STATISTICS SYLLABUS

CBCS Syllabus for

Statistics Honours

and

General Pass Course with Statistics

1. Introduction

The syllabus of Statistics for under-graduate students under Choice Based Credit System has been framed in compliance with the model syllabus outlined by University Grants Commission. The main objective of the syllabus is to give the students a holistic understanding of the subject with appropriate coverage of core courses, elective courses and skill enhancement courses. This is aimed at empowering the students to obtain job after successful completion of the course. The students can also go for self-employment by setting up ventures for offering statistical services to industrial and household sector.

This is assumed that the students of different other disciplines can select statistics courses from the given list of elective courses. Some changes have been made in the courses to keep it appropriate and relevant in the context of contemporary changes taking place in the discipline. The syllabi of Honours and General Pass courses have been clearly outlined with the list of courses to be offered in each case.

6. Statistics Syllabus
for **General Pass Course with combination of Statistics**

2.0: Scheme for CBCS Curriculum [Honours]

2.1: Credit Distribution across Courses for Honours in Statistics

	Credits		
Course Type	Total Papers	Theory + Practical	Theory*
Core Courses	14	14*4 =56 14*2 =28	14*5 =70 14*1=14
Discipline Specific Electives	4	4*4=16 4*2=8	4*5=20 4*1=4
Generic Electives	4	4*4=16 4*2=8	4*5=20 4*1=4
Ability Enhancement Language Courses	2	2*2=4	2*2=4
Skill Enhancement Courses	2	2*2=4	2*2=4
Totals	22	140	140

*Tutorials of 1 Credit will be conducted in case there is no practical component

2.2 Scheme for CBCS Curriculum

Semester	Course Name	Course Detail	Credits
I	Ability Enhancement Compulsory Course – I	English communication / Environmental Science	2
	Core course – I	Descriptive Statistics	4
	Core course – I Practical	Descriptive Statistics Lab	2
	Core course – II	Probability and Probability Distributions I	4
	Core course – II Practical	Probability and Probability Distributions I Lab	2
	Genetic Elective – 1	TBD	4
	Generic Elective – 1 Practical	TBD	2
II	Ability Enhancement Compulsory Course – II	English communication / Environmental Science	2
	Core course – III	Mathematical Analysis	6
	Core course – III Practical	-	-
	Core course – IV	Probability and Probability Distribution II	4
	Core course – IV Practical	Probability and Probability Distributions II Lab	2
	Generic Elective – 2	TBD	4
	Generic Elective – 2 Practical	TBD	2
III	Core course – V	Linear Algebra and Numerical Analysis	6
	Core course – V Practical	-	-
	Core course – VI	Demography and Vital Statistics	4
	Core course – VI Practical	Demography and Vital Statistics Lab	2
	Core course – VII	Statistical Computing using C/C++ Programming	4
	Core course – VII Practical	Statistical Computing using C/C++ Programming Lab	2
	Skill Enhancement Course – 1	TBD	2

	Generic Elective – 3	TBD	4
	Generic Elective – 3 Practical	TBD	2
IV	Core course – VIII	Survey Sampling and Indian Official Statistics	4
	Core course – VIII Practical	Survey Sampling and Indian Official Statistics Lab	2
	Core course – IX	Statistical Inference- I and Sampling Distribution	4
	Core course – IX Practical	Statistical Inference- I and Sampling Distribution Lab	2
	Core course – X	Time Series Analysis	4
	Core course – X Practical	Time Series Analysis Lab	2
	Skill Enhancement Course-2	TBD	2
	Generic Elective – 4	TBD	4
	Generic Elective – 4 Practical	TBD	2
V	Core course – XI	Statistical Inference II	4
	Core course – XI Practical	Statistical Inference II Lab	2
	Core course – XII	Linear Models	4
	Core course – XII Practical	Linear Models Lab	2
	Discipline Specific Elective – 1	TBD	4
	Discipline Specific Elective – 1 Practical	TBD	2
	Discipline Specific Elective – 2	TBD	4
	Discipline Specific Elective – 2 Practical	TBD	2
VI	Core course – XIII	Design of Experiments	4
	Core course – XIII Practical	Design of Experiments Lab	2
	Core course – XIV	Multivariate Analysis and Nonparametric Methods	4
	Core course – XIV Practical	Multivariate Analysis and Nonparametric Methods Lab	2
	Discipline Specific Elective – 3	TBD	4

	Discipline Specific Elective – 3 Practical	TBD	2
	Discipline Specific Elective – 4	TBD	4
	Discipline Specific Elective – 4 Practical	TBD	2

2.3 Choices for Discipline Specific Electives for Honours

Discipline Specific Elective – 1 to Discipline Specific Elective – 4 (Choose any 4)			
Statistical Quality Control	Econometrics	Survival Analysis	
Stochastic Processes and Queuing Theory	Operations Research	Project Work	

2.4 Choices for Skill Enhancement Courses for Honours

Skill Enhancement Course-1 & Skill Enhancement Course-2		
Statistical Data Analysis Using R	Research Methodology	Monte Carlo Method
Data Base Management Systems		

3. Core Subjects Syllabus

3.1 Core T1 – Descriptive Statistics

	4 Credits
Unit 1	
1. Statistics: Definition and scope, concepts of statistical population and sample. 2. Data: quantitative and qualitative, 3. Scales of measurement: nominal, ordinal, interval and ratio. Frequency distribution. 4. Presentation: tabular and graphical, including histogram and ogives.	
Unit 2	
1. Measures of Central Tendency: Mean, Median, Mode. 2. Measures of Dispersion: range, mean deviation, standard deviation, coefficient of variation, Gini's Coefficient, Lorenz Curve. Moments, skewness and kurtosis, Quantiles and measures based on them. Box Plot. Outlier Detection. Quantile-Quantile Plot.	
Unit 3	
1. Bivariate data: Definition, scatter diagram, simple correlation, linear regression, principle of least squares. 2. Analysis of Categorical Data: Contingency table, association of attributes, odds ratio, Pearson's measure, Goodman-Kruskal's γ ; Binary response and logistic regression. Spearman's Rank correlation.	
Unit 4	
Index Numbers: Weighted means, price and quantity index numbers, choice of weights, Laspeyres' and Paasche's index numbers. Tests of index numbers and Fisher's Ideal index number.	
Suggested Readings	
Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002): Fundamentals of Statistics, Vol. I& II, 8th Edn. The World Press, Kolkata.	

Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.

Mood, A.M., Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edn. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.

Tukey, J.W. (1977): Exploratory Data Analysis, Addison-Wesley Publishing Co.

Agresti, A. (2010): Analysis of Ordinal Categorical Data, 2nd Edition, Wiley.

Freedman, D., Pisani, R. and Purves, R.(2014): Statistics, 4th Edition, W. W. Norton & Company.

3.2 Core P1 – Descriptive Statistics Lab

Descriptive Statistics Lab	2 Credits

List of Practical

1. Graphical representation of data.
2. Problems based on measures of central tendency.
3. Problems based on measures of dispersion.
4. Problems based on combined mean and variance and coefficient of variation.
5. Problems based on moments, skewness and kurtosis.
6. Fitting of quadratic and exponential function.
7. Karl Pearson correlation coefficient.
8. Correlation coefficient for a bivariate frequency distribution.
9. Lines of regression, angle between lines and estimated values of variables.
10. Spearman's rank correlation.
11. Box Plot and Q-Q Plot.
12. Calculation of price and quantity index numbers.

3.3 Core T2 – Probability and Probability Distributions-I

	4 Credits
Unit 1	
Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability – classical, statistical, and axiomatic.	
Unit 2	
Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications.	
Unit 3	
1. Random variables: discrete random variables, p.m.f. and c.d.f., statement of properties of c.d.f, illustrations and properties of random variables. 2. Standard discrete probability distributions: Binomial, Poisson, geometric, negative binomial, hyper-geometric, uniform.	
Unit 4	
Two dimensional random variables: discrete type, joint, marginal and conditional p.m.f and c.d.f., statement of properties of c.d.f, independence of variables, trinomial distribution.	
Suggested Readings	
Chung, K.L. (1983): Elementary Probability Theory with Stochastic Process, Springer / Narosa. Feller, W. (1968): An Introduction to Probability Theory & its Applications, John Wiley. Goon, A.M., Gupta, M.K. & Dasgupta, B. (1994): An Outline of Statistical Theory (Vol-1), World Press. Parzen, E. (1972): Modern Probability Theory and its Applications, John Wiley . Uspensky, J.V. (1937): Introduction to Mathematical Probability, McGraw Hill. Cacoullos, T. (1973): Exercises in Probability. Narosa. Rahman, N.A. (1983): Practical Exercises in Probability and Statistics, Griffen. Ross, S. (2002): A First Course in Probability, Prentice Hall.	

3.4 Core P2 – Probability and Probability Distributions-I Lab

	2 Credits
List of Practical	
1. Application problems based on Classical Definition of Probability. 2. Application problems based on Bayes Theorem. 3. Fitting of binomial distributions for n and p = q = ½. 4. Fitting of binomial distributions for given n and p. 5. Fitting of binomial distributions after computing mean and variance. 6. Fitting of Poisson distributions for given value of mean. 7. Fitting of Poisson distributions after computing mean. 8. Fitting of negative binomial distribution. 9. Fitting of suitable distribution. 10. Application problems based on binomial distribution. 11. Application problems based on Poisson distribution. 12. Application problems based on negative binomial distribution.	

3.5 Core T3 – Mathematical Analysis

	6 Credits
Unit -1	
Representation of real numbers as points on a line. Algebraic, Order and Completeness properties of R (Concepts only). Bounded and unbounded sets, neighbourhood of a point, Supremum and infimum. Functions Countable, Uncountable sets and Uncountability of R. Sequences and their convergence, monotonic sequences, bounded sequences, squeeze theorem Limits of some special sequences such as r^n, $\left(1+\frac{1}{n}\right)^n$ and $n^{\frac{1}{n}}$ Infinite series, positive termed series and their convergence, Comparison test, ratio test and root test. Absolute convergence of series, Leibnitz's test for the convergence of alternating series, Conditional convergence.	
Unit 2	
Review of limit, continuity and differentiability. Indeterminate form, L' Hospital's rule. Rolle's and Lagrange's Mean Value theorems. Taylor's theorem with lagrange's form of remainder (without proof). *Taylor's* Series Expansion of sinx, cosx, e^x $(1+x)^n$ and log $(1+x)$ Maxima and Minima of functions	
Unit 3	
Integral Calculus: definite integral (definition). Statements of properties, Fundamental Theorem of Integral Calculus. Improper Integral, Beta and Gamma functions: properties and relationship between them.	
Unit 4	
Functions of two variables and Partial Derivatives. Maxima and Minima of such Functions. Constrained Maximization and minimization, use of Lagrange Multiplier. Double Integral (intuitive-graphical approach), change of order of integration, transformation of variables and Jacobians (statement of relevant theorems and their uses).	

