UNIVERSITY OF CALCUTTA

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To
The Principals/T.I.C.
of all the Undergraduate Colleges
offering B.Sc. (Honours & General) in Statistics
affiliated to the University of Calcutta

Sir/Madam,

The undersigned is to inform you that the proposed **semester wise draft Syllabus for Statistics (General)** and **corrected version of semester wise draft Syllabus for Statistics (Honours)** Courses of Studies under **CBCS has been uploaded in the Calcutta University website (www.caluniv.ac.in).**

The said syllabus has been prepared by the **U.G. Board of Studies in Statistics, C.U.**

You are requested kindly to go through it and send your feedback within 20th March, 2018.

In this regard you may send your observation/ suggestion to the **Department of U.G. Councils, C.U.** or through email (u.g.councilsc.u@gmail.com), and you also may contact **Prof. Asis Kumar Chattopadhyay,** Department of Statistics through e-mail **(akcstat@caluniv.ac.in).**

Your cooperation in this regard will be highly appreciated. Kindly treat the matter as urgent.

Thanking you,

Yours faithfully,

05/03/18

Secretary

B. Sc 3 years general course Syllabus (Statistics)

Core Course

Descriptive Statistics

Descriptive Statistics	
	3 Credits
Unit 1	**15 L**
Introduction: Definition and scope of Statistics, concepts of statistical population and sample. Data: quantitative and qualitative, attributes, variables, scales of measurement - nominal, ordinal, interval and ratio. Frequency distribution, Presentation: tabular and graphic, including histogram and ogives.	
Unit 2	**18 L**
Measures of Central Tendency: mathematical and positional. Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation, moments, skewness and kurtosis.	
Unit 3	**12 L**
Bivariate data: Definition, scatter diagram, simple, partial and multiple correlation (3 variables only), rank correlation (Spearman). Simple linear regression, principle of least squares and fitting of polynomials and exponential curves.	
Reference Books	
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. AndBoes, D.C. (2007): Introduction to theTheory of Statistics, 3rd Edn. (Reprint), Tata McGraw-Hill Pub. Co. Ltd. Goon A.M., Gupta M.K. and Dasgupta B. : Basic Statistics. The World Press, Kolkata. Chakraborty, Arnab (2016) : Probability and Statistics. Sarat Book House.	

Descriptive Statistics

Descriptive Statistics Lab	
	3 Credits
List of Practical	
Graphical representation of data Problems based on measures of central tendency Problems based on measures of dispersion Problems based on combined mean and variance and coefficient of variation Problems based on moments, skewness and kurtosis Fitting of polynomials, exponential curves Karl Pearson correlation coefficient Partial and multiple correlations (3 variables only) Spearman rank correlation with and without ties. Correlation coefficient for a bivariate frequency distribution Lines of regression, angle between lines and estimated values of variables.	

Elementary Probability Theory

Elementary Probability Theory	
	3 Credits
Unit 1	**15 L**
Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability – classical, statistical, and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications.	
Unit 2	**10 L**
Random Variables: Discrete and continuous random variables, p.m.f., p.d.f., c.d.f. Illustrations of random variables and its properties. Expectation, variance, moments.	
Unit 3	**20 L**
Standard probability distributions: Binomial, Poisson, geometric, negative binomial, Uniform, normal, exponential. Weak law of large numbers and Lindeberg-Levy Central Limit Theorem (C.L.T).	
Reference Books	
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 Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I& II, 8th Edn. The World Press, Kolkata. Chakraborty, Arnab (2016) : Probability and Statistics. Sarat Book House. Ross, S. (2002): A First Course in Probability, Prentice Hall.	

Elementary Probability Theory Lab

Elementary Probability Theory Lab	
	3 Credits
List of Practical	
Fitting of binomial distributions for n and p = q = ½ Fitting of binomial distributions for n and p given Fitting of binomial distributions computing mean and variance Fitting of Poisson distributions for given value of lambda Fitting of Poisson distributions after computing mean Application problems based on binomial distribution Application problems based on Poisson distribution Problems based on area property of normal distribution To find the ordinate for a given area for normal distribution Application based problems using normal distribution Fitting of normal distribution when parameters are given Fitting of normal distribution when parameters are not given	

Introduction to Statistical Inference

Introduction to Statistical Inference	
	3 Credits
Unit 1	**10 L**
Population and Sample, Parameter and Statistic, Population distribution and Sampling distribution. Statistical Inference: Point Estimation, Interval Estimation and Testing of Statistical Hypothesis. Four useful distributions for statistical Inference; Normal, χ^2 , t and F (Statement of the pdf's & shape of the curves)	
Unit 2	**20 L**
Estimation of population mean, confidence intervals for the parameters of a normal distribution (one sample and two sample problems). The basic idea of significance test. Null and alternative hypothesis. Type I& Type II errors, level of significance, concept of p-value. Tests of proportions. Tests of hypotheses for the parameters of a normal distribution (one sample and two sample problems). Sign test	
Unit 3	**15 L**
Analysis of variance, one-way and two-way classification. Brief exposure of three basic principles of design of experiments, Statistical concepts of "treatment", "plot" and "block". Analysis of completely randomized design, randomized complete block design.	
Reference Books	
Daniel, Wayne W., Bio-statistics (2005): A Foundation for Analysis in the Health Sciences. John Wiley . Goon, A.M., Gupta M.K. & Das Gupta (2005):Fundamentals of statistics, Vol.-I & II. Dass, M. N. &Giri, N. C.: Design and analysis of experiments. John Wiley. Dunn, O.J (1977): Basic Statistics: A primer for the Biomedical Sciences. John Wiley.	

Introduction to Statistical Inference Lab

Introduction to Statistical Inference Lab	
	3 Credits
List of Practical	
Estimators of population mean. Confidence interval for the parameters of a normal distribution (one sample and two sample problems). Tests of hypotheses for the parameters of a normal distribution (one sample and two sample problems). Test for proportions. Sign test for median. Analysis of Variance of a one way classified data Analysis of Variance of a two way classified data. Analysis of a CRD. Analysis of an RBD.	

