INDIAN STATISTICAL INSTITUTE

First Year

1st Semester	2nd Semester
Analysis I (C)	Analysis II (C)
Probability Theory I (C)	Probability Theory II (C)
Vector and Matrices I (C)	Vector and Matrices II (C)
Statistical Methods I (C)	Statistical Methods II (C)
Introduction to Programming and Data Structures	Numerical Analysis
Remedial English (Non-Credit)	

Second Year

1st Semester	2nd Semester
Analysis III (C)	Introduction to Markov Chains
Probability Theory III (C)	Discrete Mathematics
Statistical Methods III (C)	Statistical Methods IV (C)
Elements of Algebraic Structures	Economic and Official Statistics and Demography
Elective Course I	Elective Course II

Third Year

1st Semester	2nd Semester
Linear Statistical Models (C)	Nonparametric and Sequential Methods (C)
Parametric Inference (C)	Design of Experiments (C)
Sample Surveys (C)	Statistics Comprehensive (C)
Statistical Quality Control and Operations Research	Design and Analysis of Algorithms
Elective Course III	Optional Course

1. Statistics Courses

- ## Statistical Methods I

History of statistics. (3 lectures)
Various kinds of statistical problems and studies. (5 lectures)
Collection and summarization and presentation of different types of univariate and bivariate data. (8 lectures)
Descriptive statistics: measures of location, spread, skewness, kurtosis; various properties of these measures and their utility. (20 lectures)
Summarization and analysis of different types of bivariate data. Correlation, measures of non-linear associations, simple linear regression and properties. (20 lectures)
Illustration with specific examples and numerical exercises using statistical packages (such as R).

- ## Statistical Methods II

Summarization and analysis of different types of multivariate data. Multiple regression. Partial and multiple correlation. (15 lectures)
Simulation of probability distributions and stochastic models. Applications of simulation techniques. (10 lectures)
Methods of estimation: method of moments, maximum likelihood estimation, Fisher's scoring. Problem of missing data, finding MLEs using EM algorithm. (18 lectures)
Fitting probability distributions and stochastic models to observed data. Goodness of fit using Pearson's χ^2 and Q-Q plots (applications only). (12 lectures)
Practicals using statistical packages (such as R).

- ## Statistical Methods III

Point estimation: Criteria for good estimates: Unbiasedness, minimum variance, mean square error. (8 lectures)
Tests of hypotheses: Different types of statistical hypotheses. Error probabilities, level of significance and power of a test, non-central χ^2. Tests for parameters of normal distributions based on single and two populations. Large sample tests for parameters in Binomial and Poisson distributions. Conditional tests. (24 lectures)
Confidence intervals: criteria for goodness, pivotal quantities, relationship with tests of hypothesis, illustrations. (6 lectures)
Elements of Time Series analysis: Trend/secular, seasonal/cyclic and random components of a time series, moving averages, autocorrelation function, correlogram and periodogram. (10 lectures)
Sampling distributions of sample mean and sample variance. Central and non-central χ^2, t and F distributions. (6 lectures)
Practicals using statistical packages (such as R).

- ## Statistical Methods IV

Statistical methods for estimation and hypothesis testing for parameters in bivariate and multivariate normal distributions. Estimation and testing problems in simple and multiple linear regression. (18 lectures)
Probit and logit analysis. Logistic regression. (6 lectures)
Basics of non-linear regression. Iteratively re-weighted least square estimation and algorithm.

Method of least absolute deviation. (6 lectures)
Likelihood ratio and large-sample tests and confidence intervals. Variance stabilizing transformations. χ^2-tests for independence and homogeneity. (12 lectures)
Sample quantiles and their properties. (4 lectures)
Resampling techniques such as Jackknife, Bootstrap, Cross-validation as data analytic tools. (10 lectures)
Practicals using statistical packages (such as R).

Reference Texts for Statistical Methods I-IV

1. J.M. Tanur (ed.): *Statistics: A Guide to the Unknown.*
2. D. Freedman, R. Pisani and R. Purves: *Statistics*.
3. M. Tanner: *An Investigation for a Course in Statistics*.
4. M.G. Kendall and A. Stuart: *The Advanced Theory of Statistics, Vol. 1 and 2*.
5. J.F. Kenney and E.S. Keeping: *Mathematics of Statistics*.
6. G.U. Yule and M.G. Kendall: *An Introduction to the Theory of Statistics*.
7. C.R. Rao: *Linear Statistical Inference and its Applications*.
8. F.E. Croxton and D.J. Cowden: *Applied General Statistics*.
9. W.A. Wallis and H.V. Roberts: *Statistics: A New Approach*.
10. C. Chatfield: *The Analysis of Time Series: An Introduction*.
11. P. J. Bickel and K. A. Doksum: *Mathematical Statistics.*

- ## Linear Statistical Models

Theory of generalized inverse of a matrix.
Introduction to stochastic models; formulation and illustrations. Linear statistical models; illustrations. (6 lectures)
Least square estimation, estimable linear functions, Normal equations, Best Linear Unbiased Estimates (BLUEs). Gauss - Markov Theorem. (14 lectures)
Degrees of freedom. Fundamental Theorems of Least Square. Testing of linear hypotheses. One way and two way classification models, ANOVA and ANCOVA. Nested models. Multiple comparisons. (15 lectures)
Introduction to random effect models. Log-linear models. (6 lectures)
Introduction to Generalized Linear Models (GLMs), illustration using logit and probit analysis. Linear predictor, link function, canonical link function, deviance. Maximum likelihood estimation using iteratively re-weighted least square algorithm. Goodness of fit test. (15 lectures)
Practicals using statistical packages (such as R).

