude Birth Rate (CBR), General Fertility Rate (GFR), Specific Fertility Rate (SFR), and Total Fertility Rate (TFR). Measurement of Population Growth: Crude rates of natural increase, Pearl's Vital Index, Gross Reproduction Rate (GRR), and Net Reproduction Rate (NRR).

**PRACTICAL/LAB WORK - 30 hours**

**List of Practicals:**

1. To calculate CDR and Age Specific death rate for a given set of data.
2. To find a standardized death rate by (i) Direct method and (ii) Indirect method.
3. To construct a complete life table.
4. To fill in the missing entries in a life table.
5. To calculate CBR, GFR, SFR, TFR for a given set of data.
6. To calculate Crude rate of Natural Increase and Pearle's Vital Index for a given set of data.
7. Calculate GRR and NRR for a given set of data and compare them.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008). Fundamentals of Statistics, Vol. II, 9thEd., World Press.
- Biswas, S. (1988). Stochastic Processes in Demography & Application, Wiley Eastern Ltd.


**SUGGESTED READING:**


- Mukhopadhyay, P. (1999). Applied Statistics, Books and Allied (P) Ltd.

● Keyfitz, N. and Beekman,J.A. (1985). Demography through Problems. S-Verlag, New York.
● Croxton, Fredrick, E. Cowden, Dudley J. and Klein, S. (1973). Applied General Statistics, 3rd Ed., Prentice Hall of India Pvt. Ltd.

**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## B.Sc. (P)/B.A(P) with Statistics as Non- Major
## Category III

**DISCIPLINE SPECIFIC CORE COURSE 4: ELEMENTS OF STATISTICAL INFERENCE**

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the Course | | | Eligibility Criteria | Pre-requisite of the Course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Elements of Statistical Inference | 4 | 3 | 0 | 1 | Class XII with Mathematics | Basic probability, probability distributions and sampling distributions |

### Learning Objectives:

The learning objectives of this course are as follows:

- To understand the concept of estimation theory and testing of hypothesis.
- To infer about the unknown population parameters based on random samples.
- To validate the estimation/ inference about the population using hypothesis testing.

### Learning Outcomes:

After successful completion of this course, students will be able to:

- Understand estimation theory, point and interval estimations.
- Comprehend the characteristics of a good estimator and different methods of estimation.
- Apply the techniques in data analysis.
- Develop the best/most powerful statistical tests to test the hypotheses regarding unknown population parameters by using the Neyman-Pearson theory.

### SYLLABUS OF DSC-4

**Theory**

**UNIT I:** **(15 hours)**

**Estimation Theory:**

Estimation: Parameter space, sample space, point estimation, requirement of a good estimator, consistency, unbiasedness, efficiency, sufficiency, Minimum variance unbiased estimators, Factorization theorem, Fisher- Neyman Criterion: statement and applications, Cramer- Rao inequality: statement and application, MVB estimators and their applications, Statement of Rao-Blackwell theorem and Lehmann-Scheffe theorem..

**UNIT II** **(15 hours)**

**Methods of estimation:**

Maximum likelihood, least squares and minimum variance, Properties of maximum likelihood estimators (illustration), Interval Estimation: confidence interval and confidence limits for the parameters of normal distribution, confidence intervals for large samples.

**UNIT III** **(15 hours)**

**Test of significance**

Principles of test of significance: Null and alternative hypotheses, simple and composite, Type-I and Type-II errors, critical region, level of significance, power of the test, best critical region, most powerful test, uniformly most powerful test, uniformly most powerful unbiased critical region (UMPU), Neyman- Pearson Lemma: statement and its applications to construct most powerful test.

**Practical / Lab Work: - 30 hours**

**List of Practicals:** Practicals based on

1. Unbiased estimators and consistent estimators.
2. Efficient estimators and relative efficiency of estimators.
3. Sufficient estimators and factorization theorem.
4. Cramer- Rao inequality and MVB estimators.
5. Method of maximum likelihood estimation.
6. Method of least squares and minimum variance.
7. Confidence interval and confidence limits for the parameters of normal distribution.
8. Confidence intervals in case of large samples.
9. Type I and Type II errors, power of the test.
10. Most powerful critical region (NP Lemma).

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Gupta, S.C. and Kapoor, V. K. (2020): Fundamentals of Mathematical Statistics, 12th Ed., Sultan Chand and Sons.
- Miller, I. and Miller, M. (2013). John E. Freund's Mathematical Statistics, 8th Ed., Prentice Hall of India.
- Hogg, R. V., Craig, A. T., and Mckean, J. W. (2005): Introduction to Mathematical Statistics, 6th Edition, Pearson Education.
- Goon, A.K., Gupta, M. K. and Das Gupta, B. (2003): An Outline of Statistical Theory (Vol. II), 4th Edition., World Press, Kolkata.


**SUGGESTED READINGS:**


- Rohtagi, V. K. and Md., A. K. Saleh, E. (2009): An Introduction to Probability and Statistics, 2nd Edition, John Wiley and Sons.
- Casella, G. and Berger, R. L. (2002): Statistical Inference, 2nd Edition, Thomson Duxbury.
- Mood A.M., Graybill F.A. and Boes D.C. (1974). Introduction to the Theory of Statistics, McGraw Hill.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

# Discipline Specific Elective
## Category-V

## DISCIPLINE SPECIFIC ELECTIVE COURSE-2A: COMPUTER PROGRAMMING IN C

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the Course | | | Eligibility Criteria | Pre-requisite of the Course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical / Practice | | |
| Computer Programming in C | 4 | 3 | 0 | 1 | Class XII with Mathematics | --- |

### Learning Objectives:

The learning objectives of this course are as follows:

- To introduce computer programming and its roles in problem-solving.
- To describe data structures
- To develop logics that will help to create well-structured programs using C language

### Learning Outcomes:

After successful completion of this course, students will be able to:

- Understand various data types, operators, library functions, Input/Output operations.
- Decision making and branching and looping.
- Use Arrays, Characters, and strings.
- Understand user-defined functions, and recursive functions.
- Storage class of Variables
- Apply Pointers and Structure
- Pre-processors: Macro substitution, macro with argument
- File inclusion in C, I/O operations on files.

### SYLLABUS OF DSE-2A

**Theory**

**UNIT I** **(6 hours)**

**Introduction to C**

History and importance of C. Components, basic structure programming, character set, C tokens, Keywords and Identifiers and execution of a C program. Data types: Basic data types, Enumerated data types, derived data types. Constants and variables: declaration and assignment of variables, Symbolic Constants, overflow and underflow of data.

**UNIT II** **(9 hours)**

**Expressions and I/O functions**

Operators and Expressions: Arithmetic, relational, logical, assignment, increment/decrement and conditional operators, precedence of operators in an expression. Managing input and output from the standard devices.

**UNIT III** **(12 hours)**

**Branching and Arrays**

Decision making and branching - if…else, nesting of if…else, else if ladder, switch. Looping in C: for, while, do…while, jumps in and out of loops.

Arrays: Declaration and initialization of one-dim and two-dim arrays. Character arrays and strings: Declaring and initializing string variables, reading and writing strings from Terminal (using scanf and printf only).

**UNIT IV** **(9 hours)**

**Functions and Storage class**

User- defined functions: definition of functions, return values and their types, function prototypes and calls. Category of Functions and recursive function. Passing arrays to functions, Storage class of Variables.

**UNIT V** **(9 hours)**

**Pointers, Macros and Files**

Pointers: Declaration and initialization of pointer variables, accessing the address of a variable, accessing a variable through its pointer, pointer expressions, pointer increments/decrement and scale factor. Pointers and arrays, functions returning pointers. Introduction of structure. Pre-processors: Macro substitution, macro with argument, file inclusion in C. Defining and opening a file (only r, w and a modes), closing a file, I/O operations on files-fscanf and fprintf functions.

**PRACTICAL/LAB WORK – 30 Hours**

**List of Practicals:**

1. Roots of a quadratic equation (with imaginary roots also)
2. Sorting of an array and hence finding median
3. Mean, Median and Mode of a Grouped Frequency Data
4. Variance and coefficient of variation of a Grouped Frequency Data
5. Preparing a frequency table
6. Value of n! using recursion
7. Random number generation from exponential, normal (using CLT) and gamma distribution calculate sample mean and variance.
8. Matrix addition, subtraction, multiplication, Transpose and Trace
9. Fitting of Binomial distribution and apply Chi-square test for goodness of fit
10. Chi-square contingency table
11. t-test for difference of means
12. Paired t-test
13. F-ratio test
14. Multiple and Partial correlation.
15. Compute ranks and then calculate rank correlation(without tied ranks)

16. Fitting of lines of regression

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Balagurusamy, E. (2019): Programming in ANSI C, 8th Edition, Tata McGraw Hill.
- Gottfried, B.S. (1998): Schaum's Outlines: Programming with C, 2nd Edition, Tata McGraw Hill
- Kernighan, B.W. and Ritchie, D. (1988): C Programming Language, 2ndEdition,Prentice Hall.


**SUGGESTED READING:**


- Kanetkar, Y. (2020) : Let Us C, 18th Edition, BPB Publications
- Perry, G. and Miller, D. (2015) : C Programming Absolute Beginner's Guide, 3rd Edition, Pearson Publications


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC ELECTIVE-2B: ADVANCED TECHNIQUES OF SAMPLE SURVEYS

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title and code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lectures | Tutorials | Practical/ Practice | | |
| Advanced Techniques of Sample Surveys | 4 | 3 | 0 | 1 | Class XII with Mathematics | Knowledge of sample surveys |

### Learning Objectives:

The learning objectives of this course are as follows:

- To introduce advanced techniques relating to stratified and systematic sampling, ratio and regression methods of estimation.
- To introduce cluster and two-stage sampling when the population is divided into groups.
- To describe the errors due to factors other than the inductive process of inferring about the population from a sample.

### Learning Outcomes:

After successful completion of this course, students will be able to:

- Understand Post Stratification,
- Determine the optimum number of strata and their construction
- Comprehend Circular systematic sampling

- Apply Ratio and Regression method of estimation under the Superpopulation model
- Use Cluster sampling, and Two-stage sampling
- Classify non-sampling errors

## SYLLABUS OF DSE-2B

**Theory**

**UNIT I** **(15 Hours)**

**Stratified and Systematic Sampling**

Stratified Sampling: Post Stratification, effect of increasing the number of strata, determination of optimum number of strata, construction of strata (Neyman allocation, Proportional allocation and approximate method by Dalenius and Hodges), method of collapsed strata, allocation requiring more than 100% sampling.

Systematic Sampling: Circular systematic sampling, Yates' and Cochran method of estimation of sampling variance.

**UNIT II** **(15 Hours)**

**Superpopulation Model and Cluster Sampling**

Superpopulation model, Ratio method of estimation under superpopulation model, regression method of estimation under superpopulation model.

Cluster Sampling (equal-sized clusters): Estimation of population mean and its variance, efficiency of cluster sampling, the effect of formation of clusters randomly, efficiency of cluster sampling in terms of intra-class correlation, estimation of efficiency, optimum size of cluster.

**UNIT III** **(15 Hours)**

**Two-Stage Sampling and Non-Sampling Errors**

Two-stage sampling/sub-sampling (Equal first stage units): Estimation of population mean and its variance, Estimator of variance of the sample mean, allocation of sample to two-stages, comparison of two-stage with one-stage sampling.

Non-sampling errors: Classification of non-sampling errors, types of non-sampling errors, bias due to non-response, Hansen and Hurwitz technique, comparison of Hansen and Hurwitz technique with SRS under a cost constraint

**PRACTICAL/LAB WORK – 30 Hours**

**List of Practicals:**

Practical Work based on:

1. Dalenius and Hodges method of construction of strata
2. Determination of optimum number of strata
3. Cluster sampling
4. Circular systematic sample
5. Ratio method of estimation under superpopulation model
6. Regression method of estimation under superpopulation model
7. Two-stage sampling

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**

- Cochran, W.G. (2011): Sampling Techniques ( 3rd Ed.), Wiley Eastern John Wiley and Sons..
- Sukhatme, P. V., Sukhatme, B. V., Sukhatme, S., Asok, C.(1984). Sampling Theories of Survey with Application, IOWA State University Press and Indian Society of Agricultural Statistics.
- Gupta, S.C. and Kapoor, V.K. (2007): Fundamentals of Applied Statistics, Sultan Chand and Sons.
- Singh, D. and Chaudhary, F. S. (2015): Theory and Analysis of Sample Survey Designs.


**SUGGESTED READING:**


- Murthy M.N. (1977): Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
- Des Raj and Chandhok P. (1998): Sample Survey Theory, Narosa Publishing House.
- Goon, A. M., Gupta, M. K. and Dasgupta, B. (2001): Fundamentals of Statistics (Vol.2), World Press.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC ELECTIVE-2C: DEMOGRAPHY (Not for category II)

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title and code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lectures | Tutorials | Practical/ Practice | | |
| Demography | 4 | 3 | 0 | 1 | Class XII with Mathematics | knowledge of basic statistics |

### Learning Objectives:

The learning objectives of this course are as follows:

- To introduce various demographic concepts and to explain the nature and scope of population studies.
- To explain evaluation and adjustments in age data using different indices.
- To introduce the construction of abridged life tables and the estimation and projection of population by different methods.
- To describe the Graduation of mortality rates by different methods.