Applications of Statistics

Applications of Statistics	
	3 Credits
Unit 1	**15L**
Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. 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, estimates of: population mean, total and proportion, variances of these estimates, estimates of their variances. Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations.	
Unit 2	**15L**
Index numbers: Definition, Criteria for a good index number, different types of index numbers. Construction of index numbers of prices and quantities, consumer price index number & wholesale price index number. Uses and limitations of index numbers. Economic Time Series: Components of time series, Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series. Measurement of trend by method of free-hand curve, method of least squares.	
Unit 3	**15L**
Demographic Methods: Introduction, measurement of population, rates and ratios of vital events. Measurement of mortality: CDR, SDR (w.r.t. Age and sex), IMR, Standardized death rates. Life (mortality) tables: definition of its main functions and uses. Measurement of fertility and reproduction: CBR, GFR, and TFR. Measurement of population growth: GRR, NRR.	
Reference Books	
Mukhopadhyay, P. (1999): Applied Statistics, New Central Book Agency, Calcutta. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II,9th Edition World Press, Kolkata. Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals Of Applied Statistics, 4th Edition (Reprint), Sultan Chand & Sons	

Applications of Statistics Lab

Applications of Statistics Lab	
	3 Credits
List of Practical	
To select a SRS with and without replacement. 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. For SRSWOR, estimate mean, standard error, the sample size. Stratified Sampling: allocation of sample to strata by proportional and Neyman's methods. Construction of price and quantity index numbers by Laspeyre's formula, Paasche's formula, Marshall-Edgeworth's formula, Fisher's Formula. Comparison and interpretation. Construction of Consumer and wholesale price index numbers, fixed base index number and consumer price index number with interpretation. Measurement of trend: Fitting of linear, quadratic trend, exponential curve and plotting of trend values and comparing with given data graphically. Computation of measures of mortality. Completion of life table. Computation of measures of fertility and population growth.	

Elective Course

Operations Research

Operations Research	
	3 Credits
Unit 1	**15L**
Introduction and Historical Background, Phases of Operations Research, model building, various types of O.R. problems. Linear Programming Problem, Requirements of LPP, Mathematical Formulation of LPP, Graphical Methods to Solve Linear Programming Problems.	
Unit 2	**12L**
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 3	**18L**
Introduction, Formulation of Transportation Problem (TP). 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.	
Reference Books	
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	

Operations Research Lab

Operations Research Lab	
	3 Credits
List of Practical (Using TORA/WINQSB/LINDO/LINGO)	
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.	

Survival Analysis

Survival Analysis	
	3 Credits
Unit 1	**15L**
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	**15L**
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	15L
Non-parametric methods: Actuarial and Kaplan-Meier methods for estimating survival function and variance of the Estimator.	
Reference Books	
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.	

Survival Analysis Lab

Survival Analysis Lab	
	3 Credits
List of Practical	
To estimate survival function. To determine death density function and hazard function. To identify type of censoring and to estimate survival time for type I censored data. To identify type of censoring and to estimate survival time for type II censored data. To identify type of censoring and to estimate survival time for progressively type I censored data. Estimation of mean survival time and variance of the estimator for type I censored data. Estimation of mean survival time and variance of the estimator for type II censored data. Estimation of mean survival time and variance of the estimator for progressively type I censored data. To estimate the survival function and variance of the estimator using Non-parametric methods with Actuarial methods. To estimate the survival function and variance of the estimator using Non-parametric methods with Kaplan-Meier method.	

Skill Based Electives

Statistical Data Analysis using R-I

Statistical Data Analysis Using R-I	
	1Credit
Unit 1	**5 L**
Introduction to R: Installation, commandline environment, overview of capabilities, brief mention of open source philosophy. 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. Standard functions, e.g., sin, cos, exp, log.	
Unit 2	**5 L**
The different types of numbers in R: Division by zero leading to Infor -Inf. NaN. NA. No need to go into details. Variables. Creating a vector using c(), seq() and colon operator. How functions map overvectors. Functions to summarise a vector: sum, mean, sd, medianetc. Extracting a subset from the vector (by index, by property). R as a graphing calculator: Introduction to plotting. Plot(), lines(), abline(). No detailsabout 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	**5 L**
Matrix operations in R: Creation. Basic operations. Extracting submatrices. 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.	
Reference Books	

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 **https://cran.r-project.org/doc/contrib/Paradis-rdebuts_en.pdf**)

Statistical Data Analysis using R-II

Statistical Data Analysis Using R-II	
	1Credit
Unit 1	**6 L**
Problems on discrete probability distributions.	
Unit 2	**9 L**
Problems on continuous probability distributions.	
Reference Books	
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 **https://cran.r-project.org/doc/contrib/Paradis-rdebuts_en.pdf**)	

Research Methodology	
	1 Credit
Unit 1 **8L**	
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 **7L**	
Survey Methodology and Data Collection, Develop a questionnaire, collect survey data pertaining to a research problem, Sampling frames and coverage error, non-response.	
Reference Books	
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.	

Monte Carlo Method	
	1 Credit
Unit 1	**4L**
Using the computer for random number generation. (treated as a black box) A brief look at some popular approaches (nomathematical justification needed). Simulating a coin toss, a die roll and a card shuffle.	
Unit 2	**4 L**
CDF inversion method. Simulation from standard distributions. Finding probabilities and moments using simulation.	
Unit 3	**3L**
Monte Carlo integration. Basic idea of importance sampling.	
Unit 4	**4 L**
Generating from Binomial, and comparing the histograms to the PMFs. Generating from Uniform(0,1) distribution, and applying inverse CDF transforms. Simulating Gaussian distribution using Box-Muller method.	
Reference Books	
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.	

STATISTICS(Hons)

1. Scheme for CBCS Curriculum

1.1 Credit Distribution across Courses

		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

1.2 Scheme for CBCS Curriculum

Semester	Course Name	Course Detail	Credits
I	Ability EnhancementCompulsoryCourse–I	English communication / Environmental Science	2
	Corecourse–I	Descriptive Statistics	4
	Corecourse–IPractical	Descriptive Statistics Lab	2
	Corecourse–II	Probability and Probability Distribitions-I	4
	Corecourse–IIPractical	Probability and Probability Distributions-I Lab	2
	GeneticElective–1	TBD	4
	GenericElective–1Practical	TBD	2
II	Ability EnhancementCompulsoryCourse–II	English communication / Environmental Science	2
	Corecourse–III	Mathematical Analysis	5
	Corecourse–III Tutorial	Mathematical Analysis	1
	Corecourse–IV	Probability and Probability Distributions -II	4
	Corecourse–IVPractical	Probability and Probability Distributions -II Lab	2
	GenericElective–2	TBD	4
	GenericElective–2Practical	TBD	2
III	Corecourse–V	Linear Algebra	4
	Corecourse–VPractical	Linear Algebra Lab	2
	Corecourse–VI	Demography and Vital Statistics	4
	Core course – VI Practical	Demography and Vital Statistics Lab	2
	Corecourse–VII	Numerical Analysis and C Programming	4
	Corecourse–VIIPractical	Numerical Analysis and C Programming Lab	2
	SkillEnhancementCourse–1	TBD	2
	GenericElective–3	TBD	4
	GenericElective–3Practical	TBD	2