Reference Texts

1. S.R. Searle: *Linear Models.*
2. F.A. Graybill: *An introduction to Linear Statistical Models, Vol. I.*
3. J.H. Stapleton: *Linear Statistical Models.*
4. R.R. Hocking: *Methods and Applications of Linear Models.*
5. R. Christensen*: Plane Answers to Complex Questions: The Theory of Linear Models.*
6. C. R. Rao: *Linear Statistical Inference.*
7. D. Sengupta and S. R. Jammalamadaka: *Linear Models, An Integrated Approach.*
8. P. McCullagh and J. A. Nelder: *Generalized Linear Models.*

- ## Economic and Official Statistics and Demography

Economic Statistics:

Index numbers: Construction of index numbers, properties, some well-known index number formulae, problem of construction of index numbers, chain indices, cost of living indices, splicing of index numbers, different types of index numbers used in India. (6 lectures)

Analysis of income and allied size distributions: Pareto and log-normal distributions, genesis, specification and estimation, Lorenz curve, Gini coefficient. (6 lectures)

Demand analysis: Classification of commodities, Engel curve analysis using cross-section and time series data, Engel curves incorporating household characteristics, demand projection, specific concentration curves. (8 lectures)

Production analysis: Profit maximization, cost minimization, returns to scale, Cobb-Douglas and ACMS production functions. (6 lectures)

Official Statistics:

Indian Statistical System: Official Organisations for collecting/compiling/publishing national/state level data on different variables – CSO, NSSO, RBI, Planning Commission, State Statistical Bureaus, Labour Bureau, Population Census; Role of Centre and State. Selected topics on Statistics (for All India/ Different states of India) relating to agriculture and allied areas including meteorology and environment; Industry, Trade, Finance including money supply and banking statistics; National Accounts and Infrastructure; Population, Health, Education, Prices, Level of living, Labour, Employment and other socio-economic variables. International Statistical System: Comparison of major macro variables – National Income/ GDP. Selected topics from: Purchasing power parity; Indicators relating to Energy, environment, Gender, Industry, National accounts, Social Statistics and Trade. (10 lectures)

Demography:

Sources of demographic data - census, registration of vital events. Rates and ratios. Measures of mortality. Life Table - construction and applications. Stable and stationary population. Measures of fertility and reproduction. Standardization of vital rates. Population growth curves, population estimates and projections. Measures of migration. Use of demographic data for policy formulation. (18 lectures)

Reference Texts for Economic Statistics

1. P.H. Karmel and M. Polasek: *Applied Statistics for Economists.*
2. R.G.D. Allen: *Price Index Numbers.*
3. N. Kakwani: *Income Inequality and Poverty.*
4. L.R. Klein: *An Introduction to Econometrics.*
5. J.S. Cramer: *Empirical Econometrics.*
6. M.D. Intrilligator: *Econometric Models, Techniques and Applications.*

Reference Texts for Official Statistics

1. M.R. Saluja: *Indian Official Statistical Systems.*
2. CSO (MOSPI) Publication*: Statistical System in India.*
3. United Nations publications
4. RBI: *Handbook of Statistics for the Indian Economy* (various years)
5. *Economic Survey,* Govt. of India, Ministry of Finance (various years)

Reference Texts for Demography

1. R. Ramkumar: *Technical Demography.*
2. K. Srinivasan: *Demographic Techniques and Applications.*
3. B.D. Mishra: *An Introduction to the Study of Population.*
4. H.S. Shryock: *The Methods and Materials in Demography.*

- ## Statistical Quality Control and Operations Research

Statistical Quality Control (SQC):

Introduction to quality: Concept of quality and its management – quality planning, quality control and quality improvement; concept of variations and its impact, relevance of exploratory data analysis, run plot, lag plot, frequency distribution and other QC tools. (5 lectures)

Measurement System: Introduction to measurement system; types of measurement; measurement validity; measurement errors and their estimation. (5 lectures)

Use of Control Chart: Introduction to control chart, control chart for variables and attributes - X-MR chart, $\bar{X}$-R chart, $\bar{X}$-s chart, p-chart, np-chart and c-chart; u-chart, CUSUM chart, EWMA chart; process capability analysis. (8 lectures)

Acceptance Sampling: Introduction to acceptance sampling; concept of AQL, LTPD, producer's risk and consumer's risk; single sampling plan and its OC function; acceptance rectification plan - concept of AOQ, AOQL ATI, acceptance sampling tables; concept of double and multiple sampling plan; average sample number. (7 lectures)

Operations Research (OR):

Introduction to Operations Research (3 lectures)

Optimization Theory: Mathematical modeling and concept of optimization problems: linear, nonlinear and integer programming problems; formulation and application of optimization problems; convex analysis in optimization theory; linear programming problem - graphical method to solve linear programming problem, simplex algorithm, sensitivity analysis, solution procedure of two person zero-sum games; optimality conditions and duality theory; nonlinear programming problem and its classification. (19 lectures)