### Learning Outcomes:

After successful completion of this course, students will be able to:

- Understand the various components of Demography, sources of demographic data collection and errors therein.
- Comprehend population potential, density and concentration.
- Analyse the completeness of registration data using the Chandrasekharan-Deming formula.
- Use concepts of Stable and Stationary Populations.
- Use Balancing Equations.

- Use Myer's and UN indices in evaluating age data.
- Apply measures of the aging of population.
- Understand the concept of Abridged life tables and their construction by Reed and Merrell method and Greville's method.
- Synthesize population estimation and projection by different methods.
- Use Graduation of mortality rates by Makeham's and Gompertz graduation formula.
- Fit of Logistic curve and Makeham's formula.
- Understand the scope of population studies and its relationship with other disciplines.

## SYLLABUS OF DSE-2C

**Theory**

**UNIT I: (15 Hours)**

**Demographic concepts**

Definition of demography and its various components, Major sources of demographic data collection and errors therein; Coverage and content errors, Rate of population change, Population density, Population potential, Population composition, Scale of urbanization and scale of population concentration, Concept of Stationary and stable populations, Nature and scope of population studies and its relationship with other disciplines. Balancing equations and its uses.

**UNIT II: (15 Hours)**

**Adjustment of demographic data and abridged life tables**

Measures of aging of population: Aged-child ratio, Old-age dependency ratio, Child dependency ratio, Age-dependency ratio, Adjustment of age data at younger age groups and adult ages. Chandrasekharan-Deming formula to check completeness of registration data. Myer's index, United Nation's index.

Abridged life tables: Concept and its construction by Reed-Merrell method and Greville's method.

**UNIT III (15 Hours)**

**Population Estimates and Projections and Graduation of Mortality Rates:**

Inter-censal and post-censal estimates by mathematical and component method ; Population Projection by the mathematical method: Logistic curve and its fitting by Pearl and Reed method and Rhodes method. Graduation of mortality rates: Makeham's and Gompertz graduation formula. Fitting of Makeham's formula.

**PRACTICAL/LAB WORK - 30 hours**

**List of Practicals:**

1. To find the Population density of a place.
2. To find Population Potential.
3. To find Rate of population change
4. To find Age Dependency ratio.
5. To find Aged Child ratio.
6. To find Child Dependency ratio.
7. To construct Abridged Life Table by Reed and Merrell method.
8. To Construct Abridged Life Table by Greville's method.

9. To fit Logistic curve by Pearl and Reed method.
10. To fit Logistic curve by Rhode's method.
11. To fit Makeham's formula by the method of Four Selected Points.
12. To fit Makeham's formula by the method of Partial Sums.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edition, World Press.
- Mukhopadhyay P. (1999): Applied Statistics, Books and Allied (P) Ltd.
- Biswas, S. (1988): Stochastic Processes in Demography & Application, Wiley Eastern Ltd.
- Pathak, K. B. and F. Ram (1998), *Techniques of Demographic Analysis*, 2nd Edition, Himalaya Publishing House, Bombay.


**SUGGESTED READINGS:**


- Croxton, Fredrick E., Cowden, Dudley J. and Klein, S. (1973): Applied General Statistics, 3rd Edition. Prentice Hall of India Pvt. Ltd.
- Keyfitz N., Beckman John A. (1985): Demography through Problems S-Verlag New York
- Ramakumar R. (1986): Technical Demography. Wiley Eastern Limited.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

**COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY DEPARTMENT OF STATISTICS CATEGORY-VI**

# GENERIC ELECTIVE 4A: BASICS OF STATISTICAL INFERENCE

## CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the Course | | | Eligibility Criteria | Pre-requisite of the Course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Basics of Statistical Inference | 4 | 3 | 0 | 1 | Class XII with Mathematics | Basic knowledge of probability, probability distributions and sampling distributions |

### Learning Objectives:

The learning objectives of this course are as follows:

- To introduce the concept of estimation theory and testing of hypothesis.
- To infer about the unknown population parameters based on random samples.
- To introduce the estimation/ inference about the population using hypothesis testing.

### Learning Outcomes:

After successful completion of this course, students will be able to:

- Understanding of estimation theory, Point and interval estimations.
- Characteristics of a good estimator and different methods of estimation.
- Demonstrate the use of these techniques in data analysis.
- Develop the best/most powerful statistical tests to test the hypotheses regarding unknown population parameters by using the Neyman-Pearson theory.

### SYLLABUS OF GE 4A

**Theory**

**UNIT I:** **(15 Hours)**

**Estimation Theory**

Estimation: Parameter space, sample space, point estimation, requirement of a good estimator, consistency, unbiasedness, efficiency, sufficiency, Minimum variance unbiased estimators, Factorization theorem, Fisher- Neyman Criterion: statement and applications, Cramer- Rao inequality: statement and application, MVB estimators and their applications, Statement of Rao-Blackwell theorem and Lehmann-Scheffe theorem..

**UNIT II: (15 Hours)**

**Methods of Estimation**

Methods of estimation: maximum likelihood, least squares and minimum variance, Properties of maximum likelihood estimators (illustration), Interval Estimation: confidence interval and confidence limits for the parameters of normal distribution, confidence intervals for large samples.

**UNIT III: (15 Hours)**

**Test of Significance**

Principles of test of significance: Null and alternative hypotheses, simple and composite, Type-I and Type-II errors, critical region, level of significance, power of the test, best critical region, most powerful test, uniformly most powerful test, uniformly most powerful unbiased critical region (UMPU), Neyman- Pearson Lemma: statement and its applications to construct most powerful test.

**PRACTICAL/LAB WORK – 30 Hours**

**List of Practical / Lab Work**:

1. Unbiased estimators and consistent estimators.
2. Efficient estimators and relative efficiency of estimators.
3. Sufficient estimators and factorization theorem.
4. Cramer- Rao inequality and MVB estimators.
5. Method of maximum likelihood estimation.
6. Method of least squares and minimum variance.
7. Confidence interval and confidence limits for the parameters of normal distribution.
8. Confidence intervals in case of large samples.
9. Type I and Type II errors, power of the test.
10. Most powerful critical region (NP Lemma).

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Miller, I. and Miller, M. (2013). John E. Freund's Mathematical Statistics, 8th Ed., Prentice Hall of India.
- S.C. Gupta and V.K. Kapoor (2020): Fundamentals of Mathematical Statistics, 12th Ed., Sultan Chand and Sons.
- R.V. Hogg, A.T. Craig and J.W. Mckean (2005): Introduction to Mathematical Statistics, 6th Edition, Pearson Education.

● A.M. Goon, M.K. Gupta and B. Das Gupta (2003): An Outline of Statistical Theory (Vol. II), 4th Ed.,World Press, Kolkata.

**SUGGESTED READING:**

● G. Casella and R.L. Berger (2002): Statistical Inference, 2nd Edition, Thomson Duxbury.
● E.J. Dudewicz and S.N. Mishra (1988): Modern Mathematical Statistics, John Wiley and Sons.
● V.K. Rohtagi and A.K. Md. E. Saleh (2009): An Introduction to Probability and Statistics, 2nd Edition, John Wiley and Sons.
● Mood A.M., Graybill F.A. and Boes D.C. (1974). Introduction to the Theory of Statistics, McGraw Hill.

**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## GENERIC ELECTIVE 4B: STATISTICAL COMPUTING USING R

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| **Statistical Computation using R** | **4** | **2** | 0 | **2** | Class XII pass with Mathematics. | Basic knowledge of computers and basics of Statistics |

### Learning Objectives:

The learning objectives of this course are as follows:

- Review and expand upon core topics in probability and statistics.
- Practice of graphical interpretation, probability distribution and data analysis using `R'.

### Learning Outcomes:

After completing this course, students would have developed a clear understanding of:

- Various Graphical representation and interpretation of data.
- Automated reports giving detailed descriptive statistics.
- Understanding data and fitting suitable distribution.
- Testing of hypothesis, p-value and confidence interval.

- Random number generation and sampling procedures.
- Importing data, Code editing in R and flow controls if (), for (), while ()

## SYLLABUS OF GE 4B

**Theory**

**UNIT I** **(07 hours)**

**Overview of the R language**

Installing R and R studio; working on R studio, scripts and text editors, creating and saving R workspaces, installing packages and loading libraries.

Data types in R (Numeric, Integer, Character, Logical, and Complex) Data structures in R (Vector, Matrix, Data frames, List). Mathematical operators, Relational Operators, and Logical operators and use of functions: class(), names(), head(), tail(),rbind(), cbind(), rownames(), colnames() etc. Learn how to load data, importing a data file viz. .xlsx. handling missing data in R

**UNIT II** **(10 hours)**

**Descriptive statistics and Graphs**

Generate automated reports giving detailed descriptive statistics mean, median, mode, variance, skewness, five-point summary , frequency table. Statistical/mathematical functions, scan(), summary(),str(), table(), cut(),cumsum(), cumprod()etc.

Graphical representation of data: bar-plot, pie-chart, boxplot, frequency polygon, ogives , scatter plot, Fitting of curve lm(): linear, quadratic, exponential functions, correlation, and linear and multiple regression with the interpretation of results.

**UNIT III** **(10 hours)**

**Decision-making and distributions**

Introduction to flow control: if, if-else, while, and for loops, simple coding. Distribution functions(r,d,p,q) for Binomial, Poisson, Exponential, and Normal . Data distribution: qqplot(), qqnorm()

**UNIT IV** **(08 hours)**

**Testing of Hypothesis and Time series**

Basics of statistical inference in order to understand hypothesis testing, and compute p-values and confidence intervals. Applications on t-test, F-test, and Chi-square test with the interpretation of results. Time series analysis, components of a time series data, time series model, ts(), decomposition(), and smoothing with the interpretation of results.

**PRACTICAL/LAB WORK – 30 Hours**

**List of Practical / Lab Work**:

1. Graphical representation of data with bar-plot, pie-chart, and boxplot.
2. Histogram with equal and unequal class intervals, frequency polygon
3. Less than and more than Ogives.
4. Fitting of curve linear, quadratic, exponential functions,
5. Scatter plots, correlation
6. Linear and multiple regression

7. Drawing sample using SRSWR, SRSWOR
8. Drawing sample using stratified under proportion allocation and systematic sampling,
9. functions(r,d,p,q) for discrete distributions viz. Binomial, Poisson.
10. functions(r,d,p,q) for continuous distribution viz. Uniform,Exponential, and Normal .
11. Test the goodness of fit for Binomial, Poisson distribution.
12. Chi- Square test for independence of attributes.
13. Single, paired and independent samples t-test.
14. Components of a time series data.
15. decomposition(), and smoothing() under time series data

**ESSENTIAL READINGS:**


- Braun, W. J., and Murdoch, D. J. (2007). A First Course in Statistical Programming with R. Cambridge University Press. New York.
- Gardener, M. (2012). Beginning R: The Statistical Programming Language, Wiley Publications.


**SUGGESTIVE READING:**


- Crawley, M. J. (2012). The R Book. 2nd Ed., John Wiley & Sons.
- Dalgaard, P. (2008). Introductory Statistics with R. 2nd Ed., Springer.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

# Semester 5

# DEPARTMENT OF STATISTICS

# B. Sc. (H) Statistics

## Category I

**DISCIPLINE SPECIFIC CORE COURSE – 13: THEORY OF ESTIMATION**

**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Theory of Estimation | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | Basic knowledge of probability, probability distributions and sampling distributions |

### Learning Objectives

The learning objectives include:

- Characterisation of the population based on sample information
- Understanding process of learning and determining the population characteristics based the available data.
- Strength and weakness of various methods for obtaining point and interval estimators with respect to optimal/desirable properties.

### Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- List desirable properties of point estimators based on an unknown parameter of a distribution viz. Unbiasedness, Consistency, Efficiency and Sufficiency.
- Derive the UMVUE of a parameter or function of a parameter (Using Cramer- Rao inequality, Rao-Blackwell theorem, and Lehmann- Scheffé Theorem).
- Understand and apply different techniques of finding optimal point estimators such as Maximum Likelihood Estimation, Method of Least Squares, Method of moments and the method of minimum chi-Squares

- Construct interval estimators, pivot method (Confidence Intervals) for unknown population parameters.

## SYLLABUS OF DSC-13

**Theory**

**UNIT I** **(18 hours)**

**Estimation**

Estimation: Concepts of estimation, unbiasedness, sufficiency, consistency and efficiency. Fisher-Neyman Criterion (statement and applications), Factorization theorem. Complete statistic, Minimum variance unbiased estimator (MVUE), Rao-Blackwell and Lehmann-Scheffe theorems and their applications. Cramer-Rao inequality, Minimum Variance Bound estimators (MVBE) and their applications.