Suggested Readings

Malik S.C. and Savita Arora (1994): Mathematical Analysis, Second Edition, Wiley Eastern Limited, New Age International Limited, New Delhi.

Somasundram, D. And Chaudhary, B (1987).: A First Course in Mathematical Analysis, Narosa Publishing House, New Delhi.

Gupta S.L. and Nisha Rani (1995): Principles of Real Analysis, Vikas Publ. House Pvt. Ltd., New Delhi.

Apostol, T.M (1987).: Mathematical Analysis, Second Edition, Narosa Publishing House, New Delhi.

Shanti Narayan (1987): A course of Mathematical Analysis, 12th revised Edition, S. Chand & Co. (Pvt.) Ltd., New Delhi.

Singa,l M.K. and Singal A.R (2003): A First Course in Real Analysis, 24th Edition, R. Chand& Co., New Delhi.

Bartle, R. G. and Sherbert, D. R. (2002): Introduction to Real Analysis (3rd Edition), John Wiley and Sons (Asia) Pte. Ltd., Singapore.

Ghorpade, Sudhir R. and Limaye, Balmohan V. (2006): A Course in Calculus and Real Analysis, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint.

Chakraborty, Arnab (2014): Real Analysis, volumes 1, 2, 3, second edition. Sarat Book House.

3.6 Core T4 – Probability and Probability Distributions -II

	4 Credits

Unit 1

Continuous random variables, p.d.f. and c.d.f., illustrations and properties, univariate transformations with illustrations. Two dimensional random variables: continuous type, joint, marginal and conditional, p.d.f., and c.d.f.. Independence of two variables.

Unit 2

Mathematical Expectation (discrete and continuous): Single & bivariate random variables and their properties. Probability generating function. Moments. Moment generating function. Correlation coefficient, Conditional expectation and variance.

Probability Inequalities: Markov & Chebyshev.

Unit 3

Standard continuous probability distributions: uniform, normal, exponential, Cauchy, beta, gamma, lognormal, logistic, double exponential and Pareto along with their properties and limiting/approximation cases.

Unit 4

Bivariate Normal Distribution (BVN): p.d.f. of BVN, properties of BVN, marginal and conditional p.d.f. of BVN.

Suggested Readings

Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi.

Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.

Myer, P.L. (1970): Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.

Rohatgi, V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2nd Edn. (Reprint) John Wiley and Sons.

Ross, S. (2002): A First Course in Probability, Prentice Hall.

Feller, W. (1968): An Introduction to Probability Theory & its Applications, Vol-I, John Wiley

3.7 Core P4 – Probability and Probability Distributions -II Lab

	2 Credits
List of Practical	
1. Problems based on area property of normal distribution. 2. To find the ordinate for a given area for normal distribution. 3. Application based problems using n222ormal distribution. 4. Fitting of normal distribution when parameters are given. 5. Fitting of normal distribution when parameters are not given. 6. Problems similar to those in 1 to 5 in cases of other continuous distributions.	

3.8 Core T5 – Linear Algebra and Numerical Analysis

6 Credits

Unit 1

Vector spaces, Subspaces, sum of subspaces, Span of a set, Linear dependence and independence, dimension and basis, dimension theorem. Algebra of matrices - A review, theorems related to triangular, symmetric and skew symmetric matrices, idempotent matrices, orthogonal matrices, singular and non-singular matrices and their properties. Trace of a matrix, Adjoint and inverse of a matrix and related properties.

Unit 2

Determinants of Matrices: Definition, properties and applications of determinants for 3rd and higher orders, evaluation of determinants of order 3 and more using transformations. Symmetric and Skew symmetric determinants, product of determinants. Use of determinants in solution to the system of linear equations, row reduction and echelon forms, the matrix equations AX=B, solution sets of linear equations, linear independence, Applications of linear equations, inverse of a matrix.

Unit 3

Rank of a matrix, row-rank, column-rank, standard theorems on ranks, rank of the sum and the product of two matrices. Partitioning of matrices and simple properties. Characteristic roots and Characteristic vector, Properties of characteristic roots, Quadratic forms: Classification & canonical reduction. Linear transformation. Applications of Linear Algebra in Statistics.

Unit 4

Numerical Analysis: Polynomials and Difference Tables. Approximation of functions and Weierstrass Theorem (statement). Lagrange and Newton formulae for Interpolation. Trapezoidal and Simpson's 1/3 Rules for approximations of definite integrals. Approximate solutions of Numerical Equations by Fixed-point Iteration and Newton-Raphson methods. Conditions of convergence.

Suggested Readings

Lay David C (2000): Linear Algebra and its Applications, Addison Wesley.

Schaum's Outlines (2006): Linear Algebra, Tata McGraw-Hill Edition, 3rd Edition.

Krishnamurthy, V., Mainra V.P. and Arora J.L.: An Introduction to Linear Algebra (II, III, IV, V).

Biswas, S. (1997): A Textbook of Matrix Algebra, New Age International.

Gupta, S.C (2008): An Introduction to Matrices (Reprint). Sultan Chand & Sons.

Artin, M (1994): Algebra. Prentice Hall of India.

Datta, K.B (2002): Matrix and Linear Algebra. Prentice Hall of India Pvt. Ltd.

Hadley, G (2002): Linear Algebra. Narosa Publishing House (Reprint).

Searle, S.R (1982): Matrix Algebra Useful for Statistics. John Wiley &Sons.

Chakraborty, Arnab (2014): Linear Algebra, first edition. Sarat Book House.

Jain, M. K., Iyengar, S. R. K. and Jain, R. K. (2003): Numerical methods for scientific and engineering computation, New age International Publisher, India.

Mukherjee, Kr. Kalyan (1990): Numerical Analysis. New Central Book Agency.

Sastry, S.S. (2000): Introductory Methods of Numerical Analysis, 3rd edition, Prentice Hall of India Pvt. Ltd., New Del.

Scarborough, J.B. (1966): Numerical Mathematical Analysis. Oxford and IBH Publishing.

3.9 Core T6 – Demography and Vital Statistics

4 Credits

Unit 1

Population Theories: Coverage and content errors in demographic data, use of balancing equations and Chandrasekaran-Deming formula to check completeness of registration data. Adjustment of age data, use of Myer and UN indices, Population composition, dependency ratio.

Unit 2

Introduction and sources of collecting data on vital statistics, errors in census and registration data. Measurement of population, rate and ratio of vital events. Measurements of Mortality: Crude Death Rate (CDR), Specific Death Rate (SDR), Infant Mortality, Rate (IMR) and Standardized Death Rates.

Unit 3

Stationary and Stable population, Central Mortality Rates and Force of Mortality. Life (Mortality) Tables: Assumption, description, construction of Life Tables and Uses of Life Tables. Measurements of Fertility: Crude Birth Rate (CBR), General Fertility Rate (GFR), Specific Fertility Rate (SFR) and Total Fertility Rate (TFR).

Unit 4

Measurement of Population Growth: Crude rates of natural increase, Pearl's Vital Index, Gross Reproduction Rate (GRR) and Net

Reproduction Rate (NRR). Population Estimation, Projection and Forecasting: Use of A.P. and G.P. methods for population estimates,

Fitting of Logistic curve for population forecasting using Rhode's method.

Suggested Readings

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

Goon, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edition, World Press.

Biswas, S. (1988): Stochastic Processes in Demography & Application, Wiley Eastern Ltd.

Keyfitz, N and Caswell. H (2005): Applied Mathematical Demography, Springer.

Chattopadhyay, & Saha, A.K. (2012): Demography: Techniques & Analysis, Viva Books

Ramakuar, R. and Gopal, Y.S. (1986): Technical Demography. Wiley Eastern Ltd

3.10 Core P6 – Demography and Vital Statistics Lab

	2 Credits
List of Practical	
1. To calculate CDR and Age Specific death rate for a given set of data 2. To find Standardized death rate by:- a. Direct method b. 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 8. Population Estimation.	

3.11 Core T7 – Statistical Computing using C/C++ Programming

	4 Credits

Unit 1

1. Components, basic structure programming, character set, C/C++ tokens, Keywords and Identifiers and execution of a C/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.
2. Operators and Expressions: Arithmetic, relational, logical, assignment, increment/decrement, operators, precedence of operators in arithmetic, relational and logical expression. Implicit and explicit type conversions in expressions, library functions. Managing input and output operations: reading and printing formatted and unformatted data

Unit 2

1. Decision making and branching - if...else, nesting of if...else, else if ladder, switch, conditional (?) operator. Looping in C/C++: for, nested for, while, do…while, and jumps in and out of loops.
2. 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 3

User- defined functions: A multi-function program using user-defined functions, definition of functions, return values and their types, function prototypes and calls. Category of Functions : no arguments and no return values, arguments but no return values , arguments with return values, no arguments but returns a value, functions that return multiple values. Recursion function. Passing arrays to functions, Storage class of Variables.

Unit 4

1. 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, arrays of pointers, pointers as function arguments, functions returning pointers
2. Structure: Definition and declaring, initialization, accessing structure members, copying and comparison of structure variables, array of structures, structure pointers. Dynamic memory allocation functions: malloc, calloc and free.

3. Pre-processors: Macro substitution, macro with argument
4. File inclusion in C/C++: Defining and opening a file (only r, w and a modes), closing a file, I/O operations on files-fscanf and fprintf functions.

Suggested Readings

Kernighan, B.W. and Ritchie, D.(1988): C Programming Language,2nd Edition, Prentice Hall.

Balagurusamy, E. (2011): Programming in ANSI C, 6th Edition Tata McGraw Hill.

Gottfried, B.S. (1998): Schaum's Outlines: Programming with C, 2nd Edition, TataMcGraw Hill.