Queuing Theory: Queuing system in practice and importance in Operations Research; pure birth process, birth and death process; introduction to M/M/1 and M/M/C queues; finite queuing system; application of queuing system and limitation. (6 lectures)

Concluding remark: Synthesizing Statistical Quality Control and Operations Research. (1 lecture)

Reference Texts

1. *Statistical Quality Control*- E.L. Grant & R.S. Leavenworth, McGraw-Hill, N.Y.
2. *Quality Control and Industrial Statistics* - A. J. Duncan, Irwin, Homewood, Ill
3. *Introduction to Statistical Quality Control*- D.C. Montgomery, Wiley, N.Y.
4. *Exploratory Data Analysis*- J. W. Tukey, Addison-Wesley
5. *Principles of Quality Control*- Jerry Banks, John Wiley
6. *Defect Prevention* – Victor E Kane, Marcel Dekker, New York
7. *Juran's Quality Control Handbook*-J. M. Juran & F. M. Gryne, McGraw Hill.
8. *Introduction to Linear Optimization*, D. Bertsimas and J. N. Tsitsiklis, Athena, Scientific, Belmont, Massachusetts, 1999.
9. *Linear and Nonlinear Programming*, D. G. Luenberger, Second Edition, Addison-Wesley, Reading, MA, 1984.

10. *Linear Programming* - G. Hadley, Addison Wesley.
11. *Linear Programming* - K. G. Murty, John Wiley
12. *Linear Programming and Network Flows*, M. S. Bazaraa and J. J. Jarvis, John Wiley & Sons, Inc., New York,.
13. *Nonlinear Programming: Theory and Algorithms*, M. S. Bazaraa, H. D. Sherali, and C. M. Shetty, New York, NY: John Wiley & Sons Inc.
14. *Introduction to Operations Research*. Hillier and Lieberman, McGraw-Hill, Boston., MA.
15. *Numerical Optimization with Applications*, S. Chandra, Jayadeva and Aparna Mehra, Narosa Publishing House (2009).

- ## Parametric Inference

Basic inference problems. Sufficiency, factorization theorem, minimal sufficiency. Completeness, Lehmann-Scheffe Theorem. Ancillarity, Basu's Theorem. Exponential families of distributions, canonical parameters and canonical sufficient statistics. Point Estimation: Criteria for goodness: mean square error, unbiasedness, relative efficiency, Cramer-Rao inequality, Bhattacharya bounds, UMVUE, Rao-Blackwell theorem. Consistency. (25 lectures)
Bayesian techniques, priors, posteriors, Bayes' estimators and Bayesian credible regions. (6 lectures)
Tests of Hypotheses: Statistical hypothesis, simple and composite hypothesis, critical regions. Neyman-Pearson Lemma and MP test, randomization UMP, UMPU and LMP tests; illustrations. Monotone likelihood ratio family of distributions. Likelihood ratio tests. Test of multiple hypotheses, union-intersection principle. (25 lectures)

Reference Texts

1. P.J. Bickel and K.A. Doksum: *Mathematical Statistics*.
2. G. Casella and R.L. Berger: *Statistical Inference*.
3. C.R. Rao: *Linear Statistical Inference and its Applications*.
4. E.L. Lehmann: *Theory of Point Estimation*.
5. E.L. Lehmann: *Testing Statistical Hypotheses*.

- ## Nonparametric and Sequential Methods

Nonparametric Methods: Formulation of the problems. Review of order statistics and their distributions. Permutation tests, sign test, test for symmetry, signed rank test, Wilcoxon-Mann-Whitney test, Kruskal-Wallis test. Linear rank statistics. Run test, tests for independence. Kolmogorov-Smirnov goodness of fit test. Concepts of asymptotic relative efficiency of tests. Estimation of location and scale parameters. (26 lectures)
Nonparametric function estimation: histogram, frequency polygon, kernel density estimation and regression. (10 lectures)
Sequential Analysis: Wald's SPRT, ASN, OC function. Stein's two stage fixed length confidence interval. Illustrations with Binomial and Normal distributions. Sequential estimation, illustration with examples. (20 lectures)

Reference Texts

1. E.L. Lehmann: Nonparametrics: Statistical Methods Based on Ranks.
2. L. Wasserman: All of Nonparametric Statistics.

3. M. Hollander and D.A. Wolfe: Nonparametric Statistical Methods.
4. R.H. Randles and D. A. Wolfe: Introduction to the Theory of Nonparametric Statistics.
5. A. Wald: Sequential Analysis.