**UNIT II** **(10 hours)**

**Methods of Estimations**

Methods of Estimation: Method of moments, method of maximum likelihood estimation and method of minimum Chi-square.

**UNIT III** **(12 hours)**

**Interval estimation**

Interval estimation - Confidence intervals for parameters of various distributions, confidence interval for Binomial proportion, confidence interval for population correlation coefficient for Bivariate Normal distribution, pivotal quantity method of constructing confidence intervals, shortest length confidence intervals, large sample confidence intervals.

**UNIT IV** **(5 hours)**

**Censored Data**

Failure censored samples, time censored sample, estimation of expected lifetime in failure censored samples for one parameter exponential lifetime distribution

**PRACTICAL/LABWORK (30 hours):**

**List of Practical**

1. Unbiased estimators (including unbiased but absurd estimators)
2. Consistent estimators, efficient estimators and relative efficiency of estimators.
3. Cramer-Rao inequality and MVB estimators
4. Sufficient Estimators – Factorization Theorem, Complete Sufficient estimators, Rao-Blackwell theorem.
5. Lehman-Scheffe theorem and UMVUE
6. Maximum Likelihood Estimation
7. Asymptotic distribution of maximum likelihood estimators
8. Estimation by the method of moments,
9. Estimation by method of minimum Chi-square
10. Confidence interval based on large sample test
11. Confidence interval based on exact sample test

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Gun, A.M.; Gupta, M.K.; Dasgupta, B. (2013).: An Out Line of Statistical Theory, Volume 2, The World Press, Kolkata.
- Gupta, S.C. and Kapoor, V.K.(2020): Fundamental of Mathematical Statistics, 12th Edn. Sultan Chand and Sons.
- Sinha, S.K. (1986):Reliability and Life testing; Wiley Eastern.


**SUGGESTIVE READINGS:**


- Hogg, R.V. and Craig, A.T (2018): Introduction to Mathematical Statistics, 8th Edn. Pearson Education.
- Casella, G. and Berger, R.L. (2002): Statistical Inference. 2nd Edition, Duxbury Press, Pacific Grove.
- Hogg, R.V. and Tanis, E.A. (1988): Probability and statistical Inference, 6th Edn. Pearson Education
- Rohatgi V.K, (2013): Statistical Inference- Dover Publication, New York.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC CORE COURSE-14: LINEAR MODELS

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title & code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lectures | tutorials | practical | | |
| Linear Models | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | Basic knowledge of matrix theory, probability distributions and sampling distributions |

### Learning Objectives:

learning objectives include:

- Developing a clear understanding of the fundamental concepts of linear models.
- Developing associated skills allowing the students to work effectively with them.

### Learning Outcomes:

After completion of this course, students will develop a clear understanding of:

- Theory and estimation of Linear Models.
- Gauss-Markov Theorem and its use.
- Distribution of quadratic forms.
- Simple and Multiple linear regression models and their applications.

- Fitting of these models to real or synthetic data, derivation of confidence and prediction intervals, and a sound scientific interpretation of the results.
- Techniques of Analysis of Variance and Covariance under fixed effects model.
- Assessment of the quality of the fit using classical diagnostics, awareness of potential problems (outliers, etc.) and application of remedies to deal with them.

## SYLLABUS OF DSC-14

**THEORY**

**UNIT I** **(10 Hours)**

**Estimation theory and Distribution of Quadratic forms**

Gauss-Markov setup, Theory of linear estimation, Estimability of linear parametric functions, Method of least squares, Gauss-Markov theorem, Estimation of error variance. Cochran's theorem and distribution of quadratic forms.

**UNIT II** **(10 Hours)**

**Analysis of Variance**

Definition of fixed, random, and mixed effect models, Technique of ANOVA, assumptions for its validity, analysis of variance in one-way classified data and in two-way classified data with an equal number of observations per cell for fixed effect models.

**UNIT III** **(14 Hours)**

**Regression analysis:**

Estimation and hypothesis testing in case of simple and multiple linear regression analysis, Confidence intervals, and Prediction intervals, Concept of model matrix and its use in estimation. Effect of orthogonal columns in the X matrix, Partial F-test and Sequential F-test, Bias in regression estimates.

**UNIT IV** **(4 Hours)**

**Analysis of Covariance:**

Technique of ANOCOVA, assumptions for its validity, use, and analysis of covariance in one-way classified data with a single concomitant variable.

**UNIT V** **(7 Hours)**

**Model checking and Model Building**

Prediction from a fitted model, Residuals and Outliers, Lack of fit and pure error, Violation of usual assumptions concerning normality, Homoscedasticity, and collinearity, Diagnostics using quantile-quantile plots. Techniques for Variable selection. Polynomial Regression models: Orthogonal Polynomials.

**PRACTICAL/LABWORK -30 Hours**

**List of Practicals**

1. Estimability when X is a full rank matrix.
2. Estimability when X is not a full rank matrix.
3. Distribution of Quadratic forms.
4. Simple Linear Regression.
5. Multiple Regression.
6. Tests for Linear Hypothesis.
7. Bias in regression estimates.
8. Lack of fit.
9. Stepwise regression procedure.

10. Analysis of Variance of a one-way classified data.
11. Analysis of Variance of two-way classified data with one observation per cell.
12. Analysis of Variance of two-way classified data with m (> 1) observations per cell.
13. Analysis of Covariance of a one-way classified data.
14. Residual Analysis.
15. Orthogonal Polynomials.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**


- Montgomery, D. C., Peck, E. A. and Vining, G. G. (2012): Introduction to Linear Regression Analysis, 5th Ed., John Wiley and Sons.
- Rencher, A. C. and Schaalje, G. B. (2008): Linear Models in Statistics, 2nd Ed., John Wiley and Sons.
- Draper, N. R. and Smith, H. (1998): Applied Regression Analysis, 3rd Ed., John Wiley and Sons.


**SUGGESTIVE READINGS:**


- Weisberg, S. (2005): Applied Linear Regression, 3rd Ed., John Wiley and Sons.
- Rawlings, John O. Pantula Sastry G. Dickey, David A. (1998) Applied Regression Analysis: A Research Tool, Second Edition
- Bapat, R.B.(1993): Linear Algebra and Linear Models, Hindustan Book Agency.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC CORE COURSE 15 –: STOCHASTIC PROCESSES

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| **Stochastic Processes** | 4 | 3 | 0 | 1 | Class XII pass with Mathematics. | Knowledge of probability, probability distributions, and sampling distributions |

**Learning Objectives:**

- To define, design and model

- To analyze transitions through Markov chains
- To identify the real life applications of stochastic processes

**Learning Outcomes:**

After completing this course, students will develop a clear understanding of:

- The fundamental concepts of stochastic processes.
- Tools needed to analyze stochastic processes.
- Markov processes and Markov chains.
- Markov chain applications.
- Poisson process and its variations.
- Random walk and ruin theory

## SYLLABUS OF DSC-15

**Theory**

**UNIT I** **(13 hours)**

**Introduction of Stochastic Process**

Probability Distributions: Generating functions, Bivariate probability generating functions, and their application.

Stochastic Process: Introduction, Covariance stationary, and Stationary Process.

**UNIT II** **(15 hours)**

**Markov Chains**

Markov Chains: Definition of Markov Chain, transition probability matrix, order of Markov chain, Markov chain as graphs, higher transition probabilities.

Classification of states and chains, stationary process, and stability of Markov system. Generalization of independent Bernoulli trials,

**UNIT III** **(12 hours)**

**Poisson Process**

Poisson Process: postulates of Poisson process, and properties of Poisson process and applications.

Gambler's Ruin Problem: Classical ruin problem, expected duration of the game.

**PRACTICAL/LAB WORK – (30 hours)**

**List of Practical:**

1. Applications of Partial Fraction Theorem.
2. Problems based on (covariance) stationary processes.
3. Simulation of Markov chains.
4. Calculation of transition probability matrices.
5. To check whether the given chain is irreducible or not.
6. Classification of states.
7. Computation of probabilities in case of generalizations of independent Bernoulli trials.
8. Simulation and applications of Poisson processes.
9. Transition Markov chain in case of gambler's ruin problem .
10. Calculation of probabilities for ruin problems.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**


- Feller, W. (1968). Introduction to probability Theory and Its Applications, Vol I, 3rd Ed., Wiley International.
- Medhi, J. (2019). Stochastic Processes,4th Ed., Reprint, New Age International Publishers.


**SUGGESTIVE READINGS:**


- Sheldon M. Ross (2007) : Introduction to Probability Models, 9th edition, Academic Press publications
- Karlin & Taylor (1975) : A first course in stochastic processes, 2nd edition, Academic Press publications
- Basu, A.K. (2005). Introduction to Stochastic Processes, Narosa Publishing.
- P. G. Hoel, S. C. Port and C. J. Stone: Introduction to Stochastic Processes.
- J. G. Kemeny, J. L. Snell and A. W. Knapp: Finite Markov Chains.
- Geoffrey R, Grimmett & David R. Stirzaker : Probability and Random Processes
- Bhat,B.R. (2000). Stochastic Models: Analysis and Applications, New Age International Publishers.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

# B.Sc. (P)/B.A(P) with Statistics as Major

## Category II

**DISCIPLINE SPECIFIC CORE COURSE - 9: INTRODUCTION TO DESIGN OF EXPERIMENTS**

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Introduction to Design of Experiments | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of inferential statistics, and ANOVA |

**Learning Objectives:**

The learning objectives include

- To design and conduct experiments.
- To analyze and interpret data.

**Learning Outcomes:**

After completing this course, students will developed a clear understanding of

- The fundamental concepts of Design of Experiments.
- Introduction to planning valid and economical experiments.
- Completely randomized design.
- Randomized block design.
- Latin square design.
- Balanced incomplete block design.
- Full and confounded factorial designs with two levels.
- Fractional factorial designs with two levels.

### SYLLABUS OF DSC-9

**Theory**

**UNIT I** **(15 hours)**

**Experimental designs**

Experimental designs: Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks. Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) - layout, model and statistical analysis, relative efficiency.

**UNIT II** **(09 hours)**

**Balanced Incomplete Block Designs**

Balanced Incomplete Block Design (BIBD)- parameters, relationships among its parameters, incidence matrix and its properties, Symmetric BIBD, Resolvable BIBD, Affine Resolvable BIBD.

**UNIT III** **(15 hours)**

**Factorial experiments**

Factorial experiments**:** Concepts, notations and advantages, $2^2$, $2^3 \ldots 2^n$ factorial experiments, design and analysis, Total and Partial confounding for $2^n$ ($n \leq 5$). Factorial experiments in a single replicate.

**UNIT IV** **(06 hours)**

**Fractional factorial experiments**

Fractional factorial experiments**:** Construction of one-half and one-quarter fractions of $2^n$ ($n \leq 5$) factorial experiments, Alias structure, Resolution of a design.

**PRACTICAL/LAB WORK – (30 hours)**
**List of Practical:**

1. Analysis of CRD, RBD & LSD.
2. Analysis of $2^2$ and $2^3$ factorial experiments in CRD and RBD.
3. Analysis of a completely confounded two level factorial designs in 2 and 4 blocks.
4. Analysis of a partially confounded two level factorial design.
5. Analysis of a single replicate of a $2^n$ design.
6. Analysis of one-half and one-quarter fractions of $2^n$ factorial design.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**


- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics, Vol. II, 8thEd. World Press, Kolkata.
- Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley.
- Das., M.N. and Giri, N.C. (1986): Design and Analysis of Experiments, Wiley Eastern.
- Mukhopadhyay, P (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied (P) Ltd.


**SUGGESTIVE READINGS**


- Cochran, W.G. and Cox, G.M. (1959): Experimental Design, Asia Publishing House.
- Kempthorne, O. (1965): The Design and Analysis of Experiments, John Wiley.
- Joshi, D.D. (1987): Linear Estimation and Design of Experiments, John Wiley & Sons.
- Dey, Aloke (1986): Theory of Block Designs, Wiley Eastern Ltd.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC CORE COURSE– 10: STATISTICAL SIMULATION

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Statistical Simulation | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of basic statistics |

### Learning Objectives

The learning objectives include:

- Concept of simulation and simulation modelling.
- Generation of Pseudo random number generators as well as from standard statistical distributions. Monte-Carlo simulation technique.
- Application of simulation techniques.

### Learning Outcomes

After completing this course, students will possess skills concerning:

- How simulation may be used to understand the behavior of real world systems by utilizing mathematical models with an emphasis on simulation.
- How to generate random numbers by the different methods.
- Hands-on experience in using simulation software packages/structured programming languages.

### SYLLABUS OF DSC- 10

**Theory**

**UNIT I** **(12 Hours)**

**Introduction to simulation:**

Introduction, Definitions of simulation, Need for simulation, general principles, types of simulation, Simulation models, Phases in simulation models, Event type simulation, Monte Carlo simulation technique.

**UNIT II** **(18 Hours)**

**Random numbers generation:**

Methods for the generation of Random numbers, Pseudo random number generators, Mid square method for the generation of random number and its limitations, the inverse transform method; Generating the Discrete and Continuous random variables.