IV	Corecourse–VIII	Survey Sampling & Indian Official Statistics	4
	Corecourse–VIIIPractical	Survey Sampling & Indian Official Statistics Lab	2
	Corecourse–IX	Statistical Inference-I and Sampling Distributions	4
	Corecourse–IXPractical	Statistical Inference-I and Sampling Distributions Lab	2
	Corecourse–X	Index Numbers and Time Series Analysis	4
	Corecourse–XPractical	Index Numbers and Time Series AnalysisLab	2
	SkillEnhancementCourse-2	TBD	2
	GenericElective–4	TBD	4
	GenericElective–4Practical	TBD	2
V	Corecourse–XI	Statistical Inference-II	4
	Corecourse–XIPractical	Statistical Inference-II Lab	2
	Corecourse–XII	Linear Models and Regression	4
	Corecourse–XIIPractical	Linear Models and Regression Lab	2
	DisciplineSpecificElective–1	TBD	4
	DisciplineSpecificElective– 1Practical	TBD	2
	DisciplineSpecificElective–2	TBD	4
	DisciplineSpecificElective– 2Practical	TBD	2
VI	Corecourse–XIII	Design of Experiments	4
	Corecourse–XIIIPractical	Design of Experiments Lab	2
	Corecourse–XIV	Multivariate Analysis and Nonparametric Methods	4
	Corecourse–XIVPractical	Multivariate Analysis and Nonparametric Methods Lab	2
	DisciplineSpecificElective–3	TBD	4
	DisciplineSpecificElective– 3Practical	TBD	2
	DisciplineSpecificElective–4	TBD	4
	DisciplineSpecificElective– 4Practical	TBD	2

*Use of suitable software such as MS-EXCEL/ MINITAB/SPSS etc. depending on the availability of faculty and resources for all the core practical courses.

1.3 Choices for Discipline Specific Electives

DisciplineSpecificElective–1 to DisciplineSpecificElective–5 (Choose any 4)			
Statistical Quality Control	Econometrics	Survival Analysis	Operations Research
Project Work (Sixth Semester)			

1.4 Choices for Skill Enhancement Courses

Skill Enhancement Course-1 & Skill Enhancement Course-2	
Statistical Data Analysis Using R	Research Methodology
Monte Carlo Methods	

1.5 General Electives

General Elective–1 to GeneralElective–5			
Statistical Methods	Introductory Probability	Basics of Statistical Inference	Introduction to Operations Research
Applied Statistics			

2. Core Subjects Syllabus

2.1 Core T1 –Descriptive Statistics 6 Credits

Descriptive Statistics	
	4 Credits
Unit 1	**15L**
Statistics: Definition and scope. Concepts of statistical population and sample. Data: quantitative and qualitative, cross-sectional and time-series, discrete and continuous. Scales of measurement: nominal, ordinal, interval and ratio. Presentation of data: tabular and graphical. Frequency distributions, cumulative frequency distributions and their graphical representations. Stem and leaf displays.	
Unit 2	**15L**
Measures of Central Tendency: Mean, Median, Mode. 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. Outliers.	
Unit 3	**18L**
Bivariate data: Definition, scatter diagram, simple correlation, linear regression, principle of least squares, fitting of polynomial and exponential curves, correlation ratio, correlation index, intraclass correlation. Rank correlation – Spearman's and Kendall's measures.	
Unit 4	**12L**
Analysis of Categorical Data: Contingency table, independence and association of attributes, measures of association - odds ratio, Pearson's and Yule's measure, Goodman-Kruskalgamma.	
Reference Books	
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. andBoes, 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.	

2.2 Core P1 – Descriptive Statistics Lab

Descriptive Statistics	
	2 Credits
List of Practical	
Diagrammatic representation of data. Problems based on construction of frequency distributions, cumulative frequency distributions and their graphical representations, stem and leaf plot. Problems based on measures of central tendency. Problems based on measures of dispersion. Problems based on combined mean and variance and coefficient of variation. Problems based on moments, skewness and kurtosis. Problems related to quantiles and measures based on them, construction of box plot. Problems based on analysis of bivariate data. Problems based on measures of rank correlation. Problems based on analysis of categorical data.	

2.3 Core T2 –Probability -I 6 Credits

Probability and Probability Distributions -I	
	4Credits
Unit 1	**20L**
Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability – classical, statistical, and axiomatic,	
Unit 2	**15L**
Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications.	
Unit 3	**10L**
Random Variables : Definition of discrete and continuous random variables, cumulative distribution function (c.d.f.) and its properties (with proof), probability mass function (p.m.f.) and probability density function (p.d.f.)	

Unit 4	**15L**
Expectation and Moments, Dispersion, Skewness, Kurtosis, Quantiles. Probability inequalities (Markov's and Chebychev's).	

Reference Books

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.

2.4 Core P2 – Probability and Probability Distributions-I Lab

Probability and Probability Distributions -I	
	2 Credits

List of Practical

Application problems based on Classical Definition of Probability.
Application problems based on Bayes Theorem.
Finding moments, quantiles from a given probability distribution.
Applications of probability inequalities.
Application based problems on probability distributions.

2.5 Core T3 – Mathematical Analysis 6 Credits

Mathematical Analysis	
	6 Credits

Unit 1	**25L**
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 andUncountability of **R**. Sequences and their convergence, monotonic sequences, bounded sequences, squeeze theorem Limits of some special sequences such asr^n, $(1+\frac{1}{n})^n$, $n^{\frac{1}{n}}$.

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 20L

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 expansions of sinx, cosx, e^x, $(1+x)^n$, log (1+x).

Maxima and Minima of Functions. Successive Differentiation.

Unit 3 **12L**

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 **18L**

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 theoremsand their uses).

Reference Books

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.

2.6 Core T4 – Probability and Probability Distributions -II 6 Credits

Probability and Probability Distributions-II

	4 Credits
Unit 1 **15L**	
Generating functions, p.g.f and m.g.f Standard discrete probability distributions: Binomial, Poisson, geometric, negative binomial, hypergeometric, uniform. Limiting/approximation cases, Truncated distributions.	
Unit 215L	
Standard continuous probability distributions: uniform, normal, exponential, Cauchy, beta, gamma, lognormal, logistic, double exponential and Pareto along with their properties, Truncated distributions. Limiting /approximation cases.	
Unit 3 **15L**	
Two dimensional random variables: joint, marginal and conditional distributions, properties of c.d.f, independence of variables, Theorems on sum and product of expectations of random variables, Conditional Expectation, Correlation and Regression.	
Unit 4 **15L**	
Trinomial distribution and its properties. Bivariate Normal Distribution (BVN): p.d.f. of BVN, properties of BVN, marginal and conditional p.d.f. of BVN.	
Reference Books	
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.	