- ## Sample Surveys

Concepts of population, sample, survey and census. Sampling designs and schemes. Properties of good estimators based on different approaches: design, predictive, super-population-modeling and model-assisted. Sampling strategies. (6 lectures)
Drawing simple random samples (SRS) with replacement (WR) and without replacement (WOR) using random numbers, estimation, sample size determination. Narain, Horvitz & Thompson estimator. Sen, Yates & Grundy estimator. Stratified sampling, cluster sampling, multi-stage sampling. (20 lectures)
PPS sampling--WR and WOR. Systematic sampling--equal and unequal probabilities, linear and circular, unbiased variance estimation. Ratio and Regression estimation for equal and unequal probability sampling, Hartley-Ross estimator. Interpenetrating Network of Sub-sampling (IPNS) and half-sampling. (20 lectures)
Double sampling—non-response and `not-at-homes'. Sampling on successive occasions. Acquaintance with National Sample Surveys and other large-scale surveys, controlling non-sampling errors. (10 lectures)

Reference Texts

1. W.G. Cochran: *Sampling Techniques*.
2. M.N. Murthy: *Sampling Theory and Methods*.
3. Chaudhuri, A. (2010). *Essentials of survey sampling*.
4. Hedayat, A.S. and Sinha, B. K. (1979). *Design and inference in finite population sampling*.
5. Cassel, C. M., Sarndal, C.E. and Wretman, J.H. (1977): *Foundations of inference in survey sampling*.

- ## Design of Experiments

The need for experimental designs and examples, basic principles, uniformity trials, use of completely randomized designs. (6 lectures)
Designs eliminating heterogeneity in one direction: General non-orthogonal block designs and their analysis under fixed effects model, tests for treatment contrasts, concepts of connectedness and orthogonality of classifications with examples; randomized block designs and their use. (15 lectures)
Orthogonal designs eliminating heterogeneity in two or more directions: analysis and use of Latin square designs and mutually orthogonal latin square designs; construction of MOLs based on Galois fields. (12 lectures)
Missing plot technique. (4 lectures)
Use of concomitant variables in orthogonal designs and related analysis. General full factorial designs, their use, advantage and analysis; confounding and partial confounding in 2^n designs and relative efficiencies of the effects; experiments with factors at 3 levels, useful designs using confounding in 3^2, 3^3 experiments. (15 lectures)
Split-plot designs, their use and analysis. (4 lectures)
Practicals using statistical packages.

Reference Texts

1. A. Dean and D. Voss: *Design and Analysis of Experiments.*
2. D.C. Montgomery: *Design and Analysis of Experiments.*
3. W.G. Cochran and G.M. Cox: *Experimental Designs.*
4. O. Kempthorne: *The Design and Analysis of Experiments.*
5. A. Dey: *Theory of Block Designs.*

- ### Statistics Comprehensive/Statistical Data Analysis/Data Analysis Project:

Review of data analytic tools.
Project Work involving data collection, survey and analysis with credit at least 100 marks.
Special Topics assigned by the teacher related to but not restricted to Project Work

2. Probability Courses

- ### Probability Theory I

Elementary concepts: experiments, outcomes, sample space, events. Discrete sample spaces and probability models. Equally Likely Set-up and Combinatorial probability. (12 lectures)
Fluctuations in coin tossing and random walks, Combination of events. (14 lectures)
Composite experiments, conditional probability, Polya's urn scheme, Bayes theorem, independence. (8 lectures)
Discrete random variables. Standard discrete distributions. Expectation/mean, variance, moments, functions of discrete random variables, moment generating functions, probability generating functions. (14 lectures)
Joint distributions of discrete random variables, independence, conditional distributions, conditional expectation. Distribution of sum of two independent random variables. Functions of more than one discrete random variables. (10 lectures)

- ### Probability Theory II

Uncountable sample spaces and concept of events and random variables, properties of probability (6 lectures)
Introduction to cumulative distribution functions (CDF) and properties. Distributions with densities. Standard univariate densities (Uniform, Exponential, Beta, Gamma, Normal and other densities), Functions of random variables with densities (12 lectures)
General definition of Expectation, Properties of expectation. Limit theorems: Monotone Convergence Theorem (MCT), Fatou's Lemma, Dominated Convergence Theorem (DCT), Bounded Convergence Theorem (BCT), Cauchy-Schwartz and Chebyshev inequalities. (12 lectures)
Expectation of functions of random variables with densities as integrals, Variance and moments of random variables. (6 lectures)
Moment generating function: properties, illustrations; Characteristic function: properties, illustrations, inversion formula. (10 lectures)
Bivariate continuous distributions, bivariate CDFs, independence, distribution of sums, products and quotients for bivariate continuous distributions, Student-t, χ^2, F densities. (8 lectures)
Conditional and marginal distributions, conditional expectation, examples, Bivariate Normal

distribution. (8 lectures)

- ## Probability Theory III

Multivariate distributions and properties. Multivariate densities and multivariate singular distributions. Conditional distributions and independence. Distributions of functions of random vectors and Jacobian formula. Examples of multivariate densities. (8 lectures)
Multivariate Normal distribution and properties, Sampling distribution for mean and sample variance, Distributions of linear and quadratic forms, Dirichlet density and properties (14 lectures)
Different modes of convergence and their relations, Weak Law of large numbers, First and Second Borel-Cantelli Lemmas, Kolmogorov Maximal inequality, Strong Law of large numbers. (14 lectures)
Levy continuity theorem (statement only), CLT in i.i.d. finite variance case. Slutsky's Theorem. δ-method. Multivariate CLT, Cramer-Wald device. (8 lectures)
Poisson process on $[0,\infty)$ and basic properties. (12 lectures)

Reference Texts for Probability Theory I – III

1. W. Feller: *Introduction to the Theory of Probability and its Applications*, (Vols. 1 & 2).
2. K. L. Chung: *Elementary Probability Theory*.
3. S. M. Ross: *A First Course in Probability*.
4. R. Ash: *Basic Probability Theory*.
5. P. G. Hoel, S. C. Port and C. J. Stone: *Introduction to Probability Theory*.
6. J. Pitman: *Probability*.
7. P. G. Hoel, S. C. Port and C. J. Stone: *Introduction to Stochastic Processes*.