**UNIT III** **(15 Hours)**

**Applications of simulation:**

Applications of simulation in different fields of study, simulation of Inventory problems and simulation of Queueing problems. Advantages and disadvantages of simulation, Simulation languages, Scope of simulation techniques.

**Practical/Lab Work – (30 hours)**

**List of Practical:**

1. Pseudo random number generators;
2. Generation of U(0,1).
3. Generation using the inverse transform method applied to:
   (a) Discrete distribution and
   (b) Continuous distribution.
4. Monte Carlo simulation method and applications.
5. Problems based on Queueing systems.
6. Problems based on Inventory Controls, etc.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READING:**


- Sheldon M. Ross (2022) Simulation, Sixth Edition, Elsevier Academic press publication.
- Taha, H. A. (2010). Operations Research. An Introduction, 9th Ed, Pearson.
- Swarup, K. Gupta, P.K. and Mohan, M. (2019). Operations Research, 15th Ed, Sultan Chand & Sons.


**SUGGESTED READINGS:**


- Voss, J. (2013). An introduction to statistical computing: A simulation-based approach, 1st Ed., Wiley series in computational statistics.
- Sharma, J. K. (2017). Operations Research: Theory and applications, 6th Edition, Trinity Press.
- Payer T.A. (1982). Introduction to simulation, McGraw Hill.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

# B.Sc. (P)/B.A(P) with Statistics as Non- Major

## Category III

**DISCIPLINE SPECIFIC CORE COURSE - 5: INTRODUCTION TO DESIGN OF EXPERIMENTS**

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Introduction to Design of Experiments | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of inferential statistics, and ANOVA |

**Learning Objectives:**

The learning objectives include

- To design and conduct experiments.
- To analyze and interpret data.

**Learning Outcomes:**

After completing this course, students will develop a clear understanding of

- The fundamental concepts of Design of Experiments.
- Introduction to planning valid and economical experiments.
- Completely randomized design.
- Randomized block design.
- Latin square design.
- Balanced incomplete block design.
- Full and confounded factorial designs with two levels.
- Fractional factorial designs with two levels.

### SYLLABUS OF DSC-5

**Theory**

**UNIT I** **(15 hours)**

**Experimental designs**

Experimental designs: Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks. Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) - layout, model and statistical analysis, relative efficiency.

**UNIT II** **(09 hours)**

**Balanced Incomplete Block Designs**

Balanced Incomplete Block Design (BIBD)- parameters, relationships among its parameters, incidence matrix and its properties, Symmetric BIBD, Resolvable BIBD, Affine Resolvable BIBD.

**UNIT III** **(15 hours)**

**Factorial experiments**

Factorial experiments**:** Concepts, notations and advantages, $2^2$, $2^3 \ldots 2^n$ factorial experiments, design and analysis, Total and Partial confounding for $2^n$ ($n \leq 5$). Factorial experiments in a single replicate.

**UNIT IV** **(06 hours)**

**Fractional factorial experiments**

Fractional factorial experiments**:** Construction of one-half and one-quarter fractions of $2^n$ ($n \leq 5$) factorial experiments, Alias structure, Resolution of a design.

**PRACTICAL/LAB WORK – (30 hours)**
**List of Practical:**

1. Analysis of CRD, RBD & LSD.
2. Analysis of $2^2$ and $2^3$ factorial experiments in CRD and RBD.
3. Analysis of a completely confounded two level factorial designs in 2 and 4 blocks.
4. Analysis of a partially confounded two level factorial design.
5. Analysis of a single replicate of a $2^n$ design.
6. Analysis of one-half and one-quarter fractions of $2^n$ factorial design.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**


- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics, Vol. II, 8thEd. World Press, Kolkata.
- Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley.
- Das., M.N. and Giri, N.C. (1986): Design and Analysis of Experiments, Wiley Eastern.
- Mukhopadhyay, P (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied (P) Ltd.


**SUGGESTIVE READINGS**


- Cochran, W.G. and Cox, G.M. (1959): Experimental Design, Asia Publishing House.
- Kempthorne, O. (1965): The Design and Analysis of Experiments, John Wiley.
- Joshi, D.D. (1987): Linear Estimation and Design of Experiments, John Wiley & Sons.
- Dey, Aloke (1986): Theory of Block Designs, Wiley Eastern Ltd.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

# Discipline Specific Elective
## Category-V

**DISCIPLINE SPECIFIC ELECTIVE COURSE – 3A: ACTUARIAL STATISTICS**

**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Actuarial Statistics | 4 | **3** | 0 | 1 | Class XII pass with Mathematics | ---- |

**Learning Objectives**

The learning objectives include:

· To learn basics of Actuarial Science.

· To learn advanced techniques in Actuarial Science with practical applications in daily life.

**Learning Outcomes:**

After completing this course, students will develop a clear understanding of:

· Basics of Actuarial Science.

· Tools for applying actuarial methods in phenomena for financial research and insurance.

· computation of premiums and settlement of claims

**SYLLABUS OF DSE-3A**

**Theory**

**UNIT I** **(9 Hours)**

**Introductory Statistics and Insurance Applications**

Introductory Statistics and Insurance Applications: Discrete, continuous and mixed probability distributions. Insurance applications, sum of random variables. Utility theory: Utility functions, expected utility criterion, types of utility function, insurance and utility theory.

**UNIT II** **(12 Hours)**

**Principles of Premium Calculation**

Principles of Premium Calculation**:** Properties of premium principles, examples of premium principles. Individual risk models: models for individual claims, the sum of independent claims, approximations and their applications.

**UNIT III** **(6 Hours)**

**Survival Distribution and Life Tables:**

Survival Distribution and Life Tables: Uncertainty of age at death, survival function, time-until-death for a person, curate future lifetime, force of mortality, life tables with examples, deterministic survivorship group, life table characteristics

**UNIT IV** **(15 Hours)**

**Life Insurance**
Life Insurance: Models for insurance payable at the moment of death, insurance payable at the end of the year of death and their relationships. Life annuities: continuous life annuities, discrete life annuities. Premiums: continuous and discrete premiums.

**PRACTICAL/LAB WORK – (30 hours)**
**List of Practical:**
1. Risk computation for different utility models.
2. Discrete and continuous risk calculations.
3. Calculation of aggregate claims for collective risks.
4. Calculation of aggregate claim for individual risks.
5. Computing Ruin probabilities and aggregate losses.
6. Annuity and present value of contract.
7. Computing premium for different insurance schemes.
8. Practical based on life models and tables.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**


- Dickson, C. M. D. (2005): Insurance Risk And Ruin (International Series On Actuarial Science), Cambridge University Press. Bowers, N. L., Gerber, H. U., Hickman,
- Atkinson, M.E. and Dickson, D.C.M. (2011): An Introduction to Actuarial Studies, Elgar Publishing.


**SUGGESTIVE READINGS**


- J. C., Jones, D. A. And Nesbitt, C. J. (1997): .Actuarial Mathematics, Society Of Actuaries, Itasca, Illinois, U.S.A.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC ELECTIVE COURSE– 3B: SIMULATION TECHNIQUES IN STATISTICS (Not for category II)

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Simulation Techniques in Statistics | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of basic statistics |

## Learning Objectives

The learning objectives include:

- The objective of this course is to introduce the nuances of techniques involved in simulation studies as applicable to modeling of systems.
- The programming implementations will be completed using C/MATLAB/R/Python.

## Learning Outcomes

After completing this course, students will possess skills concerning:

- Use of simulation to understand the behavior of real world systems.
- Ability to generate Pseudo-random numbers by the different methods.
- Random variable generation from theoretical distributions.
- Use of Monte Carlo methods and regenerative simulation.
- Ability to develop programs for the purpose of simulation.

## SYLLABUS OF DSE- 6d

**Theory**

**UNIT I** **(12 Hours)**

**Introduction to simulation**

Introduction, Systems, Simulation models, Classification of simulation models; Simulation and Monte Carlo Methods, Pseudo-random number generators; Statistical tests of Pseudo-random numbers.

**UNIT II** **(18 Hours)**

**Generation of random numbers**

Random number generation. Random variable generation- Inverse transform method, Composition method, Acceptance-Rejection method. Generating from common statistical distributions- Discrete and Continuous. Simulation of random vectors, Generating Poisson processes and Markov chain.

**UNIT III** **(15 Hours)**

**Applications of simulation**

Discrete event simulation; Monte Carlo integration; Variance reduction techniques; Applications to statistical inference; Point Estimators, Confidence Intervals and hypothesis tests.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**PRACTICAL/ LAB WORK – (30 hours)**

**List of Practical:**

1. Pseudo random number generators.
2. Generation of U (0, 1).
3. Problems based on statistical tests.
4. Application to standard statistical distributions (discrete and continuous):
   (a) The inverse transforms method.

(b) Acceptance-Rejection method.

5. Problems based on Composition Method.
6. Problems based on Monte Carlo integration.
7. Problems based on Regenerative methods.

**ESSENTIAL READINGS:**


- Rubinstein, R.Y. (2017). Simulation and the Monte Carlo Methods, Wiley.
- Voss, J. (2014). An introduction to statistical computing: a simulation-based approach, Wiley series in computational statistics.
- Sheldon M. Ross (2022) Simulation, Sixth Edition, Elsevier Academic press publication.
- Averill M. Law and W. David Kelton (1991). Simulation modeling and analysis: McGraw-Hill, Inc., New York.


**SUGGESTED READINGS:**


- Reitman, J. (1971). Computer simulation Applications, John Wiley & Sons.
- Swarup, K. Gupta, P.K. and Mohan, M. (2014). Operations Research, 15th Ed, Sultan Chand & Sons.
- Fishman, G.S. (1996). Monte Carlo-Concepts, Algorithms and Applications, Springer.
- Sheskin, D. J. (2011). Handbook of parametric and nonparametric statistical procedures, CRC Press. Boca Raton, FL.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE-SPECIFIC ELECTIVE COURSE–3C: ENVIRONMENTAL STATISTICS

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Environmental Statistics | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of sampling distributions and linear models |

**Learning Objectives**

The learning objectives include:

· To study the role of Statistics in Environmental Science.

· To study different Statistical distributions, sampling procedures, linear models and analysis of variance.
- To study environmental monitoring.
- To study time-series analysis and Spatial-data analysis.
- To learn about censored data and risk assessment.

**Learning Outcomes:**

After completing this course, students will develop a clear understanding of:

- The role of Statistics in Environmental Science.
- Uses and applications of different Statistical distributions, sampling procedures, linear models and analysis of variance.
- Environmental monitoring.
- Time-series analysis and Spatial-data analysis.
- Censored data and risk assessment.
- They will be able to do risk analysis using spreadsheet.

## SYLLABUS OF DSE – 3C

**Theory**

**UNIT I: ( 9 hours)**

**Introduction**

The Role of Statistics in Environmental Science: Introduction, Examples, Base-line, Targeted, Regular monitoring, Role of Statistics in Environmental Science. Environmental Sampling: Introduction, Sampling Procedures, Sampling in the wild.

**UNIT II: (9 hours)**

**Models for Data and Environmental Monitoring**

Models for Data: Statistical models, Discrete statistical distribution, Continuous statistical distributions, Linear Models, ANOVA. Environmental Monitoring: Detection of changes by ANOVA, Detection of changes using control chart, Chi squared tests for a change in a distribution.

**UNIT III: (9 hours)**

**Time Series and Spatial-Data Analysis**

Introduction to Time Series Analysis, Components of Time Series, Serial correlation. Introduction to Spatial-Data Analysis, Types of spatial data, Spatial Patterns in quadrat counts, and Correlation between quadrat counts.

**UNIT IV: (9 hours)**

**Censored Data and Risk Assessment:**

Introduction to Censored Data, Single sample estimation, Types of censoring. Introduction to Risk Assessment, Principles for Monte Carlo Risk Assessment, Risk Analysis using spreadsheet.

**PRACTICAL/LAB WORK - ( 30 HOURS)**

**List of Practical:**

1. Collection of environmental data.

2. Fitting different discrete distributions. Case: Estimate the survival rates of salmon in rivers and continuous distributions,
3. Fitting regression model (simple and multiple), Case: Chlorophyll-a in lakes/rivers as an indicator of lake/river water quality, Soil, and Vegetation data.
4. Change detection in the environment using ANOVA, Control Charts, Hypotheses testing- Case: pH values, $SO_4$ concentrations etc in lakes/rivers, Annual ring widths in trees,
5. Time series analysis- Case: World Temperature data, Annual sunspot data, Rainfall data, or on any environmental issues.
6. Serial correlation- Case: Northern and Southern Hemisphere temperatures
7. Single sample estimation,
8. Correlation between quadrats counts- Case: Correlation between counts for two different species in a water body.
9. Analysis of censored environmental data,
10. Risk analysis- Case: Contaminant uptake in Tap-water

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Bryan F. J. Manly (2009): Statistics for Environmental Science and Management, 2nd Edition, Chapman and Hall.
- Barnett, Vic (2006): Environmental Statistics: Methods and Applications, Reprinted 2004, Wiley.