3.12 Core P7– Statistical Computing using C/C++ Programming Lab

	2 Credits
List of Practical	

1. Plot of a graph y = f(x).
2. Roots of a quadratic equation (with imaginary roots also).
3. Sorting of an array and hence finding median.
4. Mean, Median and Mode of a Grouped Frequency Data.
5. Variance and coefficient of variation of a Grouped Frequency Data.
6. Preparing a frequency table.
7. Random number generation from uniform, exponential, calculate sample mean and variance and compare with population parameters.
8. Matrix addition, subtraction, multiplication, Transpose and Trace.
9. Fitting of Binomial, Poisson distribution.
10. Compute ranks and then calculate rank correlation (without tied ranks).
11. Fitting of lines of regression.
12. Numerical methods: Solving one-variable equations using Newton-Raphson method.
13. Trapezoidal rule for numerical integration.
14. Solving a linear system of equation.

3.13 Core T8 – Survey Sampling and Indian Official Statistics

	4 Credits

Unit 1

1. Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors.
2. Types of sampling: non-probability and probability sampling, basic principle of sample survey, simple random sampling with and without replacement, definition and procedure of selecting a sample,
3. Estimates of: population mean, total and proportion, variances of these estimates, estimates of their variances and sample size determination.

Unit 2

1. Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. Practical difficulties in allocation, estimation of gain in precision, post stratification and its performance.
2. Systematic Sampling: Technique, estimates of population mean and total, variances of these estimates (N = n x k). Comparison of systematic sampling with SRS & stratified sampling in the presence of linear trend and corrections.

Unit 3

Introduction to Ratio and regression methods of estimation, first approximation to the population mean and total (for SRS of large size), MSE of these estimates and estimates of these variances, MSE in terms of correlation coefficient for regression method of estimation and their comparison with SRS. Cluster sampling (equal clusters only) estimation of population mean and its variance, comparison (with and without randomly formed clusters). Concept of sub sampling. Two-stage Sampling, Estimation of Population mean and variance of the estimate.

Unit 4

1. An outline of present official statistical system in India, Methods of collection of official statistics, their reliability and limitations. Role of Ministry of Statistics & Program Implementation (MoSPI), Central Statistical Office (CSO), National Sample Survey Office (NSSO), Registered General Office and National Statistical Commission. Government of India's Principal publications containing data on the topics such as Agriculture, price, population, industry, finance and employment.

2. Consumer price Index, Wholesale price index number and index of industrial production.
3. National Income: Basic idea and a brief description of income, expenditure and production approaches.

Suggested Readings

Cochran, W.G. (1984): Sampling Techniques (3rd Ed.), Wiley Eastern.

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

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. (2008): Fundamentals of Statistics (Vol.2), World Press.

Guide to current Indian Official Statistics, Central Statistical Office, GOI, and New Delhi.

http://mospi.nic.in/

3.14 Core P8 – Survey Sampling and Indian Official Statistics Lab

	2 Credits

List of Practical

1. To select a 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 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 above two methods relative to SRS.
5. Estimation of gain in precision in stratified sampling.
6. Comparison of systematic sampling with stratified sampling and SRS in the presence of a linear trend.
7. Ratio and Regression estimation: Calculate the population mean or total of the population. Calculate mean squares. Compare the efficiencies of ratio and regression estimators relative to SRS.
8. Cluster sampling: estimation of mean or total, variance of the estimate.
9. Two-stage Sampling.
10. Tabular and graphical exercises based on available official statistics.
11. Construction of Consumer and wholesale price index numbers.

3.15 Core T9 – Statistical Inference-I and Sampling Distribution

	4 Credits

Unit 1

Problems of Statistical Inference: Population & parameter, random sample & statistic, Point and Interval Estimation, Confidence level, Testing of Hypothesis, Null and alternative hypotheses, level of significance, Type I and Type II errors, their probabilities and critical region. Sampling distribution of a statistic.

Unit 2

1. Derivation of the sampling distribution of sample mean and variance for a normal population, standard errors of sample mean, sample variance and sample proportion.
2. **Exact sampling distribution:** Definition and derivation of p.d.f. of χ^2 with n degrees of freedom (d.f.), nature of p.d.f. curve for different degrees of freedom, mean, variance, m.g.f., additive property of $\chi 2$ distribution.
3. **Exact sampling distributions:** Student's and Fisher's t-distributions, Derivation of its p.d.f., nature of probability curve with different degrees of freedom, mean, variance and limiting form of t distribution.
4. **Snedecor's F-distribution:** Derivation of p.d.f., nature of p.d.f. curve with different degrees of freedom, mean, variance. Distribution of 1/F (n_1, n_2). Relationship between t, F and $\chi 2$ distributions.
5. Distribution of sample correlation coefficient in the null case.

Unit 3

Order Statistics: Introduction, distribution of the rth order statistic, smallest and largest order statistics. Joint distribution of rth and sth order statistics, distribution of sample median and sample range.

Unit 4

Exact tests and confidence intervals: classical and p-value approaches. Binomial proportion(s), Poisson mean(s), Univariate Normal mean (s), standard deviation(s), Standard tests related to Bivariate normal parameters.

Suggested Books

Goon, Gupta, and Dasgupta (2003): An Outline of Statistical Theory, Vol. I, World Press, Kolkata.

Rohatgi V. K. & Saleh,. (2009): An Introduction to Probability and Statistics. John Wiley & Sons.

Hogg, R.V. & Tanis, E.A. (2009): A Brief Course in Mathematical Statistics. Pearson Edn

Johnson, R.A. and Bhattacharya, G.K. (2001): Statistics-Principles and Methods, 4th Edn.

Casella, G. and Berger R.L (2002). : Statistical Inference, 2nd Edn. Thomson Learning.

3.16 Core P9 – Statistical Inference-I & Sampling Distributions Lab

	2 Credits
List of Practical	
1. Testing of significance for single proportion and difference of two proportions. 2. Testing of significance for single Poisson mean and difference of two Poisson means. 3. Testing of significance and confidence intervals for single mean and difference of two means. 4. Testing of significance and confidence intervals for single standard deviation and difference of two standard deviations. 5. Testing of parameters under bivariate normal distribution.	

3.17 Core T10 – Time Series Analysis

	4 Credits

Unit 1

1. Introduction to time series data, application of time series from various fields.
2. Modelling time series as deterministic function plus IID errors:
3. Components of a time series (trend, cyclical and seasonal patterns, random error) Decomposition of time series.
4. **Estimation of trend:** free hand curve method, method of moving averages, fitting various mathematical curves and growth curves.

Unit 2

1. Effect of elimination of trend on other components of the time series.
2. Estimation of seasonal component by Method of simple averages,
3. Notions of multiplicative models: ratio to Trend.

Unit 3

1. **Introduction to stochastic modelling:** Concept of stationarity. Illustration of how a stationary time series may show temporal patterns. Stationarity in mean.
2. **Box-Jenkins modelling:** Moving-average (MA) process and Autoregressive (AR) process of orders one and two. ACF, PACF and their graphical use in guessing the order of AR and MA processes. Estimation of the parameters of AR (1) and AR (2) using Yule-Walker equations.

Unit 4

Forecasting: Exponential smoothing methods, Short term forecasting methods: Brown's discounted regression,

Suggested Readings

Chatfield C. (1980): The Analysis of Time Series – An Introduction, Chapman & Hall.

Kendall M.G. (1976): Time Series, Charles Griffin.

Brockwell and Davis (2010): Introduction to Time Series and Forecasting (Springer Texts in Statistics), 2nd Edition

3.18 Core P10 – Time Series Analysis Lab

	2 Credits
List of Practical	

1. Plotting a real life time series, and detecting various features (trend, periodic behaviours etc). Suggested data sets:
    a. Sun spot data
    b. Dollar-Rupee exchange rates
    c. Stock market data
2. Fitting and plotting of mathematical curves:
    a. modified exponential curve
    b. Gompertz curve
3. Fitting of trend by Moving Average Method
4. Plotting detrended series.
5. Measurement of Seasonal indices Ratio-to-Moving Average method
6. Plotting ACF and PACF of a given time series
7. Using Yule-Walker equation to fit AR (1) and AR (2) models to real life data.
8. Forecasting by short term forecasting methods.
9. Forecasting by exponential smoothing

3.19 Core T11 – Statistical Inference - II

	4 Credits
Unit 1	
Limit laws: Sequence of random variables, convergence in probability, convergence in mean square and convergence in distribution and their interrelations, W.L.L.N. and their applications, De-Moivre Laplace Limit theorem, Statement of Central Limit Theorem (C.L.T.) for i.i.d. variates, applications of C.L.T.	
Unit 2	
Estimation: Concepts of estimation, unbiasedness, sufficiency, consistency and efficiency. Factorization theorem. Complete statistic, Minimum variance unbiased estimator (MVUE), Rao-Blackwell and Lehmann-Scheffe theorems and their applications. Cramer-Rao inequality (statement and applications) and MVB estimators. **Methods of Estimation:** Method of moments, method of maximum likelihood estimation, method of minimum Chi-square and statements of their properties	
Unit 3	
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,Most powerful test, uniformly most powerful test, Neyman- Pearson Lemma (statement and proof of sufficiency part only) and its applications to construct uniformly most powerful test, unbiased test (definition only). Likelihood ratio test, properties of likelihood ratio tests (without proof).	
Unit 4	
Large Sample Theory: Transformations of Statistics to stabilize variance: derivation and uses of Sin-1, square root. Uses of logarithmic and z-transformations. Large sample tests for binomial proportions, Poisson means (single and two independent samples cases) and correlation coefficients. Large Sample distribution of Pearsonian $\chi 2$ –statistic and its uses.	

Suggested Books

Goon A.M., Gupta M.K.: Das Gupta.B. (2005), Outline of Statistics, Vol. I & II, World Press, Calcutta.

Rohatgi V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2ndEdn. (Reprint) John Wiley and Sons.

Miller, I. and Miller, M. (2002) : John E. Freund's Mathematical Statistics (6th addition, low price edition), Prentice Hall of India.

Dudewicz, E. J., and Mishra, S. N. (1988): Modern Mathematical Statistics. John Wiley & Sons.

Mood A.M, Graybill F.A. and Boes D.C, Introduction to the Theory of Statistics, McGraw Hill.

Bhat B.R, Srivenkatramana T and Rao Madhava K.S. (1997) Statistics: A Beginner's Text, Vol. I, New Age International (P) Ltd.