- ## Introduction to Markov Chains

Discrete Markov chains with countable state space, Examples including 2-state chain, random walk, birth and death chain, renewal chain, Ehrenfest chain, card shuffling, etc. (12 lectures)
Classification of states, recurrence and transience; absorbing states, irreducibility, decomposition of state space into irreducible classes, examples. (12 lectures)
Absorbing chains, absorption probabilities and mean absorption time, fundamental matrix (2 lectures)
Stationary distributions, limit theorems, positive and null recurrence, ratio limit theorem, reversible chains. Periodicity, cyclic decomposition of a periodic chain, limit theorems for aperiodic irreducible chains. (15 lectures)
Introduction to concept of mixing behavior of finite state space Markov chains, Definition of mixing time, relaxation time, cover time, strong uniform time. Illustration using card-shuffling and random walks on graphs. (12 lectures)
Introduction to MCMC, perfect sampling (3 lectures)

Reference Texts

1. W. Feller: *Introduction to the Theory of Probability and its Applications*, Vol. 1.
2. P. G. Hoel, S. C. Port and C.J. Stone: *Introduction to Stochastic Processes*.
3. D. Aldous and J. Fill: *Reversible Markov Chains and Random Walks on Graphs* http://www.stat.berkeley.edu/users/aldous/RWG/book
4. J. G. Kemeny, J. L. Snell and A. W. Knapp: *Finite Markov Chains*.
5. C. P. Robert and G. Casella: *Monte Carlo Statistical Methods*.

3. Mathematics Courses

- ### Analysis I

Real numbers—least upper bounds and greatest lower bounds. Sequences—limit points of a sequence, convergent sequences; bounded and monotone sequences, the limit superior and limit inferior of a sequence. Cauchy sequences and the completeness of **R**. Series—convergence and divergence of series, absolute and conditional convergence. Various tests for convergence of series. Connection between infinite series and decimal expansions, ternary, binary expansions of real numbers. *Cauchy product, Infinite products*. (24 lectures)
Continuous functions of one real variable—attainment of supremum and infimum of a continuous function on a closed bounded interval, uniform continuity. Differentiability of functions. Chain Rule, Rolle's theorem and mean value theorem. Higher order derivatives, Leibnitz formula, Taylor's theorem—various forms of remainder, infinite Taylor expansions. Maxima and minima of functions. (24 lectures)
Applications of calculus: Forming differential equations for radio-active decay, the tractrix, the catenary, the L-C-R circuit, the Brachistochrome, etc. (8 lectures)

- ### Analysis II

Riemann integration, Fundamental theorem of calculus, Picard's theorem for existence and uniqueness of a first order differential equation. Computation of definite integrals, improper integrals. (24 lectures)
Solutions of first order differential equations: homogeneous equations, integrating factors for linear equations, reduction of some second order equations to first order equations, special linear equations of second order. (8 lectures)
Sequences and Series of functions, Double sequences, Pointwise and uniform convergence, Term-by-term differentiation and integration, Power series, Power Series solutions of differential equations with analytic coefficients (examples only). Weierstrass approximation theorem. Fourier series. (24 lectures)

- ### Analysis III

Functions of several variables, Continuity, Partial derivatives, Differentiability, Taylor's theorem, Maxima and minima. (24 lectures)
Multiple integrals, Repeated integrals, The Jacobian theorem, Line, surface and volume integrals, Differential forms, Theorems of Green and Stokes. (28 lectures)
Solutions of exact differential equations, integrating factors. (4 lectures)

Reference Texts for Analysis I-III

1. W. Rudin: *Principles of Mathematical Analysis.*
2. Tom Apostol: *Mathematical Analysis.*
3. Tom Apostol: *Calculus I and II.*
4. R. Courant and F. John: *Introduction to Calculus and Analysis, Vol. I, II.*
5. Edward D Gaughan: *Introduction to Analysis.*

- **Vectors and Matrices I**

Vector spaces over real and complex fields, subspace, linear independence, basis and dimension, sum and intersection of subspaces, direct sum, complement and projection. (10 lectures)
Linear transformation and its matrix with respect to a pair of bases, properties of matrix operations, use of partitioned matrices. (7 lectures)
Column space and row space, rank of a matrix, nullity, rank of AA*. (10 lectures)
Homogeneous and non-homogeneous systems of linear equations, condition for consistency, solution set as a translate of a subspace, g-inverse and its elementary properties. (10 lectures)
Left inverse, right inverse and inverse, inverse of a partitioned matrix, lower and upper bounds for rank of a product, rank-factorization of a matrix, rank of a sum. (12 lectures)
Elementary operations and elementary matrices, Echelon form, Normal form, Hermite canonical form and their use (sweep-out method) in solving linear equations and in finding inverse or g-inverse. LDU-decomposition. (8 lectures)