2.7 Core P4 – Probability and Probability Distributions –II Lab

Probability and Probability Distributions-II

	2 Credits
List of Practical	
Fitting of binomial distributions for n and p = q = ½. Fitting of binomial distributions for given n and p. Fitting of binomial distributions after computing mean and variance. Fitting of Poisson distributions for given value of mean Fitting of Poisson distributions after computing mean. Fitting of negative binomial distribution. Fitting of suitable discrete distributions Application problems based on binomial distribution. Application problems based on Poisson distribution. Application problems based on negative binomial distribution. Problems based on area property of normal distribution. To find the ordinate for a given area for normal distribution. Application based problems using normal distribution. Fitting of normal distribution when parameters are given. Fitting of normal distribution when parameters are not given. Problems similar to those in 11 to 15 in cases of other continuous distributions. Application based Problems on trinomial distributions Application based Problems on bivariate normal distributions	

2.8 Core T5–Linear Algebra 6 credits

Linear Algebra	
	4 Credits
Unit 1	**15L**
Definition of vectors, operation of vectors (angle, distance etc.). Vector spaces, Subspaces, sum of subspaces, Span of a set, Linear dependence and independence, dimension and basis, dimension theorem. Extension of basis. Orthogonal vectors, Gram-Schmidt Orthogonalization. Algebra of matrices. Linear transformation. Elementary matrices and their uses, theorems related to triangular, symmetric and skew symmetric matrices, idempotent matrices, orthogonal matrices. Trace of a matrix.	

Unit 2	**20L**
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. Adjoint and inverse of a matrix and related properties. Singular and non-singular matrices and their properties. The system of equations A**x** = **b**, conditions for consistency, uniqueness, infinite solutions, solution sets of linear equations, linear independence, Applications of linear equations.	
Unit 3	**10L**
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	
Unit 4	**15L**
Characteristic roots and Characteristic vectors, Properties of characteristic roots, Quadratic forms: Classification & canonical reduction.	
Reference Books	
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. NarosaPublishing House (Reprint). Searle, S.R (1982).: Matrix Algebra Useful for Statistics. John Wiley &Sons. Chakraborty, Arnab (2014): Linear Algebra, first edition. Sarat Book House. Goon A.M. (1988): Vectors and Matrices, World Press	

2.9 Core P5 Linear Algebra Lab

Linear Algebra Lab	
	2 Credits
List of Practical	
Problems related vectors and vector spaces. Problems related to matrices.	

Problems related to determinant of matrices.

Problems on solution to a linear system of equations.

Problems on characteristic roots and characteristic vectors.

Problems related to quadratic forms.

2.10 CoreT6 –Demography and Vital Statistics 6 Credits

Demography and Vital Statistics	
	4 Credits
Unit1	**15L**
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	**15L**
Introduction: Sources of data on vital statistics, errors in census and registration data. Measurement of population, Rates and ratios of vital events. *Measurements of Mortality*: Crude Death Rate (CDR), Specific Death Rate (SDR), Standardized Death Rate, Cause of Death Rate, Case Fatality Rate, Infant Mortality Rate (IMR), Maternal Mortality Rate (MMR), Neonatal and Perinatal Mortality Rates.	
Unit 3	**15L**
Life (Mortality) Tables: Assumption, descriptions of Complete and Abridged Life Tables, Cohort vs. Current Life Tables, Stationary and Stable population, Construction of Complete Life Table from population and death statistics, Central Mortality Rates and Force of Mortality, Uses of Life Tables. *Measurements of Morbidity*: Morbidity Incidence and Morbidity Prevalence Rates. *Measurements of Fertility*: Crude Birth Rate (CBR), General Fertility Rate (GFR), Specific Fertility Rate (SFR) and Total Fertility Rate (TFR).	
Unit 4	**15L**
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, Use of component method for population projection, Fitting of Logistic curve for population forecasting using Rhode's method.	

Reference Books

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 (3rd edition), Springer.

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

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

Spiegelman M. (1980): Introduction to Demography, Harvard University Press.

Mishra B.D. (1980): An Introduction to the Study of Population, South Asian Pub.

2.11 Core P6 –Demography and Vital Statistics Lab

Demography and Vital Statistics Lab	
	2 Credits

List of Practical

To calculate CDR and Age Specific death rate for a given set of data

To find Standardized death rate by:-

Direct method

Indirect method

To construct a complete life table.

To fill in the missing entries in a life table.

To calculate CBR, GFR, SFR, TFR for a given set of data.

To calculate Crude rate of Natural Increase and Pearle's Vital Index for a given set of data.

To calculate GRR and NRR for a given set of data and compare them.

Population Estimation.

2.12 Core T7–Statistical Computing and Numerical Analysis Using C Programming 6 Credits

Statistical Computing and Numerical Analysis Using C Programming	
	4 Credits
Unit 1	**10L**
Approximation of numbers and functions. Absolute and Relative errors. Interpolation: Polynomial approximation, Weierstrass Theorem (Statement). Difference Table, Newton's Forward and Backward interpolation formulae and Lagrange's general interpolation formula, Error terms. Numerical Differentiation and its applications. Numerical Integration: Trapezoidal and Simpson's 1/3 rules.	
Unit 2	**5L**
Numerical solution of equations: method of fixed point iteration and Newton-Raphson method in one unknown, Conditions of convergence, rates of convergence. Extension of the iteration method to two unknowns (without convergence). Stirling's approximation to factorial n.	
Unit 3	**22L**
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. 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 4	**23L**
Decision making and branching - if...else, nesting of if...else, else if ladder, switch. Looping in C/C++: for, nested for, while, do...while, and jumps in and out of loops. Arrays: Declaration and initialization of one-dim and two-dim arrays. Character arrays and strings: Declaring and initializing string variables, reading and writing strings from Terminal (using scanf and printf only). 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.	
Reference Books	
Kernighan, B.W. and Ritchie, D.(1988): CProgramming 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. 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.

2.13 Core P7 – Statistical Computing Using C/C++ Programming Lab

Statistical Computing Using C/C++ Programming	
	2 Credits
List of Practical (Using UNIX based platforms)	
Plot of a graph y = f(x). Roots of a quadratic equation (with imaginary roots also). Sorting of an array and hence finding median. Mean, Median and Mode of a Grouped Frequency Data. Variance and coefficient of variation of a Grouped Frequency Data. Preparing a frequency table. Random number generation from uniform, exponential,calculate sample mean and variance and compare with population parameters. Matrix addition, subtraction, multiplication, Transpose,Trace , Rank and Determinant. Fitting of Binomial, Poisson distribution. Compute ranks and then calculate rank correlation(without tied ranks). Fitting of lines of regression. Numerical methods: Interpolation by Lagrange formula, Solving one-variable equations using Newton-Raphson and Iteration methods. Trapezoidal and Simpson 1/3 rdrule for numerical integration with convergence. Solving a linear system of equation. Storing the C output in a file	

2.14 Core T_8 –Survey Sampling and Indian Official Statistics 6 Credits

Survey Sampling and Indian Official Statistics	
	4 Credits
Unit 1 15L	
Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. 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, estimates of: population mean, total and proportion, variances of these estimates, estimates of their variances and sample size determination.	
Unit 2 15L	
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. Systematic Sampling: Technique, estimates of population mean and total, variances of these estimates (N=nxk). Comparison of systematic sampling with SRS and stratified sampling in the presence of linear trend and corrections.	
Unit 3 20L	
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 410L	
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. Consumer price Index, Wholesale price index number and index of industrial production. National Income: Basic idea and a brief description of income, expenditure and production approaches.	
Reference Books	
Cochran, W.G. (1984): SamplingTechniques (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-II, World Press.