Snedecor G.W and Cochran W.G. (1967) Statistical Methods. Lowa State University Press.

Casella, G. and Berger R.L. (2002). : Statistical Inference, 2nd Edn. Thomson Learning.

3.20 Core P11 – Statistical Inference – II Lab

	2 Credits
List of Practical	
1. Unbiased estimators (including unbiased but absurd estimators). 2. Consistent estimators, efficient estimators and relative efficiency of estimators. 3. Maximum Likelihood Estimation. 4. Estimation by the method of moments, minimum Chi-square. 5. Type I and Type II errors. 6. Most powerful critical region. 7. Uniformly most powerful critical region. 8. Power curves. 9. Likelihood ratio tests for simple null hypothesis against simple alternative hypothesis. 10. Likelihood ratio tests for simple null hypothesis against composite alternative hypothesis. 11. Large sample tests.	

3.21 Core T12 – Linear Models

	4 Credits
Unit 1	
Gauss-Markov set-up: Theory of linear estimation, Estimability of linear parametric functions, Method of least squares, Gauss-Markov theorem, Estimation of error variance. Fundamental Theorems on least squares (statements only).	
Unit 2	
Regression analysis: Multiple Regression. Estimation and hypothesis testing in case of simple and multiple regression models. Tests for parallelism and identity, linearity of simple regression.	
Unit 3	
Analysis of variance: Definitions of fixed, random and mixed effect models, analysis of variance and covariance in one-way classified data for fixed effect models, analysis of variance and covariance (with one concomitant variable) in two-way classified data with equal number of observations per cell, for fixed effect models. Analysis of variance one-way classified data for random effect models.	
Unit 4	
Regression Diagnostics: Model checking: Prediction from a fitted model, Violation of usual assumptions concerning normality, Homoscedasticity and collinearity, Diagnostics using quantile-quantile plots.	
Suggested Readings	
Weisberg, S. (2005). Applied Linear Regression (Third edition). Wiley. Wu, C. F. J. And Hamada, M. (2009). Experiments, Analysis, and Parameter Design Optimization (Second edition), John Wiley. Renchner, A. C. And Schaalje, G. B. (2008). Linear Models in Statistics (Second edition), John Wiley and Sons. Scheffe, H. (1959): The Analysis of Variance, John Wiley.	

3.22 Core P12 – Linear Models Lab

	2 Credits
List of Practical	
1. Simple Linear Regression. 2. Multiple Regression. 3. Tests for Linear Hypothesis. 4. Lack of fit. 5. Analysis of Variance of a one way classified data. 6. Analysis of Variance of a two way classified data with one observation per cell. 7. Analysis of Covariance of a one way classified data with one concomitant variable. 8. Analysis of Covariance of a two way classified data with one concomitant variable. 9. Analysis of Variance of a one way classified data for random effect model.	

3.23 Core T13 – Design of Experiments

	4 Credits

Unit 1

Experimental designs: Role, historical perspective, terminology: Treatments, Experimental units & Blocks, Experimental error, Basic principles of Design of Experiments (Fisher).

Uniformity trials, fertility contour maps, choice of size and shape of plots and blocks in Agricultural experiments. Uses in Industrial Experiments.

Unit 2

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 RBD and LSD.

Unit 3

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

Unit 4

Split Plot Design and Strip arrangements.

Suggested Readings

Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House.

Das, M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley Eastern Ltd.

Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics. Vol. II, 8thEdn. World Press, Kolkata.

Kempthorne, O. (1965): The Design and Analysis of Experiments. John Wiley.

Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley.

Wu, C. F. J. And Hamada, M. (2009). Experiments, Analysis, and Parameter Design Optimization (Second edition), John Wiley.

Dean A M and Voss, D. (1999): Design and Analysis of Experiments. Springer Texts in Statistics

3.24 Core P13 – Design of Experiments Lab

	2 Credits
List of Practical	
1. Analysis of a CRD. 2. Analysis of an RBD. 3. Analysis of an LSD. 4. Analysis of an RBD with one missing observation. 5. Analysis of an LSD with one missing observation. 6. Analysis of 2^2 and 2^3 factorial in CRD and 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 Split Plot and Strip Plot designs.	

3.25 Core T14 – Multivariate Analysis and Nonparametric Methods

	4 Credits

Unit 1

1. **Multivariate Data:** multiple regression, multiple and partial correlation coefficients.
2. **Random Vector:** Probability mass/density functions, Distribution function, mean vector & Dispersion matrix, Marginal & Conditional distributions. Multiple and partial correlation coefficient.

Unit 2

Multivariate Normal distribution and its properties. Multinomial Distribution and its properties. Tests for Multiple and partial correlation coefficients.

Unit 3

Applications of Multivariate Analysis: Principal Components Analysis and Factor Analysis (Application Oriented discussion, derivations not required)

Unit 4

Nonparametric Tests: Introduction and Concept, Test for randomness based on total number of runs, Empirical distribution function, **One Sample Tests:** Kolmogrov - Smirnov, Sign, Signed rank. Wilcoxon-Mann-Whitney test. Kruskal-Wallis test.

Suggested Readings

Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rd Edn., John Wiley

Muirhead, R.J. (1982): Aspects of Multivariate Statistical Theory, John Wiley.

Kshirsagar, A.M. (1972): Multivariate Analysis, 1st Edn. Marcel Dekker.

Johnson, R.A. And Wichern, D.W. (2007): Applied Multivariate Analysis, 6th Edn., Pearson & Prentice Hall

Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002): Fundamentals of Statistics, Vol. I, 8th Edn. The World Press, Kolkata.

Gibbons, J. D. and Chakraborty, S (2003): Nonparametric Statistical Inference. 4th Edition. Marcel Dekker, CRC.

Rohatgi, V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2nd Edn. (Reprint) John Wiley and Sons

3.26 Core P14 – Multivariate Analysis & Nonparametric Methods Lab

	2 Credits
List of Practical	
1. Test for Multiple Correlation. 2. Test for Partial Correlation. 3. Multivariate Normal Distribution. 4. Principal Components Analysis. 5. Factor Analysis. 6. Test for randomness based on total number of runs. 7. Kolmogorov -Smirnov test for one sample. 8. Sign test. 9. Signed rank test. 10. Wilcoxon-Mann-Whitney test. 11. Kruskal-Wallis test.	

4. Department Specific Electives Subjects Syllabus

4.1 DSE T1 – Statistical Quality Control

4 Credits

Unit 1

Quality: Definition, dimensions of quality, historical perspective of quality control and improvements starting from World War II, historical perspective of Quality Gurus and Quality Hall of Fame. Quality system and standards.

Unit 2

Introduction to ISO quality standards, Quality registration. Statistical Process Control - Seven tools of SPC, chance and assignable Causes of quality variation. Statistical Control Charts-Construction and Statistical basis of 3-σ Control charts, Rational Sub-grouping.

Unit 3

1. **Control charts for variables:** X-bar & R-chart, X-bar & s-chart.
2. **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 4

1. **Acceptance sampling plan:** Principle of acceptance sampling plans. Single sampling plan their OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, use and interpretation of Dodge and Romig's sampling inspection plan tables.
2. **Introduction to Six-Sigma:** Overview of Six Sigma. Lean Manufacturing and Total Quality Management (TQM).

Suggested Readings

Montogomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.

Goon A.M., Gupta M.K. & Dasgupta B. (2002): Fundamentals of Statistics, Vol. II, World Press, Kolkata

Mukhopadhyay, P (2011): Applied Statistics, 2nd edn, Books and Allied (P) Ltd.

Montogomery, D. C. and Runger, G.C. (2008): Applied Statistics and Probability for Engineers, 3rd Edition reprint, Wiley India Pvt. Ltd.

Ehrlich, B. H (2002): Transactional Six Sigma and Lean Servicing, 2nd Ed St. Lucie Press

4.2 DSE P1 – Statistical Quality Control Lab

	2 Credits
List of Practical	
1. Construction and interpretation of statistical control charts a. X-bar & R-chart b. X-bar & s-chart c. np-chart d. p-chart e. c-chart f. u-chart 2. Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves 3. Calculation of process capability	

4.3 DSE T2 – Econometrics

	4 Credits
Unit 1	
Introduction: Objective behind building econometric models, nature of econometrics, model building, role of econometrics, structural and reduced forms. Estimation under linear restrictions. Dummy variables, Qualitative data.	
Unit 2	
Multicollinearity: Introduction and concepts, detection of multi-collinearity, consequences, tests and solutions of multicollinearity.	
Unit 3	
Autocorrelation: Concept, consequences of auto correlated disturbances, detection and solution of autocorrelation. Generalized least squares estimation.	
Unit 4	
Heteroscedastic disturbances: Concepts and efficiency of Aitken estimator with OLS estimator under heteroscedasticity. Consequences of heteroscedasticity. Tests and solutions of heteroscedasticity. **Errors in variables:** Correlation between error and regressors. Instrumental variable method (Single-equation model with one explanatory variable)	
Suggested Readings	
Gujarati, D. and Sangeetha, S. (2007): Basic Econometrics, 4th Edition McGraw Hill Companies Johnston, J. (1972): Econometric Methods, 2nd Edition, McGraw Hill International. Koutsoyiannis, A. (2004): Theory of Econometrics, 2nd Edition, , Palgrave Macmillan Limited Maddala, G.S. and Lahiri, K. (2009): Introduction to Econometrics, 4th Edition, John Wiley & Sons.	

4.4 DSE P2 – Econometrics Lab

	2 Credits
List of Practical	
1. Problems related to consequences of Multicollinearity. 2. Diagnostics of Multicollinearity. 3. Problems related to consequences of Autocorrelation (AR(I)). 4. Diagnostics of Autocorrelation. 5. Problems related to consequences Heteroscedasticity. 6. Diagnostics of Heteroscedasticity. 7. Estimation of problems of General linear model under Heteroscedastic distance terms. 8. Problems on Autoregressive models. 9. Problems on Instrumental variable.	