- **Vectors and Matrices II**

Determinant of n^{th} order and its elementary properties, expansion by a row or column, statement of Laplace expansion, determinant of a product, statement of Cauchy-Binet theorem, inverse through classical adjoint, Cramer's rule, determinant of a partitioned matrix, Idempotent matrices, matrix version of Fisher-Cochran theorem. (12 lectures)
Norm and inner product on R^n and C^n, norm induced by an inner product, Orthonormal basis, Gram-Schmidt orthogonalization starting from any finite set of vectors, orthogonal complement, orthogonal projection into a subspace, orthogonal projector into the column space of A, orthogonal and unitary matrices. (12 lectures)
Characteristic roots, relation between characteristic polynomials of AB and BA when AB is square, Cayley-Hamilton theorem, idea of minimal polynomial, eigenvectors, algebraic and geometric multiplicities, characterization of diagonalizable matrices, spectral representation of Hermitian and real symmetric matrices, singular value decomposition. (16 lectures)
Quadratic form, category of a quadratic form, use in classification of conics, Lagrange's reduction to diagonal form, rank and signature, Sylvester's law, determinant criteria for n.n.d. and p.d. quadratic forms, Hadamard's inequality, extrema of a p.d. quadratic form, statement of interlacing theorem, simultaneous diagonalization of two quadratic forms one of which is p.d., simultaneous orthogonal diagonalization of commuting real symmetric matrices, Square-root method. (16 lectures)
Note: Geometric meaning of various concepts like subspace and flat, linear independence, projection, determinant (as volume), inner product, norm, orthogonality, orthogonal projection, and eigenvector should be discussed. Only finite-dimensional vector spaces to be covered.

Reference Texts for Vectors and Matrices I-II

1. C. R. Rao: *Linear Statistical Inference and Its Applications.*
2. A. Ramachandra Rao and P. Bhimasankaram: *Linear Algebra.*
3. K. Hoffman and R. Kunze: *Linear Algebra.*
4. F. E. Hohn: *Elementary Matrix Algebra.*
5. P. R. Halmos: *Finite Dimensional Vector Spaces.*
6. S. Axler: *Linear Algebra Done Right!*

- ## Elements of Algebraic Structures

Definitions, elementary properties, and examples of Groups, Subgroups, Rings, Ideals, and Fields.
Groups, equivalence classes, cosets, normal subgroups, quotient groups. Cyclic groups.
Homomorphism theorems. Examples of Isomorphisms and Automorphisms. Permutation groups.
Finite direct product. Finite Abelian groups. Sylow's theorems and applications. (16-20 lectures)
Rings. Ideals and quotient rings. Prime ideals and Integral domains. Maximal ideals, PID, UFD.
Polynomial rings (over commutative rings). Gauss' theorem. (24 lectures)
Fields. Roots of polynomials. Field extensions. Splitting fields. Finite fields. (12 lectures)
Applications to elementary number theory. (4 lectures)

Reference Texts

1. M. Artin: *Algebra* (Chap. 2, 10, 11.1-11.6, 13.1-13.6).
2. I. N. Herstein: *Topics in Algebra* (Chap. 2, 5.1-5.5, 7.1).
3. N. Jacobson: *Basic Algebra I* (Chap. 2).
4. *TIFR pamphlet on Galois Theory.*
5. S. Lang: *Undergraduate Algebra.*
6. J. Rotman: *A First Course in Abstract Algebra.*
7. L. Rowen: *Algebra.*

- ## Discrete Mathematics

Combinatorics:

Sets and Relations, Counting, Basic Definition, Counting using functions, Pigeonhole principle and its generalization with applications to a variety of problems, Dilworth's Lemma, Introduction to Ramsey theory, Principle of inclusion and exclusion with application to counting derangements. (8 lectures)
Generating functions, definition, operations, applications to counting, integer partitioning, Exponential generating functions, definition, applications to counting permutations, Bell numbers and Stirling number of the second kind. (6 lectures)
Recurrence Relations and its type, linear homogeneous recurrences, inhomogeneous recurrences, divide-and-conquer recurrences, recurrences involving convolution and their use in counting, Fibonacci numbers, derangement, Catalan numbers, Recurrence relation solutions, methods of characteristic root, use of generating functions. (4 lectures)

Graph Theory:

Definition of graph and directed graph, definition of degree, subgraph, induced subgraph, paths and walk, connectedness of a graph, connected components. (6 lectures)
Examples of graphs, cycles, trees, forests, integer line and d-dimensional integer lattice, complete graphs, bipartite graphs, graph isomorphism, Eulerian paths and circuits, Hamiltonian paths and circuits. (6 lectures)
Adjacency matrix and number of walks, shortest path in weighted graphs, minimum spanning tree, greedy algorithm and Kriskal algorithms, number of spanning trees, Cayley's theorem, Basics on graph reversal, Breadth-first-Search (BFS) and Depth-first-search (DFS) (12 lectures)
Planarity –definition and examples, Euler's theorem for planar graphs, Dual of a planar graph, Definition of independent sets, colouring, chromatic number of a finite graph, planar graph and chromatic number, five colour theorem for planar graphs, four colour theorem (statement only) (12 lectures)

Flows – definitions and examples, max-flow min-cut theorem (4 lectures)

Reference Texts

1. J. Matousek and J. Nesetril: *Invitation to Discrete Mathematics*.
2. Fred S. Roberts and B. Tesman: *Applied Combinatorics*.
3. Ronald L. Graham, Donald E. Knuth and O. Patashnika: *Concrete Mathematics*
4. C. L. Liu: *Elements of Discrete Mathematics*.
5. B. Kolman, R. C. Busby, S. C. Ross and N. Rehman: *Discrete Mathematical Structures*.
6. Martin J. Erickson: *Introduction to Combinatorics*.
7. Frank Harary: *Graph Theory*.
8. Douglas B. West: *Introduction to Graph Theory*.
9. Reinhard Diestel: *Graph Theory*.