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

http://mospi.nic.in/

2.15 Core P_8 – Survey Sampling and Indian Official Statistics Lab

Survey Sampling and Indian Official Statistics	
	2 Credits
List of Practical	
To select a SRS with and without replacement. 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. For SRSWOR, estimate mean, standard error, the sample size. Stratified Sampling: allocation of sample to strata by proportional and Neyman's methods. Compare the efficiencies of above two methods relative to SRS. Estimation of gain in precision in stratified sampling. Comparison of systematic sampling with stratified sampling and SRS in the presence of a linear trend. 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. Cluster sampling: estimation of mean or total, variance of the estimate. Two-stage Sampling. Tabular and graphical exercises based on available official statistics. Construction of Consumer and wholesale price index numbers.	

2.16 Core T9 –Statistical Inference-I and Sampling Distributions 6 Credits

Statistical Inference-I and Sampling Distributions	
	4Credits
Unit 1	**14L**
Basic concepts of Statistical Inference: Population & parameter, random sample & statistic, point and interval Estimation, confidence level, testing of hypothesis. Distributions of functions of random variables. Sampling distribution of a statistic and its standard error.	
Unit 2	22L
Exact sampling distributions: χ^2 distribution, definition and derivation of its p.d.f. 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 χ^2 distribution. Derivation of the sampling distribution of sample mean and variance for a normal population. 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. 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 (n1, n2). Relationship between t, F and $\chi 2$ distributions. Distributions of sample means, sample variances and sample correlation coefficient (null case) of a random sample from a bivariate normal population, distribution of the simple regression coefficient (for both stochastic and non-stochastic independent variable cases).	
Unit 3	8L
Order Statistics: Introduction, distribution of the rth order statistic, smallest and largest order statistics. Joint distribution of order statistics, distribution of sample median and sample range.	
Unit 4	16L
Elements of hypothesis testing: Null and alternative hypotheses, simple & composite hypotheses, critical region, type I and type II errors, level of significance, size, power, p-value. Exact tests and confidence intervals: classical and p-value approaches. Tests of significance related to Binomial proportion(s), Poisson mean(s), Univariate Normal mean (s), standard deviation(s) and Bivariate normal parameters. Combination of probabilities in tests of significance.	
Reference Books	
Goon, A.M., Gupta, M.K. and Dasgupta, B. (2003): An Outline of Statistical Theory, Vol. I, 4th Edn. World Press, Kolkata. Rohatgi V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2ndEdn. (Reprint) John Wiley and Sons. Hogg, R.V. And Tanis, E.A. (2009): A Brief Course in Mathematical Statistics. Pearson Education. Johnson, R.A. and Bhattacharya, G.K. (2001): Statistics-Principles and Methods, 4th Edn. John Wiley and Sons.	

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.

Hogg R.V. & Craig A.T. (1978): Introduction to Mathematical Statistics, Prentice Hall.

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

2.17 Core P9 –Statistical Inference-I and Sampling Distributions Lab

Statistical Inference-I and Sampling Distributions lab	
	2 Credits
List of Practical	
Test of significance for single proportion and difference of two proportions. Test of significance for single Poisson mean and difference of two Poisson means. Test of significance and confidence intervals for single mean and difference of two means. Test of significance and confidence intervals for single variance and ratio of two variances. Test of parameters under bivariate normal distribution.	

2.18 Core T10- Index Numbers and Time Series Analysis 6 credits

Index Numbers and Time Series Analysis	
	4 Credits
Unit 1	**12L**
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. Consumer price Index, Wholesale price index number and index of industrial production.	
Unit 2	**12L**
Stochastic Process: Introduction and Stationary Process. Introduction to time series data, application of time series from various fields. Modelling time series as deterministic function plus IID errors: Components of a time series (trend, cyclical and seasonal patterns, random error) Decomposition of time series. Estimation of trend: free hand curve method, method of moving averages, fitting various mathematical curves and growth curves. Effect of elimination of trend on other components of the time series.	

Unit 3 **12L**
Estimation of seasonal component by Method of simple averages, Notions of multiplicative models: ratio to Trend. Introduction to stochastic modelling: Concept of stationarity. Illustration of how a stationary time series may show temporal patterns. Stationarity in mean.
Unit 4 **24L**
Box-Jenkins modelling: Moving-average (MA) process and Autoregressive (AR) process of orders one and two.ACF and its graphical use in guessing the order of MA processes. Estimation of the parameters of AR (1) and AR (2) using least square and Yule-Walker equations. Forecasting: Exponential smoothing methods.
Reference Books
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. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002): Fundamentals of Statistics, Vol. II, 8th Edn. The World Press, Kolkata Mudgett B.D. (1951): Index Numbers, John Wiley Allen R.G.D. (1975): Index Numbers in Theory and Practice, Macmillan Nagar A.L. & Das R. K. (1976): Basic Statistics

2.19 Core P10 – Index Numbers and Time Series Analysis Lab

Index Numbers and Time Series Analysis	
	2 Credits
List of Practical	
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 Fitting and plotting of mathematical curves: modified exponential curve Gompertz curve	

Fitting of trend by Moving Average Method.

Plotting detrended series.

Measurement of Seasonal indices Ratio-to-Moving Average method.

Plotting ACF of a given time series.

Using Yule-Walker equation and Least squares to fit AR (1) and AR (2) models to real life data

Forecasting by exponential smoothing.

Calculation of price and quantity index numbers.

Construction of Consumer and wholesale price index numbers.

2.20 Core T11 – Statistical Inference II 6 Credits

Statistical Inference-II	
	4 Credits
Unit 1	**8L**
Limit laws: Sequence of random variables, convergence in probability, convergence in mean square and convergence in distribution and their interrelations, Weak law of large numbers 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	20L
Point Estimation: Concepts of estimation, notions of mean square error, unbiasedness, best linear unbiasedness and minimum variance unbiasedness. Necessary and sufficient condition for uniformly minimum variance unbiased estimators (UMVUE). Properties of UMVUE. Consistent estimators and asymptotic efficiency. Sufficiency, factorization theorem (discrete case only). Fisher' information (for single parameter only). Cramer-Rao inequality and minimum variance bound (MVB) estimators, Rao-Blackwell theorem and its applications. Methods of Estimation: Method of moments, method of maximum likelihood estimation and statements of their properties.	
Unit 3	20L
Theory of hypothesis testing: Test function, randomized and non-randomized tests, most powerful (MP) test, uniformly most powerful (UMP) test, Neyman - Pearson Lemma (statement and proof of sufficiency part only) and its applications to construct MP and UMP tests, uniformly most powerful unbiased (UMPU) tests (definition only). Likelihood ratio tests, properties of likelihood ratio tests (without proof). Interval Estimation: Confidence intervals, Concepts of Uniformly Most Accurate (UMA) confidence sets, relationship with tests of hypotheses.	