4.5 DSE T3 – Survival Analysis

	4 Credits
Unit 1	
Survival Analysis: Functions of survival times, survival distributions and their applications-exponential, gamma, Weibull, Rayleigh, lognormal distributions, and distribution having bath-tub shaped hazard function. Mean Residual Time.	
Unit 2	
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.	
Unit 3	
Non-parametric methods: Actuarial and Kaplan-Meier methods for estimating survival function and variance of the Estimator.	
Unit 4	
Competing Risk Theory: Indices for measurement of probability of death under competing risks and their inter-relations. Estimation of probabilities of death using maximum likelihood principle and modified minimum Chi-square methods.	
Suggested Readings	
Lee, E.T. and Wang, J.W. (2003): Statistical Methods for Survival data Analysis, 3rd Edition, John Wiley and Sons. Kleinbaum, D.G. (1996): Survival Analysis, Springer. Chiang, C.L. (1968): Introduction to Stochastic Processes in Bio Statistics, John Wiley and Sons. Indrayan, A. (2008): Medical Biostatistics, 2nd Edition Chapman and Hall/CRC.	

4.6 DSE P3 – Survival Analysis Lab

2 Credits

List of Practical

1. To estimate survival function.
2. To determine death density function and hazard function.
3. To identify type of censoring and to estimate survival time for type I censored data.
4. To identify type of censoring and to estimate survival time for type II censored data.
5. To identify type of censoring and to estimate survival time for 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 Non-parametric methods with Actuarial methods.
10. To estimate the survival function and variance of the estimator using Non-parametric methods with Kaplan-Meier method.

4.7 DSE T4 – Stochastic Processes and Queuing Theory

	4 Credits
Unit 1	
Stochastic Process: Introduction, Stationary Process.	
Unit 2	
Markov Chains: Definition of Markov Chain, transition probability matrix, order of Markov chain, Higher transition probabilities. Generalization of independent Bernoulli trials, classification of states and chains, stability of Markov system	
Unit 3	
Poisson Process: postulates of Poisson process, properties of Poisson process, inter-arrival time, pure birth process, Yule Furry process, birth and death process, pure death process.	
Unit 4	
Queuing System: General concept, steady state distribution, queuing model, M/M/1 with finite and infinite system capacity, waiting time distribution (without proof).	
Suggested Readings	

Medhi, J. (2009): Stochastic Processes, New Age International Publishers.

Basu, A.K. (2005): Introduction to Stochastic Processes, Narosa Publishing.

Bhat,B.R.(2000): Stochastic Models: Analysis and Applications, New Age International Publishers.

Taha, H. (1995): Operations Research: An Introduction, Prentice- Hall India.

Feller, William (1968): Introduction to probability Theory and Its Applications, Vol I, 3rd Edition, Wiley International.

4.8 DSE P4 – Stochastic Processes and Queuing Theory Lab

	2 Credits

List of Practical

1. Calculation of transition probability matrix.
2. Identification of characteristics of reducible and irreducible chains.
3. Identification of types of classes.
4. Identification of ergodic transition probability matrix
5. Stationarity of Markov chain.
6. Computation of probabilities in case of generalizations of independent Bernoulli trials.
7. Calculation of probabilities for given birth and death rates and vice versa.
8. Calculation of probabilities for Birth and Death Process.
9. Calculation of probabilities for Yule Furry Process.
10. Computation of inter-arrival time for a Poisson process.
11. Calculation of Probability and parameters for (M/M/1) model and change in behavior of queue as N tends to infinity.
12. Calculation of generating function and expected duration for different amounts of stake.

4.9 DSE T5 – Operations Research

	4 Credits
Unit 1	
Introduction to Operations Research, phases of O.R., model building, various types of O.R. problems. Linear Programming Problem, Mathematical formulation of the L.P.P, graphical solutions of a L.P.P. Simplex method for solving L.P.P. Charne's M-technique for solving L.P.P. involving artificial variables. Special cases of L.P.P. Concept of Duality in L.P.P: Dual simplex method.	
Unit 2	
Transportation Problem: Initial solution by North West corner rule, Least cost method and Vogel's approximation method (VAM), MODI's method to find the optimal solution, special cases of transportation problem. Assignment problem: Hungarian method to find optimal assignment, special cases of assignment problem.	
Unit 3	
Game theory: Rectangular game, minimax-maximin principle, solution to rectangular game using graphical method, dominance and modified dominance property to reduce the game matrix and solution to rectangular game with mixed strategy.	
Unit 4	
Inventory Management: ABC inventory system, characteristics of inventory system. EOQ Model and its variations, with and without shortages, Quantity Discount Model with price breaks.	
Suggested Readings	
Taha, H. A. (2007): Operations Research: An Introduction, 8 Hall of India. KantiSwarup, Gupta, P.K. and Manmohan (2007): Operations Research, 13th Edition, Sultan Chand and Sons. Hadley, G: (2002) : Linear Programming, Narosa Publications Hillier, F.A and Lieberman, G.J. (2010): Introduction to Operations Research- Concepts and cases, 9th Edition, Tata McGraw Hill	

4.10 DSE P5 – Operations Research Lab

	2 Credits
List of Practical (Using TORA/WINQSB/LINGO)	

1. Mathematical formulation of L.P.P and solving the problem using graphical method, Simplex technique and Charne's Big M method involving artificial variables.
2. Identifying Special cases by Graphical and Simplex method and interpretation
    a. Degenerate solution
    b. Unbounded solution
    c. Alternate solution
    d. Infeasible solution
3. Allocation problem using Transportation model.
4. Allocation problem using Assignment model.
5. Problems based on game matrix.
6. Graphical solution to $m \times 2$ / $2 \times n$ rectangular game.
7. Mixed strategy.
8. To find optimal inventory policy for EOQ models and its variations.
9. To solve all-units quantity discounts model.

4.15 DSE T8 – Project Work

	6 Credits
Analysing Social Change in Historical Perspective	
Objective: The aim of the course is to initiate students to write and present a statistical report, under the supervision of a faculty, on some area of human interest. The project work will provide hands on training to the students to deal with data emanating from some real life situation and propel them to dwell on some theory or relate it to some theoretical concepts.	

5. Syllabus of Skill Enhancement Subjects

5.1 SEC T1 – Statistical Data Analysis Using R

2 Credits

Unit 1

1. **Introduction to R:** Installation, commandline environment, overview of capabilities, brief mention of open source philosophy.
2. **R as a calculator:** The four basic arithmetic operations. Use of parentheses nesting up to arbitrary level. The power operation. Evaluation of simple expressions. Quotient and remainder operations for integers.
3. Standard functions, e.g., sin, cos, exp, log.

Unit 2

1. **The different types of numbers in R**: Division by zero leading to Inf or -Inf. NaN. NA. No need to go into details.
2. **Variables.** Creating a vector using c( ), seq( ) and colon operator. How functions map over vectors.
3. **Functions to summarise a vector**: sum, mean, sd, median etc. Extracting a subset from the vector (by index, by property).
4. **R as a graphing calculator:** Introduction to plotting. Plot ( ), lines( ), abline( ). No details about the graphics parameters except colour and line width. Barplot, Pie chart and Histogram. Box plot. Scatter plot and simple linear regression using lm(y~x).

Unit 3

1. **Matrix operations in R:** Creation. Basic operations. Extracting submatrices.
2. **Loading data from a file**: read.table ( ) and read.csv ( ). Mention of head=TRUE and head=FALSE. Dataframes. Mention that these are like matrices, except that different columns may be of different types.

Unit 4

Problems on discrete and continuous probability distributions

Suggested Readings:

Gardener, M (2012): Beginning R: The Statistical Programming Language, Wiley Pub

Braun W J, Murdoch D J (2007): A First Course in Statistical Programming with R. Cambridge University Press

A simple introduction to R by Arnab Chakraborty (freely available at http://www.isical.ac.in/~arnabc/)

R for beginners by Emmanuel Paradis (free available at http://cran.r-project.org/pub/R/doc/contrib/Paradis-rdebuts_en.pdf)

5.2 SEC T2 – Research Methodology

	2 Credits
Unit 1	
What is Research? Role of Research in important areas. Characteristics of Scientific Method. Process of research: Stating Hypothesis or Research question, Concepts & Constructs, Units of analysis & characteristics of interest, Independent and Dependent variables, Extraneous or Confounding variables. Measurements and scales of Measurements. Types of research: Qualitative & Quantitative Research, Longitudinal Research, Survey & Experimental Research.	
Unit 2	
Survey Methodology and Data Collection, sampling frames and coverage error, non-response.	
Unit 3	
Review of various techniques for data analysis covered in core statistics papers, techniques of interpretation, precaution in interpretation.	
Unit 4	
Develop a questionnaire, collect survey data pertaining to a research problem (such as gender discriminations in private v/s government sector, unemployment rates, removal of subsidy, impact on service class v/s unorganized sectors), questions and answers in surveys, Internal & External validity, , interpret the results and draw inferences. Formats and presentations of Reports – an overview.	
Suggested Readings	
Kothari, C.R. (2009): Research Methodology: Methods and Techniques, 2nd Revised Edition reprint, New Age International Publishers. Kumar, R (2011): Research Methodology: A Step - by - Step Guide for Beginners, SAGE publications.	

5.3 SEC T3 – Monte Carlo Method

	2 Credits
Unit 1	
1. Using the computer for random number generation. (treated as a black box) 2. A brief look at some popular approaches (no mathematical justification needed). 3. Simulating a coin toss, a die roll and a card shuffle.	
Unit 2	
1. CDF inversion method. Simulation from standard distributions. 2. Finding probabilities and moments using simulation.	
Unit 3	
Monte Carlo integration. Basic idea of importance sampling. MCMC not included.	
Unit 4	
1. Generating from Binomial and Poisson distributions, and comparing the histograms to the PMFs. 2. Generating from Uniform (0,1) distribution, and applying inverse CDF transforms. 3. Simulating Gaussian distribution using Box-Muller method. 4. Approximating the expectation of a given function of a random variable using simulation. 5. Graphical demonstration of the Law of Large Numbers. 6. Approximating the value of pi by simulating dart throwing.	
Suggested Readings	
Shonkwiler, Ronald W. and Mendivil, Franklin (2009): Explorations in Monte Carlo Methods (Undergraduate Texts in Mathematics) Carsey, Thomas M. and Harden, Jeffrey J. (2014): Monte Carlo Simulation and Resampling Methods for Social Science.	

5.4 SEC T4 – Data Base Management Systems

	2 Credits

Unit 1

Introduction: Overview of Database Management System, Introduction to Database Languages, advantages of DBMS over file processing systems.