4. Computer Science Courses

• Introduction to Programming and Data Structures

Introduction to number system*:* binary, octal, hexadecimal; (2 hours)

Introduction to digital computers*:* CPU, main memory, peripherals, I/O devices, algorithm, storage, flow-charts; (2 hours)

Imperative languages*:* Introduction to imperative language – syntax and constructs of a specific language (preferably C); variables, assignment, expressions, input/output, conditionals and branching, iteration; (12 hours)

Data handling*:* arrays and pointers, structures, dynamic allocation, Files; (8 hours)

Functions and Recursion: Function – parameter passing, procedure call, call by value, call by reference; Recursion (10 hours).

Data Structures*:* Queue, Stack, Linked lists, Trees (12 hours)

References Texts

1. B. W. Kernighan and D. M. Ritchie: *The `C' Programming Language*.
2. B. Gottfried: *Programming in C*.
3. T. A. Standish: *Data Structure Techniques*.
4. E. Horowitz and S. Sahni: *Fundamentals of Data Structures*.
5. R. L. Kruse: *Data Structures and Program Design in C*.
6. T. H. Cormen, C. E. Leiserson, R. L. Rivest, C. Stein: *Introduction to Algorithms*.
7. A. V. Aho, J. E. Hopcroft and J. D. Ullman: *Data Structures and Algorithms*.

• Numerical Analysis

Significant digits, round-off errors. Finite computational processes and computational errors. Floating point arithmetic and propagation of errors. Loss of significant digits. (1 lecture)

Interpolation with one variable: finite differences, divided differences. Lagrangian and Newtonian methods. Iterative methods. Aitken Neville's iterative scheme. Spline interpolation. Errors and remainder terms. Inverse interpolation. Interpolation with two variables. (6 lectures)

Numerical integration: Newton-Cotes; Orthogonal polynomials and Gaussian quadrature. Accuracy of quadrature formulae. (6 lectures)

Numerical differentiation. (6 lectures)

Numerical solution of ordinary differential equations: one step and multistep methods. Euler's,

Adam's, Runge-Kutta's methods. Predictor-corrector methods. Errors and accuracy. (8 lectures)
Numerical solution of nonlinear equation in one variable: Separation of roots and initial approximation. Sturm's theorem. Improvement of the initial solution using methods of bisection, Regula Falsi and Newton-Raphson. Fixed point iterative schemes. Errors. Order of convergence and degree of precision. (8 lectures)
Computation in Linear Algebra: Numerical solution of system of linear equations and matrix inversion: Gaussian elimination, square Root, L-U methods. (6 lectures)
Reduction to bidiagonal/tridiagonal form: Householder transformation, Given's transformation. (4 lectures)
Numerical computation of eigenvalues and eigenvectors: Jacobi's method, power method. (4 lectures)

Reference Texts

1. S.D. Conte and C. de Boor: *Elementary Numerical Analysis: An Algorithmic Approach*.
2. D.K. Faddeev and V.H. Faddeeva: *Computational Methods in Linear Algebra.*
3. G.E. Forsythe and G.B. Moler: *Computer Solution of Linear Algebraic Systems.*
4. W. H. Press, S. A. Teukolsky, W. T. Vetterling, B. P. Flannery: *Numerical Recipes in C.*

- ## Design and Analysis of Algorithms

Introduction and basic concepts*:* Complexity measure and asymptotic notations, notions of worst-case and average case complexity, use of recurrences in algorithms. (3 hours)
Searching algorithms: Binary search, balanced binary search tree, hashing (6 hours)
Selection and Sorting*:* Finding maximum and minimum, k^{th} largest elements, Different sorting algorithms – quicksort, mergesort, heapsort, etc. lower bound for sorting, other sorting algorithms- radix sort, bucketsort, etc. (12 hours)
Graph Algorithms*:* Basic definitions, connectivity and traversals (Breadth First Search and Depth First Search), directed acyclic graphs and topological ordering. (10 hours)
Computational Geometry*:* Convex hull, diameter of a point set (3 hours)
Greedy Algorithms*:* Shortest paths in a graph, minimum spanning trees, clustering. (6 hours)
Divide and Conquer*:* Closest pair of points, integer multiplication, matrix multiplication, Fast Fourier Transform. (8 hours)
Dynamic Programming*:* Subset sum, knapsack, all pair shortest paths in a graph. (8 hours)

References Texts

1. T. H. Cormen, C. E. Leiserson, R. L. Rivest, C. Stein: *Introduction to Algorithms*.
2. J. Kleinberg and E. Tardos: *Algorithm Design*.
3. S. Dasgupta, C. Papadimitriou, U. Vazirani: *Algorithms*.
4. A.V.Aho, J. E. Hopcroft and J.D.Ullman: *The Design and Analysis of Computer Algorithms*.
5. E. Horowitz, S. Sahni and S. Rajasekaran: *Computer Algorithms*.
6. D. E. Knuth: *The Art of Computer Programming Fundamental Algorithms*.
7. A. V. Aho, J. E. Hopcroft and J. D. Ullman: *Data Structures and Algorithms*.