**SUGGESTED READINGS:**


- Milalrd, Steben P. and Neeranchal, Nagaraj K (2000): Environmental Statistics with S-plus, CRC Press.
- Gelfand Alan E. (2019): Handbook of Environmental and Ecological Statistics, Chapman and Hall, CRC Press.
- David Valerie (2019): Statistics in Environmental Sciences, Wiley.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

**DISCIPLINE SPECIFIC ELECTIVE COURSE – 3d: REGRESSION ANALYSIS (Not for category I)**

## CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Regression Analysis | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of sampling distributions and matrix theory |

### Learning Objectives

The learning objectives include:

- Be able to carry out and interpret Correlation Analysis
- Be able to carry out and interpret inference procedures for simple linear regression.
- Know the simple and multiple linear regression models, and be able to state and explain the standard methods of estimation for these models.

### Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- Basic concept of matrix, its types and operations,
- correlation and regression techniques, the two very powerful tools in statistics,
- Linear and Multiple Linear regression,
- regression diagnostics, multicollinearity, residual plots and estimation and tests for regression coefficients.
- concept of coefficient of determination and inference on partial and multiple correlation coefficients.

### SYLLABUS OF DSE-3d

**Theory**

**UNIT I** **(15 hours)**

**Introduction**

Correlation, Types of correlation, Methods of studying simple correlation - Scatter diagram, Covariance between two variables: Definition, computation, effect of change of origin and scale, Karl Pearson's coefficient of correlation, Spearman's Rank correlation coefficient.

**UNIT II** **(15 hours)**

**Linear Regression**

Linear Regression: Meaning of regression, difference between correlation and regression, simple linear regression model, Estimation of regression parameters by least squares method (fitting of regression

model), Interpretation of parameters. Test of significance of regression and confidence interval, Concept of residual, Residual plots, comparison of two models on the basis of residual sum of squares.

**UNIT III** **(15 hours)**

**Multiple Linear Regression**

Multiple linear regression: Estimation of regression parameters by least square method and their properties, Interpretation of parameters. Concept of coefficient of determination $R^2$ and adj $R^2$. Testing of hypothesis and bias in regression estimates.

**PRACTICAL/LAB WORK – (30 hours)**

**List of Practical:**

1. Computation of covariance, coefficient of correlation, checking for independence and uncorrelatedness of two variables.
2. Lines of regression, angle between lines and estimation of parameters.
3. Lines of regression and regression coefficients.
4. Spearman rank correlation with/without ties.
5. Fitting of simple linear regression model
6. Testing of hypothesis in SLRM
7. Fitting of multiple linear regression model
8. Testing of hypothesis in MLRM
9. Bias in regression parameters

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**


- Draper, N. R. and Smith, H. (1998). Applied Regression Analysis. 3rdEdition. John Wiley.
- Montgomery, D. C., Peck, E. A. and Vining, G. G. (2013). Introduction to Linear Regression Analysis. 5th Edition. Wiley.


**SUGGESTIVE READINGS:**


- Hosmer, D. W., Lemeshow, S. and Sturdivant R.X. (2013). Applied Logistic Regression, Wiley Blackwell.
- Neter, J., Kutner, M. H., Nachtsheim, C.J. and Wasserman, W. (1996). Applied Linear Statistical Models, 4th Edition, Irwin USA.
- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2005). An Outline of Statistical Theory, Volume II, World Press.
- Arora, S. and Bansi, L. (1968). New Mathematical Statistics, 1st Ed., Vanita Printers.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

**COMMON POOL OF GENERIC ELECTIVES (GE) COURSES**
**OFFERED BY DEPARTMENT OF STATISTICS**
**CATEGORY-VI**

## GENERIC ELECTIVE -5A: INTRODUCTION TO STATISTICAL LINEAR MODELS

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title & code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lectures | tutorials | practical | | |
| Introduction to Statistical Linear Models | **4** | **3** | **0** | **1** | Class XII pass with Mathematics | knowledge of sampling distributions and matrix theory |

**Learning Objectives:**
learning objectives include:

- Developing a clear understanding of the fundamental concepts of linear models.
- Developing associated skills allowing the students to work effectively with them.

**Learning Outcomes:**
After completion of this course, students will have developed a clear understanding of:

- Theory and estimation of Linear Models.
- Gauss-Markov Theorem and its use.
- Distribution of quadratic forms.
- Simple and Multiple linear regression models and their applications.
- Fitting of these models to real or synthetic data, derivation of confidence and prediction intervals, and a sound scientific interpretation of the results.
- Techniques of Analysis of Variance under fixed effects model.
- Assessment of the quality of the fit using classical diagnostics,

### SYLLABUS OF GE-5A
**THEORY**

**UNIT I:** **(12 hours)**

**Introduction:**

Statistical linear models and their classification, Estimability of linear parametric functions, Gauss-Markov set-up, Normal equations, and Gauss-Markov theorem: full rank case and non-full rank case (without proof).

**UNIT II:** **(8 hours)**

**Distribution of Quadratic Forms:**

Cochran's theorem (without proof), Necessary and sufficient conditions for the mutual independence of quadratic forms and for the mutual independence of a linear function and a quadratic form.

**UNIT III:** **(13 hours)**

**Regression Analysis:**

Simple and Multiple linear regression: Estimation and testing of hypothesis, confidence interval, bias in regression estimates, Lack of fit and pure error, Residuals, and their plot. Techniques for Variable selection. Polynomial Regression models: Orthogonal Polynomials.

**UNIT IV:** **(12 hours)**

**Analysis of Variance (ANOVA):**

The technique of ANOVA for one-way and two-way classifications with an equal number of observations per cell under a fixed effects model.

**PRACTICAL/LABWORK -30 Hours**

**List of Practicals**

1. Estimability when X is a full rank matrix
2. Estimability when X is not a full rank matrix
3. Distribution of Quadratic forms
4. Simple Linear Regression
5. Multiple Regression
6. Tests for Linear Hypothesis
7. Bias in regression estimates
8. Lack of fit
9. Orthogonal Polynomials
10. Analysis of Variance of a one-way classified data.
11. Analysis of Variance of a two-way classified data with one observation per cell.
12. Analysis of Variance of two-way classified data with m (> 1) observations per cell.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**


- Montgomery, D. C., Peck, E. A. and Vining, G. G. (2012): Introduction to Linear Regression Analysis, 5th Ed., John Wiley and Sons.
- Rencher, A. C. and Schaalje, G. B. (2008): Linear Models in Statistics, 2nd Ed., John Wiley and Sons.
- Draper, N. R. and Smith, H. (1998): Applied Regression Analysis, 3rd Ed., John Wiley and Sons.

**SUGGESTIVE READINGS:**


- Weisberg, S. (2005): Applied Linear Regression, 3rd Ed., John Wiley and Sons.
- Rawlings, John O. Pantula Sastry G. Dickey, David A. (1998) Applied Regression Analysis: A Research Tool, Second Edition
- Bapat, R.B.(1993): Linear Algebra and Linear Models, Hindustan Book Agency.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## GENERIC ELECTIVE – 5b: STATSTICAL TECHNIQUES FOR QUALITY CONTROL

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Statistical Techniques for Quality Control | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of basic statistics |

### Learning Objectives

The learning objectives include:

- This course will help students to learn techniques and approach of SQC being used in industry to manufacture goods and services of high quality at low cost.
- This course will also give exposure to Sampling Inspection Plan.

### Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- Quality, Historical background, ISO standards.
- Statistical process control tools- Control charts for variables, attributes.
- Statistical product control tools- Sampling inspection plans, Dodge and Romig plans.

### SYLLABUS OF GE-5b

**Theory**

**UNIT I** **(10 hours)**

**Introduction, historical perspective and ISO Quality Standards**

Quality: Definition, dimensions of quality, its concept, application and importance. Brief historical perspective of quality control and improvements. Quality system and standards: Introduction to ISO quality standards. Introduction to Process and Product Control, Statistical Process Control, Chance and Assignable causes of variation.

**UNIT II** **(20 hours)**

**Statistical Control Charts**

Construction and Statistical basis of 3-σ Control charts. Control charts for variables: X-bar & R-chart, X-bar & s-chart. Rational Sub-grouping, Revised and Modified Control Limits. Control charts for attributes: np-chart, p-chart, c-chart and u-chart. Comparison between control charts for variables and control charts for attributes. Analysis of patterns on control chart, estimation of process capability.

**UNIT III** **(15 hours)**

**Acceptance sampling plan**

Principle of acceptance sampling plans. Single sampling plans their OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, use and interpretation of Dodge and Romig's sampling inspection plan tables.

**PRACTICAL/LAB WORK – (30 hours)**

**List of Practical:**

1. Construction and interpretation of statistical control charts $\bar{X}$& R-chart for known parameters.
2. Construction and interpretation of statistical control charts $\bar{X}$ & R-chart with revised control limits for unknown parameters.
3. Construction and interpretation of statistical control charts $\bar{X}$ & s-chart with revised control limits for unknown parameters.
4. Construction and interpretation of statistical control charts np chart.
5. Construction and interpretation of statistical control charts p-chart with fixed sample size.
6. Construction and interpretation of statistical control charts p-chart with variable sample size.
7. Construction and interpretation of statistical control charts c-chart.
8. Construction and interpretation of statistical control charts u-chart.
9. Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves.
10. Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves for varying acceptance number.
11. Calculation of process capability and comparison of 3-sigma control limits with specification limits.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**


- Montogomery, D. C. (2013). Introduction to Statistical Quality Control, 7th Edition, Wiley India Pvt. Ltd.


**SUGGESTIVE READINGS:**


- Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I & II, 8th Edn. The World Press, Kolkata.
- Gupta S.C., Kapoor V.K.(2007): Fundamentals of Applied Statistics. 4th Edition, Sultan Chand and Sons., New Delhi.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

# Semester 6

## DEPARTMENT OF STATISTICS

## B. Sc. (H) Statistics

## Category I

**DISCIPLINE SPECIFIC CORE COURSE – 16: TESTING OF HYPOTHESIS**

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Testing of Hypothesis | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | Basic knowledge of sampling distributions |

### Learning Objectives

The learning objectives of this course are to introduce:

- Hypothesis testing as a statistical procedure for testing whether chance is a plausible explanation of a random experiment
- The logic of hypothesis testing with focus on theory and implementation of hypothesis testing with knowledge about types of error type, power and the correct computation and interpretation of p-values
- Use of nonparametric test as an alternative when assumptions of parameterization of distribution or the family itself is violated.
- Sequential Probability Ratio test with its entities like OC Curve, ASN etc.

### Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- The notion of statistical hypothesis test, error and its nature and the idea of acceptance and rejection region.
- Identify simple and composite hypothesis. Find critical region, size and power of the test.
- Apply Neymann-Pearson lemma to find most powerful test. Find UMP and UMPU test. Make use of likelihood ratio principle for testing of hypothesis
- Make distinction between parametric and nonparametric test. Identify suitable nonparametric test for both location and scale (Kolmogorov- Smirnov one sample and two sample tests, sign test, Wilcoxon signed rank test, run test. Median test, Kruskal-Wallis one-way analysis of variance by ranks, Friedman two way analysis of variance by ranks).
- Derive SPRT for test the parameters of normal distribution, binomial and Poisson distributions also find OC function, Average sample Number etc. of a SPRT.

## SYLLABUS OF DSC-16

**Theory**

**UNIT I** **(15 hours)**

**Principles of test of significance**

Principles of test of significance: Null and alternative hypotheses (simple and composite), Type-I and Type-II errors, critical region, level of significance, size and power, best critical region, most powerful test, uniformly most powerful test, uniformly most powerful unbiased critical region (UMPU). Neyman Pearson Lemma and its application to construct most powerful tests.

**Unit II** **(10 hours)**

**Likelihood ratio test**

Likelihood ratio test and its application, properties of likelihood ratio tests (without proof).

**UNIT III** **(10 hours)**

**Sequential Probability Ratio Test**

Sequential Probability Ratio Test. Determination of stopping bounds A and B, OC and ASN functions of SPRT.

**UNIT IV** **(10 hours)**

**Non-Parametric tests**

Non-Parametric tests. Empirical distribution function, one sample and two-sample sign test. Wald-Wolfowitz run test. Run test for randomness, Median test, Wilcoxon-Mann-Whitney U-test. Kolmogorov-Smirnov one-sample test, Kruskal-Walli's test.

**PRACTICAL/LAB. WORK(30 hours):**

**List of Practical**

1. Type I and Type II errors
2. Most powerful critical region (NP Lemma)
3. Uniformly most powerful critical region
4. Unbiased critical region
5. Power curves of hypothesis tests.
6. Likelihood ratio test
7. Non Parametric test based on quantile and Empirical distribution
8. Test for location and scale both one and two samples
9. Test of Association for bivariate samples
10. SPRT for binomial, Poisson and Normal distribution
11. OC Curve and ASN function

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Gun, A.M., Gupta, M.K., and Dasgupta, B. (2005).: An Out Line of Statistical Theory, Volume 2, Third Edition.
- Gupta, S.C. and Kapoor, V.K.(2020): Fundamental of Mathematical Statistics, 12th Edn. Sultan Chand and Sons.