Unit 2

Relational Database Management System: The Relational Model, Introduction to SQL: Basic Data Types, Working with relations of RDBMS: Creating relations e.g. Bank, College Database (create table statement).

Unit 3

Modifying relations (alter table statement), Integrity constraints over the relation like Primary Key , Foreign key, NOT NULL to the tables, advantages and disadvantages of relational Database System.

Unit 4

Database Structure: Introduction, Levels of abstraction in DBMS, View of data, Role of Database users and administrators, Database Structure: DDL, DML, Data Manager (Database Control System).Types of Data Models Hierarchical databases, Network databases, Relational databases, Object oriented databases.

Suggested Readings

Gruber, M (1990): Understanding SQL, BPB publication.

Silberschatz, A, Korth, H and Sudarshan, S (2011) "Database System and Concepts", 6th Edition McGraw-Hill.

Desai, B. (1991): Introduction to Database Management system, Galgotia Publications.

6.0: Syllabus for General Pass Course with Statistics

6.11: PCC T1 – Descriptive Statistics

	4 credits
Unit 1	**10 Classes**
Type of data – Primary and secondary data, quantitative and qualitative data, nominal and ordinal data, cross section and time series data, discrete and continuous data. **Presentation of data –** Presentation by tables and by diagrams, construction of tables with one, two and three factors of classification, diagrammatic representations, frequency distributions for discrete and continuous data, graphical distribution by histogram and frequency polygon, cumulative frequency distributions (inclusive and representation of a frequency conclusive method) & Ogives.	
Unit 2	**20 Classes**
Analysis of quantitative data – Measure of location or central tendency, dispersion, moments and quartiles, measure of skewness and kurtosis for both grouped and ungrouped data.	
Unit 3	**20 Classes**
Bivariate data: Scatter diagram, regression, curve between two variables and concept of error in regression, principles of least squares & fitting of first, second and third degree. Concept of correlation coefficient & its properties, correlation ratio, polynomial regression and correlation index. Rank correlation coefficient due to Spearman and Kendall. Partial and multiple correlation.	
Unit 4	**10 Classes**
Analysis of data on two characters – Measures of association and contingency-table. Analysis of categorical data – Fundamental set of frequencies, consistency of data, association of attributes and various measurement of association.	
Suggested Readings	
1. Goon, Gupta and Dasgupta: Fundamentals of Statistics, World Press 2. Gupta & Kapoor: Fundamentals of Mathematical Statistics, S Chand 4. Kendal and Stuart: Advanced Theory of Statistics, PHI 5. Gupta S C: Fundamentals of Statistics, Himalaya Publishing House 6. Spiegel & Stephens, Statistics, Mc Graw Hill International 7. Kapoor J N & Saxena H C: Mathematical Statistics, S Chand	

6.12: PCC P1 – Descriptive Statistics

	2 Credits

List of Practical

1. Preparation of Histogram, frequency polygon and ogive from a set of given data
2. Measure of central tendency, dispersion, moments, skewness and kurtosis of frequency distribution
3. Calculation of correlation co-efficient from bivariate data
4. Calculation of rank correlation co-efficient from qualitative data
5. Fitting of regression line by least square method
6. Binomial Trials, preparation of distribution and testing similarity with theoretical frequencies
7. Poisson Experiment, preparation of distribution and testing similarity with theoretical frequencies

6.13 PCC T2 – Probability Theory & Distributions

	4 Credits	Class
Unit 1		15
Probability: Random experiment and random events. Statistical regularity and meaning of probability. Classical and empirical definition of probability and their drawbacks. Axiomatic definition. Conditional probability. Independence of events. Principal theorems on the union and intersection of events and Bayes' theorem.		
Unit 2		15
Random variable and its probability distribution. Probability mass functions and probability density functions. Mathematical expectation and variance. Joint distribution of two random variables with simple examples. Marginal and conditional distributions. Covariance, simple theorems on expectation and variance including theorems on expectation and variance of a sum of random variables and **product** of independent random variables.		
Unit 3		10
Chebyshev's inequality, weak law of large numbers including Bernouli's theorem. Statement of Central Limit Theorem (i.i.d case) and its uses.		
Unit 4		20
Standard probability distributions: Uniform, Binomial, Poisson, Hyper-geometric, Gamma, Beta, Exponential and Normal distributions with their properties and uses. Statement of the general properties of a bivariate normal distribution.		
Suggested Readings		
1. Goon, Gupta and Dasgupta: Fundamentals of Statistics, World Press 2. Gupta & Kapoor: Fundamentals of Mathematical Statistics, S Chand 3. Kendal and Stuart: Advanced Theory of Statistics, PHI 4. Gupta S C: Fundamentals of Statistics, Himalaya Publishing House 5. Spiegel & Stephens, Statistics, Mc Graw Hill International 6. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Pearson 7. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia. 8. Myer, P.L. (1970): Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.		

6.14: PCC P2 – Probability Theory & Distributions Lab

	2 Credits
List of Practical	

1. Fitting of binomial distributions for n and p = q = ½ given
2. Fitting of binomial distributions for n and p given
3. Fitting of binomial distributions computing mean and variance
4. Fitting of Poisson distributions for given value of lambda
5. Fitting of Poisson distributions after computing mean
6. Application problems based on binomial distribution
7. Application problems based on Poisson distribution
8. Problems based on area property of normal distribution
9. To find the ordinate for a given area for normal distribution
10. Application based problems using normal distribution
11. Fitting of normal distribution when parameters are given
12. Fitting of normal distribution when parameters are not given

6.15 PCC T3 - Methods of Sampling & Sampling Distribution

	4 Credits	Class
Unit 1		30
Methods of Sampling: Preliminary concepts – schedules and questionnaires, pilot survey, non-sampling errors, use of random numbers. Simple random sampling with and without replacements, random number generation– estimates of population mean and population proportion and their standard errors, estimates of these standard errors. Stratified random sampling – estimates of sample statistic and estimates of their standard errors. Allocation of sample size in stratified random sampling. Linear and circular systematic sampling. Two stage sampling (equal first stage units). Ideas of ratio and regression estimators – only estimates of sample mean.		
Unit 2		30
Sampling Distribution: Concept of random sampling from an infinite population, parameter and statistics. Random sampling and sampling distribution of a statistic and its standard error. χ^2, t and F distributions. Sampling distribution of mean and variance of independent normal variables.		
Suggested Readings		
1. Goon, Gupta and Dasgupta: Fundamentals of Statistics, World Press 2. Gupta & Kapoor: Fundamentals of Mathematical Statistics, S Chand 3. Kendal and Stuart: Advanced Theory of Statistics, PHI 4. Conover W J: Practical Non-Parametric Statistics, John Willey 5. Gupta S C: Fundamentals of Statistics, Himalaya Publishing House 6. Spiegel & Stephens, Statistics, Mc Graw Hill International 7. Cocharn W G: Sampling Techniques, Wiley Eastern 8. Johnson, R.A. & Bhattacharya, G.K. (2001): Statistics-Principles and Methods, 4th Edn. John Wiley and Sons. 9. Mood, A.M., Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edn. (Reprint).Tata McGraw-Hill Pub. Co. Ltd. 10. Hogg R.V. & Craig A.T. (1978): Introduction to Mathematical Statistics, Prentice Hall. 11. **Casella**, G. and Berger R.L (2002). : Statistical Inference, 2nd Edn. Thomson Learning		

6.16 PCC P3 – Methods of Sampling & Sampling Distribution Lab

	2 Credits

List of Practical

1. Simple random sampling with and without replacement from a finite population
2. Preparation of Sampling Distribution of mean and variance and estimates of their standard errors
3. Stratified random sampling – estimates of sample statistic and estimates of their standard errors. Allocation of sample size in stratified random sampling.
4. Determination of Sample Size for given value of confidence level and measure of dispersion

6.17 PCC T4 - Methods of Statistical Inference

	4 Credits	Class
Unit 1		15
Point estimation: Requirements of a good estimator (unbiasedness and minimum variance, consistency and efficiency). Methods of estimation – method of moments and maximum likelihood. Point estimators of parameters of Binomial, Poisson and Normal (univariate) distribution and their standard errors.		
Unit – 2		10
Interval estimation: Confidence interval and confidence co-efficient, Exact confidence interval under normal set-up for a single mean difference of two means, single variance and ratio of two variances.		
Unit – 3		15
Hypothesis Testing: Null and alternative hypothesis, two kinds of errors, critical region, level of significance and power of a test. Exact tests of hypothesis under univariate normal set-up for a single mean, the difference of two means, single variance, the ratio of two variance, Exact tests of hypotheses under bivariate normal set up for the difference of two means, ratio of two variances, simple correlation and regression coefficients.		
Unit – 4		10
Formula for standard error of a function of statistics in large sample (without derivation) and its application for the derivations of standard errors of standard deviation. Large sample tests for proportions and under normal set-up for mean, variance and simple correlation coefficient, use of z-transformation. Large sample tests for goodness of fit and for homogeneity and independence in a contingency table.		
Unit - 5		10
Analysis of variance: One-way classified data and two-way classified data with equal and unequal number of observation in each cell.		
Suggested Readings		
1. Goon, Gupta and Dasgupta: Fundamentals of Statistics, World Press 2. Gupta & Kapoor: Fundamentals of Mathematical Statistics, S Chand 3. Kendal and Stuart: Advanced Theory of Statistics, PHI 4. Conover W J: Practical Non-Parametric Statistics, John Willey 5. Gupta S C: Fundamentals of Statistics, Himalaya Publishing House 6. Spiegel & Stephens, Statistics, Mc Graw Hill International 7. Cocharn W G: Sampling Techniques, Wiley Eastern 8. Kapoor J N & Saxena: H C Mathematical Statistics, S Chand 9. Yule U & Kendal M: An Introduction to the Theory of Statistics, UBS 10. Mukhopadhyay P: Theory and Methods of Survey Sampling, PHI		

6.18 PCC P4 – Methods of Statistical Inference Lab

	2 Credits

List of Practical

1. Estimators of population mean.
2. Confidence interval for the parameters of a normal distribution (one sample and two sample problems).
3. Tests of hypotheses for the parameters of a normal distribution (one sample and two sample problems).
4. Chi-square test of proportions.
5. Chi-square tests of association.
6. Chi-square test of goodness-of-fit.
7. Test for correlation coefficient.
8. Sign test for median.
9. Sign test for symmetry.
10. Wilcoxon two-sample test.
11. Analysis of Variance of a one way classified data
12. Analysis of Variance of a two way classified data.
13. Analysis of a CRD.
14. Analysis of an RBD.