Unit 4	12L

Large Sample Theory: Delta method, Derivation of large sample standard error of sample moments, standard deviation, coefficient of variation, b1 and b2 measures, and correlation coefficient and their uses in large sample tests under normality assumption, Large sample distribution of sample quantile.

Transformations of Statistics to stabilize variance: derivation and uses of Sin^{-1}, square root, 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.

Reference 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.

2.21 Core P11 – Statistical Inference II Lab

Statistical Inference II	
	2 Credits

List of Practical

Maximum Likelihood Estimation.

Estimation by the method of moments, minimum Chi-square.

Type I and Type II errors.

Most powerful critical region.

Uniformly most powerful critical region.

Unbiased critical region.

Power curves.

Confidence intervals and UMA confidence sets.

Likelihood ratio tests for simple null hypothesis against simple alternative hypothesis.

Likelihood ratio tests for simple null hypothesis against composite alternative hypothesis.

Asymptotic properties of LR tests.

Large sample tests.

2.22 Core T12–Linear Models and Regression 6 credits

Linear Models and Regression	
	4 Credits
Unit 110L	
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), Orthogonal splitting of total variation, selection of valid error.	
Unit 216L	
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. *Regression Diagnostics*: Model checking: Prediction from a fitted model.	
Unit 328L	
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 in one-way classified data for random effect models.	
Unit 46L	
Binary and Count data regression: Logistic and Poisson Regression.	
Reference Books	
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. Goon, A.M., Gupta, M.K., Das Gupta, B. (2005). Outline of Statistics, Vol.II, World Press,	

Calcutta.

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

Chatterjee S., Hadi A.S., Price B.: Regression Analysis by Example, 3rd Edn, John Wiley & Sons.

2.23 Core P12–Linear Models and Regression Lab

Linear Models	
	2 Credits
List of Practical	
Simple Linear Regression. Multiple Regression. Tests for Linear Hypothesis. Analysis of Variance of a one way classified data. Analysis of Variance of a two way classified data with one observation per cell. Analysis of Variance of a two way classified data with more than one observation per cell. Analysis of Covariance of a one way classified data with one concomitant variable. Analysis of Covariance of a two way classified data with one concomitant variable. Analysis of Variance of a one way classified data for random effect model.	

2.24 Core T13- Design of Experiments 6 Credits

Design of Experiments	
	4 Credits
Unit 16L	
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 225L	
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 320L	
Factorial experiments: advantages, notations and concepts. 2^nexperiments: design and analysis. Total and Partial confounding for 2^n ($n \leq 5$). Factorial experiments in a single replicate.	
Unit 49L	
Split Plot Designin RBD and Strip arrangements, Groups of experiments with RBD and LSD.	
Reference Books	
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.	

2.25 Core P13 – Design of Experiments Lab

Design of Experiments	
	2 Credits
List of Practical	
Analysis of a CRD. Analysis of an RBD. Analysis of an LSD. Analysis of an RBD with one missing observation. Analysis of an LSD with one missing observation. Analysis of $\mathbf{2^2}$ and$\mathbf{2^3}$ factorial in CRD and RBD. Analysis of a completely confounded two- level factorial design in 2 blocks. Analysis of a completely confounded two- level factorial design in 4 blocks. Analysis of a partially confounded two- level factorial design. Analysis of a single replicate of a $\mathbf{2^n}$ design. Analysis of Split Plot and Strip Plot designs. Analysis of Groups of experiments in RBD and LSD	

2.26 Core T14–MultivariateAnalysisandNonparametricMethods 6 Credits

Multivariate Analysis and Nonparametric Methods	
	4 Credits
Unit 1	**20L**
Multivariate Data: multiple regression, multiple and partial correlation coefficients. Random Vector: Probability mass/density functions, Distribution function, mean vector & Dispersion matrix, Marginal & Conditional distributions. Multiple and partial correlation coefficient.	
Unit 2	**15L**
Multivariate Normal distribution and its properties. Multinomial Disrtribution and its properties.	

Tests forMultiple and partial correlation coefficients.

Unit 3 **10L**

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

Unit 4 **15L**

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.

Reference Books

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

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

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

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

Mukhopadhyay, P.: Mathematical Statistics.

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.

2.27 Core P14 – MultivariateAnalysis&NonparametricMethods Lab

Multivariate Analysis and Nonparametric Methods	
	2 Credits
List of Practical	
Test for Multiple Correlation. Test for Partial Correlation. Multivariate Normal Distribution. Principal Components Analysis. Factor Analysis. Test for randomness based on total number of runs. Kolmogorov -Smirnov test for one sample. Sign test . Signed rank test. Wilcoxon-Mann-Whitney test. Kruskal-Wallis test.	

3. Department Specific Electives Subjects Syllabus

3.1 DSE T1–Statistical Quality Control

Statistical Quality Control	
	4 Credits
Unit 1	**10L**
Quality: Definition, dimensions of quality, Difference between product control and process control, Statistical Process Control - Seven tools of SPC, chance and assignable Causes of quality variation.	
Unit 2	20L
Statistical Control Charts - Construction and Statistical basis of 3-σ Control charts, Rational Sub-grouping, Control charts for variables: X-bar & R-chart, X-bar & s-chart. 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 3	20L
Definitions related to product control, Acceptance sampling plan, Principle of acceptance sampling plans, Single sampling plan - their OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, Double sampling plan - their OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, use and interpretation of Dodge and Roming sampling inspection plan tables.	
Unit 4	10L
Introduction to Six-Sigma: Overview of Six Sigma, Lean Manufacturing and Total Quality Management (TQM), Introduction to ISO quality standards: ISO 9001, ISO 14001, BIS.	
Reference Books	
Montogomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. II, 8th Edn. The World Press, Kolkata. Mukhopadhyay, P (2011): Applied Statistics, 2nd edition revised reprint, 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.Harris(2002):Transactional Six Sigma and Lean Servicing, 2nd Edition St. Lucie Press. Hoyle, David (1995): ISO Quality Systems Handbook, Heinemann Publication. 2nd Edition, Butterworth	

3.2 DSE P1 – Statistical Quality Control Lab

Statistical Quality Control	
	2 Credits
List of Practical	
Construction and interpretation of statistical control charts X-bar & R-chart X-bar & s-chart np-chart p-chart c-chart u-chart Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves Calculation of process capability	

3.3 DSE T2 - Econometrics

Econometrics	
	4 Credits
Unit 1	**15L**
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	**15L**
Multicollinearity: Introduction and concepts, detection of multicollinearity, consequences and solutions of multicollinearity,.	
Unit 3	**15L**
Autocorrelation: Concept, consequences of auto correlated disturbances, detection and solution of autocorrelation. Generalized least squares estimation.	
Unit 4	**15L**
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)	
Reference Books	
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.	