**SUGGESTIVE READINGS:**


- Hogg, R.V, McKean, J. and Craig, A.T. (2012): Introduction to Mathematical Statistics, 7th Edn. Pearson Education.
- Casella, G. and Berger, R.L. (2002): Statistical Inference. 2nd Edition, Duxbury Press, Pacific Grove.
- Siegel, S. (1956). Nonparametric statistics for the behavioral sciences. McGraw-Hill.
- Lehmann, E. and Romano. J. (2005): Testing statistical hypotheses,3rd Edn. Springer, New York.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC CORE COURSE –17: DESIGN OF EXPERIMENTS

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Design of Experiments | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of sampling distributions and linear models |

### Learning Objectives

The learning objectives include:

- To design and conduct experiments.
- To analyze and interpret data.

### Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- The fundamental concepts of design of experiments.
- Introduction to planning valid and economical experiments within given resources.
- Completely randomized design.
- Randomized block design.
- Latin square design.
- Balanced incomplete block design.
- Full and confounded factorial designs with two levels.
- Introduction to factorial designs at three levels.
- Fractional factorial designs with two levels

### SYLLABUS OF DSC-17

**Theory**

**UNIT I** **(13 hours)**

**Experimental designs**

Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks. Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model and statistical analysis, relative efficiency, analysis with one missing observation in case of RBD.

**UNIT II (10 hours)**

**Incomplete Block Designs**

Balanced Incomplete Block Design (BIBD) – parameters, relationships among its parameters, incidence matrix and its properties, Symmetric BIBD, Resolvable BIBD, Affine Resolvable BIBD, Complimentary BIBD, Residual BIBD, Dual BIBD, Derived BIBD.

**UNIT III (12 hours)**

**Factorial experiments**

advantages, notations and concepts, $2^2$, $2^3$,…, $2^n$, $3^2$ factorial experiments, design and analysis, Total and Partial confounding for $2^n$ ($n \leq 6$), Factorial experiments in a single replicate.

**UNIT IV (10 hours)**

**Fractional factorial experiments**: Construction of one-half and one-quarter fractions of $2^n$ ($n \leq 6$) factorial experiments, Alias structure, Resolution of a design.

**PRACTICAL/LAB WORK – (30 hours)**

**List of Practical:**

1. Analysis of a CRD with equal and unequal replicates.
2. Analysis of RBD.
3. Analysis of LSD.
4. Analysis of RBD with one missing observation.
5. Analysis of $2^2$ and $2^3$ factorial in CRD, RBD and LSD.
6. Analysis of $3^2$ factorial in CRD, RBD.
7. Analysis of a completely confounded two level factorial design in 2 blocks.
8. Analysis of a completely confounded two level factorial design in 4 blocks.
9. Analysis of a partially confounded two level factorial design.
10. Analysis of a single replicate of a $2^n$ design.
11. Analysis of one half fraction of $2^n$ factorial design.
12. Analysis of one quarter fraction of $2^n$ factorial design.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**


- Das., M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley Eastern.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics. Vol. II, 8th Edition. World Press, Kolkata.
- Montgomery, D. C. (2008): Design and Analysis of Experiments. John Wiley.
- Mukhopadhyay, P (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied(P) Ltd.


**SUGGESTIVE READINGS:**


- Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House.
- Kempthorne, O. (1965): The Design and Analysis of Experiments. John Wiley.
- Federer, W. T. (1955): Experimental Design, Macmillan, N. Y.
- Anderson, V. L. and McLean, R. A. (1974): Design of Experiments, Marcel Dekker, Inc., N. Y.

● Dean, A. and Voss, D. (1999). Design and Analysis of Experiments, Springer. First Indian Reprint 2006

**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC CORE COURSE –18: ECONOMETRICS

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Econometrics | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of sampling distributions and linear models |

### Learning Objectives

A broad knowledge of regression analysis relevant for analyzing economic data.

- Interpretation and critical evaluation of the outcomes of empirical analysis.
- Distinguish the results of violating the assumptions of a classical regression model.
- To judge the validity of the economic theories and carry out their evaluation in numerical terms.
- To extract useful information about important economic policy issues from the available data.
- The course is designed to provide the students with the basic quantitative techniques needed to undertake applied research projects.
- The students learn to quantify and examine economic relationships employing statistical methods based on observed data.

### Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- Students will be trained to write a good quality undergraduate research paper in applied statistics using the econometric methods taught in this class.
- The fundamental concepts of econometrics.
- Specification of the model.
- Multiple Linear Regression.
- Multicollinearity.
- Heteroscedasticity.
- Autocorrelation.
- Autoregressive and Lag models

## SYLLABUS OF DSC-18

**Theory**

**UNIT I** **(15 hours)**

**Introduction**

Objective behind building econometric models, Nature and scope of econometrics, model building, role of econometrics. General linear model (GLM). Estimation under linear restrictions.

**UNIT II** **(10 hours)**

**Multicollinearity**

Introduction and concepts, detection of multicollinearity, consequences, remedies Multicollinearity, tests and solutions of multicollinearity.

**UNIT III** **(10 hours)**

**Generalized least squares and Autocorrelation**

Generalized least squares estimation, Aitken estimators. Autocorrelation: concept, consequences of autocorrelated disturbances, detection and solution of autocorrelation.

**UNIT IV** **(10 hours)**

**Heteroscedastic disturbances**

Heteroscedastic disturbances: Concepts and efficiency of Aitken estimator with OLS estimator under heteroscedasticity. Consequences of heteroscedasticity. Tests and solutions of heteroscedasticity. Qualitative Forecasting Methods.

**PRACTICAL/LAB WORK – (30 hours)**

**List of Practical:**

1. Problems based on estimation of General linear model.
2. Testing of parameters of General linear model.
3. Forecasting of General linear model.
4. Problems related to consequences of Multicollinearity.
5. Diagnostics of Multicollinearity.
6. Problems related to consequences of Autocorrelation (AR(I)).
7. Diagnostics of Autocorrelation.
8. Estimation of General linear model under Autocorrelation.
9. Problems related to consequences Heteroscedasticity.
10. Diagnostics of Heteroscedasticity.
11. Estimation of problems of General linear model under Heteroscedastic disturbance terms.
12. Problems concerning specification errors as a reason for induction of Autocorrelation, Heteroscedasticity and Multicollinearity.
13. Problems related to General linear model under (Aitken Estimation).
14. Forecasting methods.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**


- Gujarati, D. and Guneshker, S. (2007). Basic Econometrics, 4th Ed., McGraw Hill Companies.
- Johnston, J. (1972). Econometric Methods, 2nd Ed., McGraw Hill International.

**SUGGESTED READINGS:**


- Koutsoyiannis, A. (2004). Theory of Econometrics, 2 Ed., Palgrave Macmillan Limited.
- Maddala, G.S. and Lahiri, K. (2009). Introduction to Econometrics, 4 Ed., John Wiley & Sons.
- Greene, W. H. (2002) Econometric Analysis.5th Edition, Prentice Hall.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

# B.Sc. (P)/B.A(P) with Statistics as Major

## Category II

### DISCIPLINE SPECIFIC ELECTIVE COURSE –: 11 SURVEY SAMPLING

#### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| **Survey Sampling** | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of basic statistics |

#### Learning Objectives:

The learning objectives of this course are to introduce:

- Tools and techniques for selecting a representative sample from a target population keeping in mind the objectives to be fulfilled.
- Obtain an estimator of the population parameter on the basis of the selected sample and study its properties.

#### Learning Outcomes:

After successful completion of this course, students should be able to:

- Understand the fundamental concepts of population and sample and the principles of sample survey
- Describe the value and methodologies for sample surveys versus other approaches to collecting information from populations.
- Determine the appropriate sample size and its allocation for nationwide sample surveys or for surveys to be conducted in a program area.
- Identify a proper sampling frame and select primary sample points.
- Apply steps involved in selecting a sample using Simple Random Sampling with or without replacement, Stratified Sampling, Systematic Sampling and Ratio and Regression Methods of Estimation

## SYLLABUS OF DSC-11

**Theory**

**Unit I** **(15 Hours)**

**Basic Concepts and Simple Random Sampling**

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling basic principles of sample survey, Steps involved in survey sampling.

Simple random sampling (SRS)with and without replacement, their properties, procedures of selecting a simple random sample, estimation of population mean, and total sampling for proportions, determination of sample size.

**Unit 2** **(10 Hours)**

**Stratified random sampling:**

Estimation of population mean and its variance. Allocation of samples in different strata using equal, proportional, and Neyman allocation. Comparison of Stratified sampling under proportional and Neyman allocation with SRSWOR. Practical difficulties in adopting Neyman allocation.

**Unit 3** **(10 Hours)**

**Systematic sampling:**

Estimation of population mean, and total. Comparison of systematic sampling with simple random sampling and stratified sampling in the presence of linear trend. Definition and concept of circular systematic sampling.

**Unit 4** **(10 Hours)**

**Introduction to Indian Official Statistics:**

Present official Statistical System in India, Methods of collection official statistics, their reliability and limitations. Role of Ministry of Statistics and Programme Implementation (MOSPI), Central Statistical Office CSO, NSSO.

**PRACTICAL/LAB.. WORK: (30 Hours)**

**List of Practicals:**

1. To select SRS with and without replacement.
2. For a population of size 5, estimate population mean, population mean square, and population variance. Enumerate all possible samples of size 2 by WR and WOR.
3. Estimate mean standard error and the sample size for SRSWOR.
4. Allocation of sample to strata by proportional method.
5. Allocation of sample to strata by Neyman methods.
6. Compare the efficiencies of proportional and Neyman allocation relative to SRS.
7. Comparison of systematic sampling with stratified sampling and SRS in the presence of a linear trend.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**Essential Readings:**


- Cochran WG (2011) Sampling techniques (3rd edition) Wiley Eastern John Wiley and sons.
- Goon AM Gupta MK and Dasgupta B. (2001) Fundamentals of statistics, volume 2, World Press Gupta SC and Kapoor VK (2007) Fundamentals of Applied Statistics, Sultan Chand and sons.
- Murthy MN (1977) Sampling theory and sampling methods, Statistical Pub. Society, Calcutta.
- Singh D and Chaudhary FS (2015): Theory and Analysis of Sample Survey Designs.

- Sukhatme PV Sukhatme BV, Sukhatme S, Asok C (1984) Sampling Theories of Survey with Application, Iowa State University press and Indian Society of agricultural statistics.
- Guide to current official statistics CSO, GOI, New Delhi


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC ELECTIVE COURSE –: 12 STATISTICAL METHODS FOR PSYCHOLOGY AND EDUCATION

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| **Statistical Methods in Psychology and Education** | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of basic statistics |

### Learning Objectives:

The learning objectives include:
- To measure psychological traits and mental abilities
- To learn basic methods of test construction, item writing and item analysis
- To check the reliability and validity of test scores.

### Learning Outcomes:

After successful completion of this course, students should be able to:
- Distinguish between Psychological measurement and physical measurement.
- Understand the meaning of Tests in Psychology and Education.
- Appreciate the uses and limitations of Psychological tests.
- Learn the meaning and purpose of Item writing and analysis.
- Understand concepts of reliability and validity of test scores and their differences.
- Convert raw scores into different transformed scores.
- Apply Scaling rankings and ratings in terms of the Normal Probability Curve.

### SYLLABUS OF DSC-12

**Theory**

**Unit 1:** **(15 Hours)**

**Importance of statistics in psychology and education.**

Importance of statistics in psychology and education. Levels of measurement: nominal ordinal interval and ratio scales. Distinction between psychological and physical measurements. General problems and sources of errors in measurements.
Meaning and types of tests in psychology and education. History of psychological measurement and testing. Uses and limitations of tests. Varieties of tests. Characteristics of a good test. General steps of test construction. Test administration and scoring.
Item writing and item analysis: Meaning and types of test items, Purpose and methods for evaluating test items.

**Unit 2: (15 Hours)**

**Reliability and Validity:**

Reliability: definition Methods of determining reliability: Test-retest, Alternate or parallel forms, Split half technique, Rational equivalence. Effect upon reliability of lengthening or repeating or test. Reliability coefficient as a measure of true variance. Estimating true scores by way of regression equation and reliability coefficient. Index of reliability.
Validity: meaning; Estimation of validity; Types of validity: validity and test length; comparison between reliability and validity.

**Unit 3: (15 Hours)**

**Test Scores:**

Meaning and differences between norm referencing and criterion referencing.
Raw score transformations- percentile scores, standard score, normalised standard scores, T- scores and Stanine scores.
Intelligence: definition. Types of intelligence test scores. Psychological scaling methods- scaling of individual test items in terms of difficulty, scaling of rankings and ratings in terms of the normal probability curve.