6.20: Department Specific Elective

6.21: PDSE PT5 – Applied Statistics

	4 Credits	Class
Unit 1		15
Statistical Quality Control: Concepts of process and product control, Rational sub-grouping. Control charts underlying theory, advantages of SQC, construction and use of control charts for mean, range, number of defectives (including the case of varying sub-group size), fraction defective and number of defects. Concept of sampling inspection plan by attributes, AQL, LTPD, Consumer's risk, producer's risk, OC, ASN for single sampling plan. Use of IS 2500 part-I.		
Unit 2		15
Design of Experiments: Basic principles of Design – randomization, replication and local control. Completely Randomised design, Randomised Block design and Latin Square design. Technique of analysis of variance with reference to the analysis of above designs. Factorial experiments: un-confounded 2^2 and 2^3 experiments.		
Unit 3		15
Population Statistics: Sources of demographic data. Measurement of mortality crude. Specific standardized death rates and infant mortality rates. Complete life table. Measurement of fertility and reproduction-crude birth rate, general, specific and total fertility rates. Rate of natural increase. Gross and net reproduction rates. Population estimates and projection (mathematical method) – Inter-censal and post-censal estimates. Projection – Logistic curve and fitting of Logistic curve. Definition of stable and stationary population.		
Unit 4		15
Index Number: Definition, construction and use of price index numbers. Laspeyres', Passache's, Fisher's and Edgeworth-Marshall's index numbers. Time and factor reversal tests. Chain index number, wholesale and consumer price index numbers. **Analysis of time-series:** Different components of a time series. Determination of trend by free hand smoothing. Method of moving average and by fitting of a mathematical curve. Determination of seasonal indices by method of trend ratios and ratios to moving averages.		

Suggested Readings

1. Goon, Gupta and Dasgupta: Fundamentals of Statistics, World Press
2. Gupta & Kapoor: Applied Statistics, S Chand
3. Conover W J: Practical Non-Parametric Statistics, John Willey
4. Gupta S C: Fundamentals of Statistics, Himalaya Publishing House
5. Duncan A J: Quality Control and Industrial Statistics, Richard D Irwin
6. Kapoor J N & Saxena: Mathematical Statistics, S Chand
7. Yule U & Kendal M: An Introduction to the Theory of Statistics, UBS
8. Montogomery, D. C. and Runger, G.C. (2008): Applied Statistics and Probability for Engineers, 3rd Edition reprint, Wiley India Pvt. Ltd.
9. Ehrlich, B. Harris (2002):Transactional Six Sigma and Lean Servicing, St. Lucie Press.
10. Montogomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd

6.22: PDSE P5 – Applied Statistics Lab

	2 Credits

List of Practical

1. Measurement of trend: Fitting of linear, quadratic trend, exponential curve and plotting of trend values and comparing with given data graphically.
2. Measurement of seasonal indices by Ratio-to-trend method and plotting of trend values and comparing with given data graphically.
3. Construction of price and quantity index numbers by Laspeyre's formula, Paasche's formula, Marshall-Edgeworth's formula, Fisher's Formula. Comparison and interpretation.
4. Construction of Consumer and wholesale price index numbers, fixed base index number and consumer price index number with interpretation.
5. Gini's coefficient, Lorenz curve, Human Development Index.
6. Construction and interpretation of X bar & R-chart.
7. Construction and interpretation p-chart (fixed sample size) and c-chart.
8. Computation of measures of mortality.
9. Completion of life table.
10. Computation of measures of fertility and population growth.

6.21: PDSE T6 - Research Methodology

	4 Credits	Class
Unit 1		15
What is Research? Role of Research in important areas. Characteristics of Scientific Method. Process of research: Stating Hypothesis or Research question, Concepts & Constructs, Units of analysis & characteristics of interest, Independent and Dependent variables, Extraneous or Confounding variables. Measurements and scales of Measurements. Types of research: Qualitative & Quantitative Research, Longitudinal Research, Survey & Experimental Research.		
Unit 2		10
Survey Methodology and Data Collection, sampling frames and coverage error, non-response.		
Unit 3		15
Review of various techniques for data analysis covered in core statistics papers, techniques of interpretation, precaution in interpretation. means, ratio of two variances, simple correlation and regression coefficients.		
Unit 4		20
Develop a questionnaire, collect survey data pertaining to a research problem (such as gender discriminations in private v/s government sector, unemployment rates, removal of subsidy, impact on service class v/s unorganized sectors), questions and answers in surveys, Internal & External validity, , interpret the results and draw inferences. Formats and presentations of Reports – an overview.		
Suggested Readings		
Kothari, C.R. (2009): Research Methodology: Methods and Techniques, 2nd Revised Edition reprint, New Age International Publishers. Kumar, R (2011): Research Methodology: A Step - by - Step Guide for Beginners, SAGE Publications. Zikamund W G Barry J Babin and others (2016): Business Research Methods, Cengage Learning		

6.21: PDSE P6 – Research Methodology Lab

	2 Credits

List of Practical

Submit a Research Report based on empirical study on some real life situation. The student will personally collect, analyse, interpret the data and prepare a report under the supervision of a faculty.

6.21: PDSE T 7 – Time Series Analysis

	4 Credits

Unit 1

1. Introduction to time series data, application of time series from various fields.
2. Modelling time series as deterministic function plus IID errors:
3. Components of a time series (trend, cyclical and seasonal patterns, random error) Decomposition of time series.
4. **Estimation of trend:** free hand curve method, method of moving averages, fitting various mathematical curves and growth curves.

Unit 2

1. Effect of elimination of trend on other components of the time series.
2. Estimation of seasonal component by Method of simple averages,
3. Notions of multiplicative models: ratio to Trend.

Unit 3

1. **Introduction to stochastic modelling:** Concept of stationarity. Illustration of how a stationary time series may show temporal patterns. Stationarity in mean.
2. **Box-Jenkins modelling:** Moving-average (MA) process and Autoregressive (AR) process of orders one and two. ACF, PACF and their graphical use in guessing the order of AR and MA processes. Estimation of the parameters of AR (1) and AR (2) using Yule-Walker equations.

Unit 4

Forecasting: Exponential smoothing methods, Short term forecasting methods: Brown's discounted regression,

Suggested Readings

Chatfield C. (1980): The Analysis of Time Series – An Introduction, Chapman & Hall.

Kendall M.G. (1976): Time Series, Charles Griffin.

Brockwell and Davis (2010): Introduction to Time Series and Forecasting (Springer Texts in Statistics), 2nd Edition

6.21: PDSE P7 – Time Series Analysis Lab

	2 Credits

List of Practical

1. Plotting a real life time series, and detecting various features (trend, periodic behaviours etc). Suggested data sets:
    a. Sun spot data
    b. Dollar-Rupee exchange rates
    c. Stock market data
2. Fitting and plotting of mathematical curves:
    a. modified exponential curve
    b. Gompertz curve
3. Fitting of trend by Moving Average Method
4. Plotting detrended series.
5. Measurement of Seasonal indices Ratio-to-Moving Average method
6. Plotting ACF and PACF of a given time series
7. Using Yule-Walker equation to fit AR (1) and AR (2) models to real life data.
8. Forecasting by short term forecasting methods.
9. Forecasting by exponential smoothing

6.3: Skill Enhancement Subjects Syllabus

6.31 PSEC T1 – Statistical Data Analysis Using R

	2 Credits

Unit 1

1. **Introduction to R:** Installation, commandline environment, overview of capabilities, brief mention of open source philosophy.
2. **R as a calculator:** The four basic arithmetic operations. Use of parentheses nesting up to arbitrary level. The power operation. Evaluation of simple expressions. Quotient and remainder operations for integers.
3. Standard functions, e.g., sin, cos, exp, log.

Unit 2

1. **The different types of numbers in R**: Division by zero leading to Inf or -Inf. NaN. NA. No need to go into details.
2. **Variables.** Creating a vector using c( ), seq( ) and colon operator. How functions map over vectors.
3. **Functions to summarise a vector**: sum, mean, sd, median etc. Extracting a subset from the vector (by index, by property).
4. **R as a graphing calculator:** Introduction to plotting. Plot ( ), lines( ), abline( ). No details about the graphics parameters except colour and line width. Barplot, Pie chart and Histogram. Box plot. Scatter plot and simple linear regression using lm(y~x).

Unit 3

1. **Matrix operations in R:** Creation. Basic operations. Extracting submatrices.
2. **Loading data from a file**: read.table ( ) and read.csv ( ). Mention of head=TRUE and head=FALSE. Dataframes. Mention that these are like matrices, except that different columns may be of different types.

Unit 4

Problems on discrete and continuous probability distributions

Suggested Readings

Gardener, M (2012) Beginning R: The Statistical Programming Language, Wiley Publications.

Braun W J, Murdoch D J (2007): A First Course in Statistical Programming with R. Cambridge University Press. New York

A simple introduction to R by Arnab Chakraborty (freely available at http://www.isical.ac.in/~arnabc/)

R for beginners by Emmanuel Paradis (freely available at ftp://cran.r-project.org/pub/R/doc/contrib/Paradis-rdebuts_en.pdf)

6.32 P SEC T2 – Monte Carlo Method

	2 Credits

Unit 1

1. Using the computer for random number generation. (treated as a black box)
2. A brief look at some popular approaches (no mathematical justification needed).
3. Simulating a coin toss, a die roll and a card shuffle.

Unit 2

1. CDF inversion method. Simulation from standard distributions.
2. Finding probabilities and moments using simulation.

Unit 3

Monte Carlo integration. Basic idea of importance sampling. MCMC not included.

Unit 4

1. Generating from Binomial and Poisson distributions, and comparing the histograms to the PMFs.
2. Generating from Uniform (0,1) distribution, and applying inverse CDF transforms.
3. Simulating Gaussian distribution using Box-Muller method.
4. Approximating the expectation of a given function of a random variable using simulation.
5. Graphical demonstration of the Law of Large Numbers.
6. Approximating the value of pi by simulating dart throwing.

Suggested Readings

Shonkwiler, Ronald W. and Mendivil, Franklin (2009): Explorations in Monte Carlo Methods (Undergraduate Texts in Mathematics)

Carsey, Thomas M. and Harden, Jeffrey J. (2014): Monte Carlo Simulation and Resampling Methods for Social Science.