3.4 DSE P2 –Econometrics Lab

Econometrics Lab	
	2 Credits
List of Practical	
Problems related to consequences of Multicollinearity. Diagnostics of Multicollinearity. Problems related to consequences of Autocorrelation (AR(I)). Diagnostics of Autocorrelation. Problems related to consequences Heteroscedasticity. Diagnostics of Heteroscedasticity. Estimation of problems of General linear model under Heteroscedastic distance terms. Problems on Autoregressive models. Problems on Instrumental variable.	

3.5 DSE T_3–Survival Analysis

Survival Analysis	
	4 Credits
Unit 1	**15L**
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	**15L**
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	15L
Non-parametric methods: Actuarial and Kaplan-Meier methods for estimating survival function and variance of the Estimator.	
Unit 4	15L
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.	
Reference Books	
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.	

3.6 DSE P_3 –Survival Analysis Lab

Survival Analysis Lab	
	2 Credits
List of Practical	
To estimate survival function. To determine death density function and hazard function. To identify type of censoring and to estimate survival time for type I censored data. To identify type of censoring and to estimate survival time for type II censored data. To identify type of censoring and to estimate survival time for progressively type I censored data. Estimation of mean survival time and variance of the estimator for type I censored data. Estimation of mean survival time and variance of the estimator for type II censored data. Estimation of mean survival time and variance of the estimator for progressively type I censored data. To estimate the survival function and variance of the estimator using Non-parametric methods with Actuarial methods. To estimate the survival function and variance of the estimator using Non-parametric methods with Kaplan-Meier method.	

3.7 DSE T4-Operations Research

Operations Research	
	4 Credits
Unit 1	**12L**
Introduction and Historical Background, Phases of Operations Research, model building, various types of O.R. problems. Linear Programming Problem, Requirements of LPP, Mathematical Formulation of LPP, Graphical Methods to Solve Linear Programming Problems. Convex sets, Extreme point.	
Unit 2	**12L**
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 3	**18L**
Introduction, Formulation of Transportation Problem (TP). 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 4	**18L**
Game theory: Introduction, Competitive Situations, Characteristics of Competitive Games. Rectangular game, Two-Person Zero-Sum 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.	
Reference Books	
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	

3.8 DSE P4 – Operations Research Lab

Operations Research Lab	
	2 Credits
List of Practical (Using TORA/WINQSB/LINGO/LINDO)	
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 mx2 / 2xn rectangular game. 7. Mixed strategy.	

3.9 DSE T5–Project Work

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.	

4. General Elective Subjects Syllabus

4.1 GE T1 –Statistical Methods

Statistical Methods	
	4 Credits
Unit 1	**15L**
Introduction: Definition and scope of Statistics, concepts of statistical population and sample. Data: quantitative and qualitative, attributes, variables, scales of measurement - nominal, ordinal, interval and ratio. Frequency distribution, Presentation: tabular and graphic, including histogram and ogives.	
Unit 2	**20L**
Measures of Central Tendency: mathematical and positional. Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation, moments, skewness and kurtosis.	
Unit 3	**15L**
Bivariate data: Definition, scatter diagram, simple, partial and multiple correlation (3 variables only), rank correlation (Spearman). Simple linear regression, principle of least squares and fitting of polynomials and exponential curves.	
Unit 4	**10L**
Theory of attributes, consistency of data, independence and association of attributes, measures of association and contingency.	
Reference Books	
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. AndBoes, D.C. (2007): Introduction to theTheory of Statistics, 3rd Edn. (Reprint), Tata McGraw-Hill Pub. Co. Ltd. Goon A.M., Gupta M.K. and Dasgupta B. : Basic Statistics. The World Press, Kolkata. Chakraborty, Arnab (2016) : Probability and Statistics. Sarat Book House.	

4.2 GE P1 – Statistical Methods

Statistical Methods Lab	
	2 Credits
List of Practical	
Graphical representation of data Problems based on measures of central tendency Problems based on measures of dispersion Problems based on combined mean and variance and coefficient of variation Problems based on moments, skewness and kurtosis Fitting of polynomials, exponential curves Karl Pearson correlation coefficient Partial and multiple correlations Spearman rank correlation with and without ties. Correlation coefficient for a bivariate frequency distribution Lines of regression, angle between lines and estimated values of variables. Checking consistency of data and finding association among attributes.	

4.3 GE T2 – Introductory Probability

Introductory Probability	
	4 Credits
Unit 1	**15L**
Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability – classical, statistical, and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications.	
Unit 2 **10L**	
Random Variables: Discrete and continuous random variables, p.m.f., p.d.f., c.d.f. Illustrations of random variables and its properties. Expectation, variance, moments and moment generating function.	
Unit 3	**15L**
Standard discrete probability distributions: Binomial, Poisson, geometric, negative binomial, hypergeometric	
Unit 4	**20L**
Standard continuous probability distributions: Uniform, normal, exponential, beta, gamma.Chebyshev's inequality, Convergence in probability, weak law of large numbers, De-Moivre Laplace and Lindeberg-Levy Central Limit Theorem (C.L.T).	
Reference Books	
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 Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I& II, 8th Edn. The World Press, Kolkata. Chakraborty, Arnab (2016) : Probability and Statistics. Sarat Book House. Ross, S. (2002): A First Course in Probability, Prentice Hall.	

4.4 GE P2 –Introductory ProbabilityLab

Introductory Probability Lab	
	2 Credits
List of Practical	
Fitting of binomial distributions for n and p = q = ½ given Fitting of binomial distributions for n and p given Fitting of binomial distributions computing mean and variance Fitting of Poisson distributions for given value of lambda Fitting of Poisson distributions after computing mean Application problems based on binomial distribution Application problems based on Poisson distribution Problems based on area property of normal distribution To find the ordinate for a given area for normal distribution Application based problems using normal distribution Fitting of normal distribution when parameters are given Fitting of normal distribution when parameters are not given	

4.5 GE T3 – Basicsof Statistical Inference

Basics of Statistical Inference	
	4 Credits
Unit 1	**25L**
Population and Sample, Parameter and Statistic, Population distribution and Sampling distribution. Statistical Inference: Point Estimation, Interval Estimation and Testing of Statistical Hypothesis. Four useful distributions for statistical Inference; Normal, χ^2 , t and F (Statement of the pdf's & shape of the curves) Estimation of population mean, confidence intervals for the parameters of a normal distribution (one sample and two sample problems). The basic idea of significance test. Null and alternative hypothesis. Type I& Type II errors, level of significance, concept of p-value. Tests of hypotheses for the parameters of a normal distribution (one sample and two sample problems).	
Unit 2	**10L**
Categorical data: Tests of proportions, tests of association and goodness-of-fit using Chi- square test.	
Unit 3	**5L**
Tests for the significance of correlation coefficient. Sign test. Wilcoxon two-sample test.	
Unit 4	**20L**
Analysis of variance, one-way and two-way classification. Brief exposure of three basic principles of design of experiments, Statistical concepts of "treatment", "plot" and "block". Analysis of completely randomized design, randomized complete block design.	
Reference Books	
Daniel, Wayne W., Bio-statistics (2005): A Foundation for Analysis in the Health Sciences. John Wiley . Goon, A.M., Gupta M.K. & Das Gupta(2005):Fundamentals of statistics, Vol.-I & II. Dass, M. N. &Giri, N. C.: Design and analysis of experiments. John Wiley. Dunn, O.J (1977): Basic Statistics: A primer for the Biomedical Sciences. John Wiley. Bancroft, Holdon Introduction to Bio-Statistics (1962) P.B. Hoebar New York. Goldstein, a Biostatistics-An introductory text (1971). The Macmillion New York.	