**PRACTICAL LAB WORK (30 hours)**

**List of Practical:**

1. Computation of reliability by Rulon and Kuder Richardson formulas.
2. Computing reliability of a test whose length is increased/decreased.
3. Computing index of reliability standard error of measurement.
4. Computing validity oblique maximum validity then test length is increased.
5. Computing relative difficulty of questions difference in difficulty between different tests.
6. Problem based on Z scores.
7. Problem based on t scores.
8. Problem based on Stanine scales.
9. Problem based on percentile scores.
10. Computing numerical scores corresponding to grades or ratings.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Anastasia, A. and Urbina, S. (1997) Psychological testing (7th edition), Prentice Hall
- Garrett H.E. (2021), Statistics in Psychology and Education. Nation press.
- Gregory RJ (2016), Psychological testing: History, Principles and Applications. (updated 7th edition) Pearson
- Singh, A.K. (2006)Test, Measurements and Research in Behavioural Sciences Bharati bhavan
- Mangal S.K. (2016) Statistics in Psychology and Education. PHI learning Pvt ltd.

**SUGGESTED READINGS:**


- Gupta S.C. and Kapoor V.K. (2019) Fundamentals of Applied statistics, Sultan Chand and sons.
- Goon A.M., Gupta M.K. and Dasgupta, B. (2001) Fundamental of Statistics, Volume 2, World Press Pvt ltd.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

# B.Sc. (P)/B.A(P) with Statistics as Non- Major

## Category III

### DISCIPLINE SPECIFIC CORE COURSE –: 6 SURVEY SAMPLING

**CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE**

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| **Survey Sampling** | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of basic statistics |

**Learning Objectives:**

The learning objectives of this course are to introduce:

- Tools and techniques for selecting a representative sample from a target population keeping in mind the objectives to be fulfilled.
- Obtain an estimator of the population parameter on the basis of the selected sample and study its properties.

**Learning Outcomes:**

After successful completion of this course, students should be able to:

- Understand the fundamental concepts of population and sample and the principles of sample survey
- Describe the value and methodologies for sample surveys versus other approaches to collecting information from populations.
- Determine the appropriate sample size and its allocation for nationwide sample surveys or for surveys to be conducted in a program area.
- Identify a proper sampling frame and select primary sample points.

- Apply steps involved in selecting a sample using Simple Random Sampling with or without replacement, Stratified Sampling, Systematic Sampling and Ratio and Regression Methods of Estimation

## SYLLABUS OF DSC-6

**Theory**

**Unit I** **(15 Hours)**

**Basic Concepts and Simple Random Sampling**

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling basic principles of sample survey, Steps involved in survey sampling.

Simple random sampling (SRS)with and without replacement, their properties, procedures of selecting a simple random sample, estimation of population mean, and total sampling for proportions, determination of sample size

**Unit 2** **(10 Hours)**

**Stratified random sampling:**

Estimation of population mean and its variance. Allocation of samples in different strata using equal, proportional, and Neyman allocation. Comparison of Stratified sampling under proportional and Neyman allocation with SRSWOR. Practical difficulties in adopting Neyman allocation.

**Unit 3** **(10 Hours)**

**Systematic sampling:**

Estimation of population mean, and total. Comparison of systematic sampling with simple random sampling and stratified sampling in the presence of linear trend. Definition and concept of circular systematic sampling.

**Unit 4** **(10 Hours)**

**Introduction to Indian Official Statistics:**

Present official Statistical System in India, Methods of collection official statistics, their reliability and limitations. Role of Ministry of Statistics and Programme Implementation (MOSPI), Central Statistical Office CSO, NSSO.

**PRACTICAL/ LAB WORK (30 HOURS)**

**List of Practicals:**

1. To select SRS with and without replacement.
2. For a population of size 5, estimate population mean, population mean square, and population variance. Enumerate all possible samples of size 2 by WR and WOR.
3. Estimate mean standard error and the sample size for SRSWOR.
4. Allocation of sample to strata by proportional method.
5. Allocation of sample to strata by Neyman methods.
6. Compare the efficiencies of proportional and Neyman allocation relative to SRS.
7. Comparison of systematic sampling with stratified sampling and SRS in the presence of a linear trend.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Cochran WG (2011) Sampling techniques (3rd edition) Wiley Eastern John Wiley and sons.

- Goon AM Gupta MK and Dasgupta B. (2001) Fundamentals of statistics, volume 2, World Press Gupta SC and Kapoor VK (2007) Fundamentals of Applied Statistics, Sultan Chand and sons.
- Murthy MN (1977) Sampling theory and sampling methods, Statistical Pub. Society, Calcutta.
- Singh D and Chaudhary FS (2015): Theory and Analysis of Sample Survey Designs.
- Sukhatme PV Sukhatme BV, Sukhatme S, Asok C (1984) Sampling Theories of Survey with Application, Iowa State University press and Indian Society of agricultural statistics.
- Guide to current official statistics CSO, GOI, New Delhi


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

# Discipline Specific Elective
## Category V

**DISCIPLINE SPECIFIC ELECTIVE COURSE –4A: BIOSTATISTICS**

**CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE**

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| **Biostatistics** | **4** | **3** | 0 | **1** | Class XII pass with Mathematics . | knowledge of Statistical Inference and stochastic processes |

**Learning objectives:**

- Parametric Models for Survival data.
- Different types of censoring and its application in public health.
- Estimation of death probabilities by using the theory of competing risks.
- Non-parametric methods for incomplete survival data.
- Computation of the probability of gametes in different generations under random mating.

**Learning Outcomes:**

After completing this course, students will develop a clear understanding of:

- The fundamental concepts of survival functions and their interrelationship.
- Survival models and their applications.
- Handling censored data and estimating mean survival time of the patients.
- Actuarial and Kaplan-Meier methods.
- Competing Risk Theory.
- Basic concept of Statistical genetics.

**SYLLABUS OF DSE-4A**

**Theory**

**UNIT I** **(11 Hours)**

**Survival Analysis**

Survival Analysis: Functions of survival times, survival distributions and their applications exponential, gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shaped hazard function.

**UNIT II** **(13 Hours)**

**Censoring Schemes**

Censoring Schemes: Type I, Type II and progressive or random censoring with biological examples. Estimation of mean survival time and variance of the estimator for Type I and Type II censored data with numerical examples. Non-parametric methods: Actuarial and Kaplan-Meier methods for estimating survival function and variance of the Estimator.

**UNIT III** **(10 Hours)**

**Competing Risk Theory:**

Indices for measurement of the probability of death under competing risks and their inter-relations. Estimation of probabilities of death using maximum likelihood method and modified chi squire method.

**UNIT IV** **(11 Hours)**

**Statistical Genetics:**

Statistical Genetics: Introduction, concepts-Genotype, Phenotype, Dominance, Recessiveness, Linkage and Recombination, Coupling, and Repulsion. Mendelian laws of Heredity, Random mating, Gametic array, Genotypic array, Relation between genotypic array and gametic array under random mating. Distribution of genotypes under random mating. Hardy-Weinberg law. Concept of gene frequencies.

**PRACTICAL/ LAB. WORK (30 HOURS)**

**List of Practical:**

1. Estimation of survival function, death density function and hazard function.
2. Estimation of mean survival time using various parametric survival models.
3. To Identify and analyse type-I censored data.
4. To Identify and analyse type-II censored data.
5. To Identify and analyse progressively type I censored data.
6. Estimation of mean survival time and variance of the estimator for type I censored data.
7. Estimation of mean survival time and variance of the estimator for type II censored data.
8. Estimation of mean survival time and variance of the estimator for progressively type I censored data.
9. To estimate the survival function and variance of the estimator using Actuarial methods.
10. To estimate the survival function and variance of the estimator using Kaplan-Meier method.
11. To estimate Crude probability of death.
12. To estimate Net-type I probability of death.
13. To estimate Net-type II probability of death.
14. To estimate partially crude probability of death.
15. To estimate gene frequencies.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS:**


- Biswas, S. (2007). Applied Stochastic Processes: A Biostatistical and Population Oriented Approach, Reprinted 2nd Ed., New Central Book Agency.
- Lee, E.T. and Wang, J.W. (2003). Statistical Methods for Survival data Analysis, 3rd Ed., John Wiley & Sons.
- Indrayan, A. (2008). Medical Biostatistics, 2nd Ed., Chapman and Hall/CRC.


**SUGGESTIVE READINGS:**


- Narayan P. (1999). Statistical Genetics, New Age International Pvt. Ltd.
- Miller, R. G. (2011). Survival Analysis. John Wiley & Sons.
- Elandt-Johnson R.C (1971).Probability models and Statistical Methods in Genetics, John Wiley & Sons.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## DISCIPLINE SPECIFIC ELECTIVE COURSE – 4b: ORDER STATISTICS AND ITS APPLICATIONS

### CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Order Statistics and its Applications | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of statistical distributions and stochastic processes |

### Learning Objectives

The learning objective of this course is to make the students aware of the properties and applications of order statistics.

### Learning Outcomes:

On successful completion of the course, the student will be able to:

- Find joint, marginal distributions and conditional distributions of order statistics in the continuous and discrete case.
- Find the distribution of sample range and other systematic statistics in case of sampling from an arbitrary continuous population and from some specific continuous distributions such as uniform and exponential.
- Understand the Markov Chain property of order statistics in the continuous case.
- Learn how to obtain distribution-free confidence intervals for population quantile for population distributions based on order statistics.
- Understand the distribution-free bounds for moments of order statistics and of the range.
- Derive the recurrence relations and identities for moments of order statistics drawn from an arbitrary population (discrete or continuous), as well as from some specific distributions.
- Understand the concept of L-moments and L-moments estimation of parameters.
- Derive the Linear estimation of location and scale parameters based on the moments of order statistics.

### SYLLABUS OF DSE-4b

**Theory**

**UNIT I** **(15 hours)**
**Introduction to Order Statistics**

Definition and applications of order statistics. Basic distribution theory. Joint and marginal distributions of order statistics in the continuous case. Distribution of the median, range and other systematic statistics. Order statistics for a discrete parent. Examples based on discrete and continuous distributions.

**UNIT II** **(10 hours)**

**Conditional distribution of order statistics**

Conditional distribution of order statistics. Order statistics as a Markov Chain. Distribution-free confidence intervals for population quantiles. Distribution-free bounds for moments of order statistics and of the range.

**UNIT III** **(10 hours)**

**Moments of order statistics**

Moments of order statistics. Recurrence relations and identities for moments of order statistics from an arbitrary distribution. Recurrence relations for moments of order statistics from some specific distributions.

**UNIT IV** **(10 hours)**

**Order statistics in statistical inference**

Order statistics in statistical inference. L-moments and L-moments estimation. Linear estimation based on order statistics. Examples based on some specific continuous distributions.

**PRACTICAL/LAB WORK – (30 hours)**

**List of Practical:**

1. Problem-solving using joint, marginal, and conditional distributions of order statistics for some specific continuous distributions.
2. Distribution-free confidence intervals for population quantiles for various distributions.
3. Calculating Means, variances, and covariances by using exact expressions for the moment of order statistics for some specific continuous distribution.
4. Calculating Means, variances, and covariances by using recurrence relations for some specific continuous distributions.
5. Calculation of L-moments for some specific continuous distributions.
6. L-moments estimation of parameters for some specific continuous distributions.
7. Calculation of linear unbiased estimation for location and scale parameters for some specific continuous distributions.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**


- David, H. A. and Nagaraja, H. N. (2003). Order Statistics, 3rd ed., John Wiley & Sons.


**SUGGESTIVE READINGS:**


- Arnold, B. C., Balakrishnan, N. and Nagaraja H. N. (2008). A First Course in Order Statistics, SIAM Publishers.
- Arnold, B.C. and Balakrishnan, N. (1989). Relations, Bounds and Approximations for Order Statistics, Vol. 53, Springer-Verlag.
- Ahsanullah, M., Nevzorav, V.B. and Shakil, M. (2013). An Introduction to Order Statistics, Atlantis Studies in Probability and Statistics, Vol. III. Atlantis Press.
- Gibbons, J.D. and Chakraborti, S. (1992). Nonparametric Statistical Inference, 3rd ed., Marcel Dekker.

- Shahbaz, M. Q., Ahsanullah, M., Shahbaz, S. H. and Al-Zahrani, B. M. (2016). Ordered Random variables: Theory and Applications. Springer.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

# DISCIPLINE SPECIFIC ELECTIVE COURSE – 4c: STATISTICAL COMPUTING AND BASIC DATA MINING

## CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Statistical Computing and Basic Data Mining | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | Knowledge of MATLAB / OCTAVE / R / Python / C |

### Learning Objectives

learning objectives include:

- Understand the theoretical foundations and practical aspects of statistical computing and data mining.
- Develop skills in the use of statistical computing and data mining software to solve problems and analyze data. The programming implementations will be completed using MATLAB/OCTAVE/R/Python/C.