9.2 P SEC T2 – Monte Carlo Method

	2 Credits
Unit 1	
1. Using the computer for random number generation. (treated as a black box) 2. A brief look at some popular approaches (no mathematical justification needed). 3. Simulating a coin toss, a die roll and a card shuffle.	
Unit 2	
1. CDF inversion method. Simulation from standard distributions. 2. Finding probabilities and moments using simulation.	
Unit 3	
Monte Carlo integration. Basic idea of importance sampling. MCMC not included.	
Unit 4	

1. Generating from Binomial and Poisson distributions, and comparing the histograms to the PMFs.
2. Generating from Uniform (0,1) distribution, and applying inverse CDF transforms.
3. Simulating Gaussian distribution using Box-Muller method.
4. Approximating the expectation of a given function of a random variable using simulation.
5. Graphical demonstration of the Law of Large Numbers.
6. Approximating the value of pi by simulating dart throwing.

Suggested Readings

Shonkwiler, Ronald W. and Mendivil, Franklin (2009): Explorations in Monte Carlo Methods (Undergraduate Texts in Mathematics)

Carsey, Thomas M. and Harden, Jeffrey J. (2014): Monte Carlo Simulation and Resampling Methods for Social Science.

7. Appendix – I: Scheme for CBCS Curriculum for Pass Course

7.1 Credit Distribution across Courses

Course Type		Total Papers	Credits: Theory + Practical	Credits: Theory*+Tutorials
Core Courses	4 papers each from 3 disciplines of choice	12	12*4 =48 12*2 =24	12*5 =60 12*1=12
Elective Courses	2 papers each from 3 discipline of choice including interdisciplinary papers	6	6*4=24 6*2=12	6*5=30 6*1=6
Ability Enhancement Language Courses		2	2*2=4	2*2=4
Skill Enhancement Courses		4	4*2=8	4*2=8
Totals		24	120	120

*Tutorials of 1 Credit will be conducted in case there is no practical component

All Pass courses will have 3 subjects/disciplines of interest. Student will select 4 core courses from each discipline of choice including Statistics as one of the disciplines. The details for core courses available in Statistics have been detailed in Section 3 of this document

Student will select 2 DSE courses each from discipline of choice including Statistics as one of the disciplines. The details for elective courses available in Statistics have been detailed in Section 4 and 6 of this document

Students opting for pass course may also chose two Skill Enhancement Courses in Statistics consisting 2 credits. The details for skill enhancement courses available in Statistics have been detailed in Section 5 of this document

7.2 Scheme for CBCS Curriculum

Semester	Course Name	Course Detail	Credits
I	Ability Enhancement Compulsory Course–I	English communication / Environmental Science	2
	Core course–I	Core Course PCC T1 from Statistics	4
	Core course–I Practical	Core Course PCC P1 Lab from Statistics	2
	Core course–II	Core Course A1 from other chosen discipline	4
	Core course–II Practical	Core Course A1 Practical from other chosen discipline	2
	Core course – III	Core Course B1 from other chosen discipline	4
	Core course – III Practical	Core Course B1 Practical from other chosen discipline	2
II	Ability Enhancement Compulsory Course–II	English communication / Environmental Science	2
	Core course–IV	Core Course PCC T2 from Statistics	4
	Core course–IV Practical	Core Course PCC P2 Lab from Statistics	2
	Core course–V	Core Course 2B from other chosen discipline	4
	Core course– V Practical	Core Course 2B Practical from other chosen discipline	2
	Core course – VI	Core Course 2B from other chosen discipline	4
	Core course – VI Practical	Core Course 2B Practical from other chosen discipline	2
III	Core course VII	Core Course PCC T3 from Statistics	4
	Core course–VII Practical	Core Course PCC P3 Lab from Statistics	2
	Core course – VIII	Core Course 2C from other chosen discipline	4
	Core course – VIII Practical	Core Course 2C Practical from other chosen discipline	2
	Core course–IX	Core Course 3C from other chosen discipline	4
	Core course–IX Practical	Core Course 3C Practical from other chosen discipline	2
	Skill Enhancement Course–1	Skill Enhancement Course PSEC T1 from Statistics	2

IV	Core course–X	Core Course PCC T4 from Statistics	4
	Core course – X Practical	Core Course PCC P4 Practical from Statistics	2
	Core course–XI	Core Course 2D from other chosen discipline	4
	Core course–XI Practical	Core Course 2D Practical from other chosen discipline	2
	Core course–XII	Core Course 3D from other chosen discipline	4
	Core course–XII Practical	Core Course 3D Practical from other chosen discipline	2
	Skill Enhancement Course-2	Skill Enhancement Course PSEC T2 from Statistics	2
V	Skill Enhancement Course – 3	TBD	2
	Discipline Specific Elective 1	PDSE T1 from Statistics	4
	Discipline Specific Elective 1 Practical	PDSE P1 Practical from Statistics	2
	Discipline Specific Elective 2	DSE 2A from other chosen discipline	4
	Discipline Specific Elective 2 Practical	DSE 2A Practical from other chosen discipline	2
	Discipline Specific Elective 3	DSE 3A from other chosen discipline	4
	Discipline Specific Elective 3 Practical	DSE 3A Practical from other chosen discipline	2
VI	Skill Enhancement Course – 4	TBD	2
	Discipline Specific Elective 4	PDSE T2 from Statistics	4
	Discipline Specific Elective 4 Practical	PDSE P2 Practical from Statistics	2
	Discipline Specific Elective 5	DSE 2B from other chosen discipline	4
	Discipline Specific Elective 5 Practical	DSE 2B Practical from other chosen discipline	2
	Discipline Specific Elective 6	DSE 3B from other chosen discipline	4
	Discipline Specific Elective 6 Practical	DSE 3B Practical from other chosen discipline	2

Statistics
5. Syllabus of Generic Elective Courses

5.1 GE T1 – Statistical Methods

	4 credits
Unit 1	**10 Classes**
Type of data – Primary and secondary data, quantitative and qualitative data, nominal and ordinal data, cross section and time series data, discrete and continuous data. **Presentation of data –** Presentation by tables and by diagrams, construction of tables with one, two and three factors of classification, diagrammatic representations, frequency distributions for discrete and continuous data, representing distributions graphical by histogram and frequency polygon; cumulative frequency distributions (inclusive and representation of a frequency conclusive method) & Ogives	
Unit 2	**20 Classes**
Descriptive Statistics: Measure of central tendency; measures of dispersion, moments and quartiles, measure of skewness and kurtosis for both grouped and ungrouped data.	
Unit 3	**20 Classes**
Bi-variate and Multivariate Analysis: Scatter diagram, regression, curve between two variables and concept of error in regression, principles of least squares; fitting of first, second and third degree. Concept of correlation coefficient & its properties, correlation ratio, polynomial regression and correlation index. Rank correlation coefficient due to Spearman and Kendall. Partial and multiple correlation	
Unit 4	**10 Classes**
Analysis of Categorical Data: Fundamental set of frequencies, consistency of data; Measures of association and contingency-table; Association of attributes and various measurement of association; Analysis of data on two characters and three characters,	
Suggested Readings	
1. Goon, Gupta and Dasgupta: Fundamentals of Statistics, World Press 2. Gupta & Kapoor: Fundamentals of Mathematical Statistics, S Chand 4. Kendal and Stuart: Advanced Theory of Statistics, PHI 5. Gupta S C: Fundamentals of Statistics, Himalaya Publishing House 6. Spiegel & Stephens, Statistics, Mc Graw Hill International 7. Kapoor J N & Saxena H C: Mathematical Statistics, S Chand	

5.2 GE P1 – Statistical Methods Lab

	2 Credits

List of Practical

1. Preparation of Histogram, frequency polygon and ogive from a set of given data
2. Measure of central tendency, dispersion, moments, skewness and kurtosis of frequency distribution
3. Calculation of correlation co-efficient from bivariate data
4. Calculation of rank correlation co-efficient from qualitative data
5. Fitting of regression line by least square method
6. Computing multiple and partial correlation from a set data relating to three variables

5.3 GE T2 – Fundamentals of Probability

	4 Credits	Class
Unit 1		15
Probability: Random experiment and random events. Statistical regularity and meaning of probability. Classical and empirical definition of probability and their drawbacks. Axiomatic definition. Conditional probability. Independence of events. Principal theorems on the union and intersection of events and Bayes' Theorem.		
Unit 2		15
Random variable and its probability distribution. Probability mass functions and probability density functions. Mathematical expectation and variance. Joint distribution of two random variables with simple examples. Marginal and conditional distributions. Co-variance, simple theorems on expectation and variance including theorems on expectation and variance of a sum of random variables and **product** of independent random variables.		
Unit 3		10
Chebyshev's inequality, weak law of large numbers including Bernouli's theorem. Statement of Central Limit Theorem (i.i.d case) and its uses.		
Unit 4		20
Standard Probability Distributions: Uniform, Binomial, Poisson, Hyper-geometric, Gamma, Beta, Exponential and Normal Distributions with their properties and uses. Statement of the general properties of a bi-variate normal distribution.		
Suggested Readings		
1. Goon, Gupta and Dasgupta: Fundamentals of Statistics, World Press 2. Gupta & Kapoor: Fundamentals of Mathematical Statistics, S Chand 3. Kendal and Stuart: Advanced Theory of Statistics, PHI 4. Gupta S C: Fundamentals of Statistics, Himalaya Publishing House 5. Spiegel & Stephens, Statistics, Mc Graw Hill International 6. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Pearson 7. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia. 8. Myer, P.L. (1970): Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.		

5.4 GE P2 – Fundamentals of Probability Lab

	2 Credits
List of Practical	

1. Fitting of binomial distributions for n and p = q = ½ given
2. Fitting of binomial distributions for n and p given
3. Fitting of binomial distributions computing mean and variance
4. Fitting of Poisson distributions for given value of lambda
5. Fitting of Poisson distributions after computing mean
6. Application problems based on binomial distribution
7. Application problems based on Poisson distribution
8. Problems based on area property of normal distribution
9. To find the ordinate for a given area for normal distribution
10. Application based problems using normal distribution
11. Fitting of normal distribution when parameters are given
12. Fitting of normal distribution when parameters are not given