4.6 GE P3 – Basics of Statistical InferenceLab

Basics of Statistical InferenceLab	
	2 Credits
List of Practical	
Estimators of population mean. Confidence interval for the parameters of a normal distribution (one sample and two sample problems). Tests of hypotheses for the parameters of a normal distribution (one sample and two sample problems). Chi-square test of proportions. Chi-square tests of association. Chi-square test of goodness-of-fit. Test for correlation coefficient. Sign test for median. Sign test for symmetry. Wilcoxon two-sample test. Analysis of Variance of a one way classified data Analysis of Variance of a two way classified data. Analysis of a CRD. Analysis of an RBD.	

4.7 GE T4 –Introduction to Operations Research

Introduction to Operations Research	
	4 Credits
Unit 1	**15L**
Introduction to Operations Research, phases of Operations Research, model building, various types of Operations Research problems.	
Unit 2	**15L**
Optimum solution to a L.P.P: Simplex method, concept of artificial variables and Charne's big M-technique. Graphically identifying special cases of L.P.P. Concept of duality in L.P.P.	
Unit 3	**15L**
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. Assignment problem: Hungarian method to find optimal assignment.	
Unit 4	**15L**
Game theory: Rectangular game, minimax-maximin principle, solution to rectangular game using graphical method, dominance property to reduce the game matrix and solution to rectangular game with mixed strategy. Networking: Shortest route problem	
Reference Books	
Taha, H. A. (2007): Operations Research: An Introduction 8th Edition, Prentice Hall of India. SwarupKanti, Gupta, P.K. and Manmohan (2007): Operations Research, 13 Edition Sultan Chand and Sons Ravindran, a, Phillips, D.T., Solberg, J.J. (2005): Operations Research- Principles and Practice, John Wiley & Sons.	

4.8 GE P4 – Introduction to OperationsResearchLab

Introduction to Operations Research Lab	
	2 Credits
List of Practical	
Mathematical formulation of L.P.P and solving the problem using graphical method Simplex technique to solve L.P.P and reading dual solution from the optimal table Charne's Big M method involving artificial variables. Identifying Special cases: Degenerate solution, Unbounded solution, Alternate solution and Infeasible solution by Graphical method and interpretation Allocation problem using Transportation model Allocation problem using Assignment model Networking : Shortest route problem Problems based on game matrix: mx2 / 2xn rectangular and Mixed strategy	

4.9 GE T5 – Applied Statistics

Applied Statistics	
	4 Credits
Unit 1	**15L**
Economic Time Series: Components of time series, Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series. Measurement of trend by method of free-hand curve, method of semi-averages and method of least squares (linear, quadratic and modified exponential).Measurement of seasonal variations by method of ratio to trend.	
Unit 2	**15L**
Index numbers: Definition, Criteria for a good index number, different types of index numbers. Construction of index numbers of prices and quantities, consumer price index number & wholesale price index number. Index of Industrial Production and rate of inflation. Uses and limitations of index numbers. Measures of Inequality and Development: Gini's coefficient and Lorenz curve, Human Development Index.	
Unit 3	**15L**
Statistical Quality Control: Importance of statistical methods in industrial research and practice. Determination of tolerance limits. Causes of variations in quality: chance and assignable. General theory of control charts, process & product control, Control charts for variables: X- bar and R-charts. Control charts for attributes: p and c-charts.	
Unit 4	**15L**
Demographic Methods: Introduction, measurement of population, rates and ratios of vital events. Measurement of mortality: CDR, SDR (w.r.t. Age and sex), IMR, Standardized death rates. Life (mortality) tables: definition of its main functions and uses. Measurement of fertility and reproduction: CBR, GFR, and TFR. Measurement of population growth: GRR, NRR.	
Reference Books	
Mukhopadhyay, P. (1999): Applied Statistics, New Central Book Agency, Calcutta. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II,9th Edition World Press, Kolkata. Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals Of Applied Statistics, 4th Edition (Reprint), Sultan Chand & Sons Montogomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition Wiley India Pvt. Ltd.	

4.10 GE P5 –Applied Statistics Lab

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

Skill Enhancement Subjects Syllabus

4.11 SEC T1 – Statistical Data Analysis using R

Statistical Data Analysis Using R	
	2Credits
Unit 1 5L	
Introduction to R: Installation, commandline environment, overview of capabilities, brief mention of open source philosophy. 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. Standard functions, e.g., sin, cos, exp, log.	

Unit 2	**5L**
The different types of numbers in R: Division by zero leading to Infor -Inf. NaN. NA. No need to go into details. Variables. Creating a vector using c(), seq() and colon operator. How functions map overvectors. Functions to summarise a vector: sum, mean, sd, medianetc. Extracting a subset from the vector (by index, by property). R as a graphing calculator: Introduction to plotting. Plot(), lines(), abline(). No detailsabout 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 35L	
Matrix operations in R: Creation. Basic operations. Extracting submatrices. 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 45L	
Problems on discrete and continuous probability distributions.	
Reference Books	
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 **https://cran.r-project.org/doc/contrib/Paradis-rdebuts_en.pdf**)	

4.12 SEC T2 – Research Methodology

Research Methodology	
	2 Credits
Unit 1	**5L**
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	**5L**
Survey Methodology and Data Collection, sampling frames and coverage error, non-response.	
Unit 3	**5L**
Review of various techniques for data analysis covered in core statistics papers, techniques of interpretation, precaution in interpretation.	
Unit 4	**5L**
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.	
Reference Books	
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.	

4.13 SEC T3 – Monte Carlo Method

Monte Carlo Method	
	2 Credits
Unit 1	**5L**
Using the computer for random number generation. (treated as a black box) A brief look at some popular approaches (nomathematical justification needed). Simulating a coin toss, a die roll and a card shuffle.	
Unit 2	**5L**
CDF inversion method. Simulation from standard distributions. Finding probabilities and moments using simulation.	
Unit 3	**5L**
Monte Carlo integration. Basic idea of importance sampling. MCMC not included.	
Unit 4	**5L**
Generating from Binomial and Poisson distributions, and comparing the histograms to the PMFs. Generating from Uniform(0,1) distribution, and applying inverse CDF transforms. Simulating Gaussian distribution using Box-Muller method. Approximating the expectation of a given function of a random variable using simulation. Graphical demonstration of the Law of Large Numbers. Approximating the value of pi by simulating dart throwing.	
Reference Books	
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.	