### Learning Outcomes:

After completion of this course, students will develop a clear understanding of:

- Apply knowledge of statistical computing and data mining techniques to solve problems and analyze data.
- Communicate effectively about statistical computing and data mining concepts and techniques both orally and in writing.
- Develop ability for programming implementation using MATLAB/OCTAVE/R/Python/C.

## SYLLABUS OF DSE-4C

**Theory**

**UNIT I** **(15 hours)**

**Simulation techniques**
Random number generation: Review; Simulating multivariate distributions; Simulating stochastic processes. Variance reduction methods.

**UNIT II** **(12 hours)**
**Markov Chain Monte Carlo methods**
Markov Chain Monte Carlo methods: The Metropolis–Hastings Algorithm; Gibbs sampling.

**UNIT III** **(18 hours)**
**Data Mining and its applications**
Introduction to Data Mining and its Applications. Data Pre-processing Techniques: Data Cleaning, Data Integration, Data Transformation, and Data Reduction. Exploratory Data Analysis. Classification Techniques: Decision Trees, Naive Bayes, k-Nearest Neighbors (k-NN). Clustering Techniques: K-Means, Hierarchical Clustering. Association rule mining. Evaluation of Data Mining Models.

**PRACTICAL/LAB WORK – (30 hours)**
**List of Practical:**

1. Practical based on random number generation: univariate and multivariate distributions.
2. Practical on simulating stochastic processes; variance reduction.
3. Simple practical problems on MCMC.
4. Practical based on Data pre-processing, transformation, reduction.
5. Practical based on classification and clustering.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**ESSENTIAL READINGS**

- Rubinstein, R.Y. (2017). Simulation and the Monte Carlo Methods, Wiley.
- Voss, J. (2014). An introduction to statistical computing: a simulation-based approach,Wiley series in computational statistics.
- Tan, P. N., Steinbach, M., & Kumar, V. (2016). Introduction to data mining. Pearson Education India.
- Han, J., Kamber, M., & Pei, J. (2012). Data mining concepts and techniques third edition. University of Illinois at Urbana-Champaign Micheline Kamber Jian Pei Simon Fraser University.
- Witten, I. H., Frank, E., Hall, M. A., & Pal, C. J. (2017). Data Mining: Practical machine learning tools and techniques, Elsevier Inc.


**SUGGESTIVE READINGS:**

- Vetterling, William T., Saul A. Teukolsky, William H. Press, and Brian P. Flannery. Numerical recipes in C: the art of scientific computing. Cambridge university press, 1999.
- Christian, P. R., & George, C. (1999). Monte Carlo statistical methods. Springer Texts in Statistics.
- Hancock, M. F. (2012). Practical data mining. CRC Press.
- Shmueli, G., Bruce, P. C., Yahav, I., Patel, N. R., & Lichtendahl Jr, K. C. (2017). Data mining for business analytics: concepts, techniques, and applications in R. John Wiley & Sons.
- Shmueli, G., Bruce, P. C., Gedeck, P., & Patel, N. R. (2019). Data mining for business analytics: concepts, techniques and applications in Python. John Wiley & Sons.
- Hastie, T., Tibshirani, R., Friedman, J. (2008). The Elements of Statistical Learning: Data Mining, Inference and Prediction, 2nd ed., Springer.
- Murphy, K. P. (2012). Machine Learning: A Probabilistic Perspective. United States: MIT Press.


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## DISCIPLINE SPECIFIC ELECTIVE COURSE – 4d : RESEARCH METHODOLOGY

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Research Methodology | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | Nil |

### Learning Objectives:

The learning objectives include

- To provide scientific approaches to develop the domain of human knowledge through empirical studies.
- To enable the student researchers to understand basic concepts and aspects related to research, data collection, analyses, interpretation and report writing.

### Learning Outcomes:

After completion of this course, students will develop a clear understanding of

- Research Methods.

- Research Problems.
- Research Designs.
- Comparative study of different methods of data collection.
- Guidelines for construction of questionnaires.
- Processing and Analysis of data.
- Interpretation and Report writing.

## SYLLABUS OF DSE – 4D

**Theory**

**UNIT I** **(09 hours)**

**Introduction to Research:**

Importance and need for research ethics, Objectives of research, Types of research, Research approaches, Review of literature, Mode of literature survey: Books and Monographs, Journals, Conference proceedings, Abstracting and Indexing Journals, E-Journals/Books, Formulation of a research problem, Identifying variables, Constructing hypothesis, Conceptualization of a research design.

**UNIT II** **(09 hours)**

**Methods & Techniques of Data Collection:**

Survey methodology and Data collection, Source of data collection-Use of secondary data, Methods of collecting primary data, Develop a questionnaire, Questions and answers in surveys, Non-response, Errors in surveys, Sample size, sampling frames and coverage error.

**UNIT III** **(15 hours)**

**Data Processing & Analysis:**

Data processing, Exploratory data analysis, Review of various techniques (Parametric and Nonparametric tests, Correlation and Regression analysis, ANOVA, Multivariate Techniques) for data analysis covered in core statistics papers, Techniques of interpretation, Precaution in interpretation.

**Report writing:**

Discussions, Conclusions, Referencing and various formats for reference writing, Bibliography, Thesis writing, Formats of publications in research journals including subject classification, Impact factor, Citation index.

**UNIT IV** **(12 hours)**

**Computer Application:**

Data Communication and networks, Website, Webpage, Search Engines, Scientific search engines. Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.

**PRACTICAL/LAB WORK – (30 hours)**

**PROJECT WORK** (using a spreadsheet, Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.)

**ESSENTIAL READINGS**


- Kothari, C.R., Garg, Gaurav (2015): Research Methodology: Methods and Techniques, 3rd Edition (Reprint), New Age International Publishers.
- Kumar, R. (2011): Research Methodology: A Step-by-Step Guide for Beginners, SAGE publications.

- Anderson, J., Durston, B.H., Pooole, M. (1970): Thesis and Assignment Writing, Wiley Eastern. Ltd., New Delhi.
- Braun, J., Duncan, W. and Murdock, J. (2008): A First Course in Statistical Programming with R, Cambridge University Press, London.
- Lamport, L. (1999): LATEX: A Document Preparation System, Addison, Wesley, 2nd Edition, New York.
- Cunningham, B.J. (2012): Using SPSS: An Interactive Hands-On Approach, SAGE South Asia Edition.
- Voss, J. (2014): An Introduction to Statistical Computing: A Simulation-based Approach, Wiley series in computational statistics.


**SUGGESTIVE READINGS**


- Pannerselvan, R. (2006): Research Methodology, Prentice-Hall of India Pvt., New Delhi.
- Landau, Sabine and Everitt, Brian S. (2004): A Handbook of Statistical Analyses using SPSS, Chapman & Hall/CRC.
- Dalgaard, P. (2008): Introductory Statistics with R, Springer Science, New York.
- Gardener, M. (2012): Beginning R: The Statistical Programming Language, Wiley Publications.
- Robert, C.P. and Casella, G. (2004): Monte Carlo Statistical Methods, Springer Science, New York.
- Rubinstein, R.Y. (1981): Simulation and the Monte Carlo Methods, Wiley.
- Venkataraman, M.K. (1998): Numerical Methods in Science and Engineering, The National Publishing Company, Chennai.


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**COMMON POOL OF GENERIC ELECTIVES (GE) COURSES**

**OFFERED BY DEPARTMENT OF STATISTICS**

## Category VI

**GENERIC ELECTIVE COURSE – 6a: SURVEY SAMPLING AND DESIGN OF EXPERIMENTS**

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| **Survey Sampling and Design of Experiments** | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | knowledge of basics statistics |

### Learning Objectives

The learning objectives include:

- To learn about sample surveys, its need and objectives.
- To learn to draw appropriate sample and interpret the result.
- To learn to design and conduct experiments.
- To analyse and interpret the data.

### Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- The basic concept of sample survey and its need.
- Simple random sampling.
- Stratified random sampling
- One-way and two-way analysis of variance.
- Basic concepts of design of experiments.
- Completely randomized design.
- Randomized design.
- Latin square design.
- Factorial experiments.

### SYLLABUS OF GE-6a

**Theory**

**UNIT I** **(11 hours)**

**Sample Surveys**

Basic concepts of sample survey, concept of sampling, need for sampling, complete enumeration v/s sampling, principles of sampling theory, principal steps in a sample surveys, planning and organization of a sample survey, sampling and non-sampling errors.
Simple random sampling (SRSWR and SRSWOR): Definition and procedures of selecting a sample, properties of simple random sample, estimation of mean and sampling variance of sample mean.

**UNIT II** **(12 Hours)**

**Stratified random sampling**

Introduction, estimation of population mean and its variance, choice of sample sizes in different strata, comparison of stratified sampling under proportional and Neyman allocation with SRSWOR in terms of precision.

**Unit III** **(12 Hours)**

**Analysis of variance and Design of experiments**

One-way and two-way classified data with one observation per cell only. Design of experiments: Principles of Design of experiments, uniformity trails, completely randomized, Randomized block and Latin square designs.

**Unit IV** **(10 Hours)**

**Factorial Experiments and Designs**

Factorial experiments: $2^2$ and $2^3$, Factorial Design: construction and analysis.

**PRACTICAL/LAB WORK – (30 hours)**
**List of Practical:**

1. Select a SRS with and without replacement.
2. For a population of size 5, estimate population means, the population mean square and population variance. Enumerate all possible samples of size 2 by WR and WOR and establish all properties relative to SRS.
3. For SRSWOR, estimate mean, standard error, the sample size.
4. Stratified Sampling: allocation of sample to strata by proportional and Neyman's methods Compare the efficiencies of the above two methods relative to SRS.
5. Estimation of gain in precision in stratified sampling.
6. Analysis of Variance of one-way classified data
7. Analysis Variance of two-way classified data
8. Analysis of CRD
9. Analysis of RBD.
10. Analysis of LSD.
11. Analysis of $2^2$ and $2^3$ factorial in CRD and RBD.

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**Essential Readings:**


- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005). Fundamentals of Statistics, Vol. II, 8th Ed., World Press, Kolkata.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005). An Outline of Statistical Theory, Vol. II, 3rd Ed., World Press, Kolkata.
- Gupta, S.C. and Kapoor, V.K. (2008). Fundamentals of Applied Statistics, 4th Ed., Sultan Chand and Sons.

**Suggested Readings:**


- Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Ashok, C. (1984). Sampling Theory of Surveys with Applications, Iowa State University Press, Iowa, USA.
- Mukhopadhyay, P. (1998). Theory and Methods of Surveys Sampling, Prentice Hall of India.
- Montgomery, D.C. (2001). Designs and Analysis of Experiments, John Wiley and Sons, New York.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**

## GENERIC ELECTIVE COURSE – 6B: Statistics in Actuaries

### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|---|---|---|---|---|---|---|
| | | Lecture | Tutorial | Practical/ Practice | | |
| **Statistics in Actuaries** | 4 | 3 | 0 | 1 | Class XII pass with Mathematics | Nil |

### Learning Objectives

The learning objectives include:

- To learn about Utility theory
- To learn the principles of premium calculations
- To understand the survival distribution and life tables
- To learn Life Insurance models and life annuities

### Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- Statistics and Insurance applications
- Utility theory
- Principles of premium calculations
- Survival distribution and life tables
- Life insurance models and Life annuities.

### SYLLABUS OF GE-6B

**Theory**

**UNIT I** **(11 hours)**

**Introductory Statistics and Insurance applications**

Introductory Statistics and Insurance applications: discrete, continuous, and mixed probability distributions. Insurance applications, sum of random variables. Utility theory: Utility functions expected utility criterion, types of utility function, insurance and utility theory.

**UNIT II** **(12 Hours)**

**Principles of premium calculation**
Principles of premium calculation: Properties of premium principles, examples of premium principles

**Unit III** **(12 Hours)**
**Survival distribution and life tables**
Survival distribution and life tables: Uncertainty of age and death, survival function, time-until-death for a person, curate future lifetime, the force of mortality, life tables with examples

**Unit IV** **(10 Hours)**
**Life Insurance and annuities**
Life insurance: Models for insurance payable at the moment of death, insurance payable at the end of the year of death, and their relationships. Life annuities: continuous life annuities, discrete life annuities.

**PRACTICAL/LAB WORK – (30 hours)**
**List of Practical:**
1. Risk computation for different utility models
2. Discrete and continuous risk calculations
3. Calculation of aggregate claims for collective risks
4. Calculation of aggregate claim for individual risks
5. Computing ruin probabilities and aggregate losses
6. Annuity and present value of contract
7. Computing premium for different insurance schemes
8. Practical based on life models and tables

**Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.**

**Essential Readings:**

- Dixon C. M. D. (2005) Insurance Risk and Ruin (International Series on Actuarial Science), Cambridge University Press.
- Atkinson M.E. and Dickson, D.C.M. (2011): An Introduction to Actuarial Studies, Elgar Publishing.


**Suggested Readings:**

- Bowers N.L., Gerber H.U., Hickman J.C., Jones D.A., and Nesbitt C.J. (1997): Actuarial Mathematics, Society of Actuaries, Itasca, Illinois USA.


**Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.**