5. Elective Courses

• Microeconomics

Theory of consumer behavior: Utility theory, consumer demand, comparative statics analysis, market demand. (12 lectures)
Theory of firm: Production function, law of variable proportions, returns to scale, elasticity of substitution. (5 lectures)
Theory of cost: concepts of long-run and short-run costs, cost curves. (10 lectures)
Markets: Perfect competition, monopoly, oligopoly, factor markets. (15 lectures)
General equilibrium and welfare. (8 lectures)

Reference Texts

1. J.P. Quirk: *Intermediate Microeconomics*
2. H. Varian: *Microeconomic Analysis.*

• Macroeconomics

National income accounting. National income determination - short-term macroeconomic models: (18 lectures)
Simple Keynesian model- fiscal and monetary policies for raising employment and output. (12 lectures)
Monetary sector and investment function – IS-LM model, discussion on effectiveness of fiscal and monetary policies. (12 lectures)
Open economy macroeconomics - determination of exchange rate under perfect capital mobility and flexible exchange rate, adjustments in a fixed exchange rate. (8 lectures)

Reference Texts

1. R. Dornbusch and S. Fischer: *Macroeconomics.*
2. N. Mankiw : *Macroeconomics.*

• Geology

Theory:
Definition and objectives of Geology: different branches of geology, its relationship with other subjects and its contribution to mankind. (2 lectures)
The earth: the earth and the solar system, physical and chemical characteristics of the earth, minerals and rocks, ores etc., definition, origin and types of sedimentary, igneous and metamorphic rocks, surface processors - weathering and erosion, deep seated processes and their products - folds and faults, major geologic features of the earth's exterior, major developments in the lithosphere. (20 lectures)
Time in Geology: Geological time scale, absolute and relative time, fossils and their usage, succession of the through time, organic evolution. (5 lectures)
Important Geologic Principles. (1 lecture)
Geology vis-a-vis industry (with reference to India): Raw material for steel, ferro-alloy, Cu-Al-Pb-Za industries, cement, refractory, building material, coal, oil, gas and water resources. (2 lectures)
Quantitative aspects of Geology: Nature and source of geologic data, possible applications of various statistical and mathematical tools, example of such usage. (5 lectures)

Practical:

Identification of minerals, rocks and fossils. Introducing topsheets and simple geological maps. (8 lab hours)

Measurement and graphical representation of grain-size and paleocurrent data. (8 lab hours)

Field Work: basic geologic mapping, collection of scalar and vector data, mine visits, etc. (4 days)

Reference Texts

1. Frank Press and Raymond Siever: *Understanding Earth.*
2. W.A. Deer, R.A. Howie and J. Zussman: *Introduction to the Rock Forming Minerals.*
3. J. Suppe: *Principles of Structural Geology.*
4. M.R. Leeder: *Sedimentology and Sediment*
5. E.N.K. Clarkson: *Invertebrate Palaeontology and Evolution.*
6. J.C. Davis: *Statistics and Data Analysis in Geology.*

- ## Molecular Biology

1. Distinguishing characteristics of living and non-living things (4 classes)
2. Cell structure and functions (4 classes)
3. Metabolism of protein, carbohydrate and fat (8 classes)
4. Structure and function of DNA and RNA (8 classes)
5. Replication, transcription, translation, cell division (mitosis, meiosis) (8 classes)
6. Definition of gene and genetic code; relationship between them (6 classes)
7. Mendel's Law of genetics and application in human population (8 classes)
8. Practical (8 classes)

Reference Texts

1. *Instant notes on Biochemistry*: B D Hames, N M Hooper, J D Houghton (Viva publications)
2. *Instant notes on Genetics*: P C Winter, G I Hickey and H L Fletcher (Viva Publication)
3. *Instant notes on Molecular Biology*: P C Turner, A C McLenan, A D Bates and M R H White (Viva publications)
4. *Principles of genetics*: D P Snustad and M J Simmons (John Wiley & Sons Inc)

- ## Agricultural Science

Agroclimatology:

Agroclimatology- Definition and scope, its importance in Agriculture. Weather and climate, weather elements and factors affecting them. Environmental factors in agriculture. Climate change and global warming: definitions of terms; causes of climate change and global warming; greenhouse gases, ozone depletion; Weather forecasting system: definition, scope and importance; types of Forecasting. (5 lectures)

Agronomy:

Introduction and importance of agriculture, ancient agriculture, history of agricultural development in India. Agro-climatic zones of India.

Meaning and scope of agronomy, principles of agronomy.
Distribution, Climatic requirement, Soil requirements, Rotations, Improved varieties, Agronomic practices (land preparation, seed rate & seed treatment, weed control, fertilizer application, irrigation) and harvesting of :- Cereals (Rice, Wheat), Oilseeds (Groundnut, Indian mustard), Pulses (Moong, Lentil), Vegetables Solanaceous (Potato). (15 lectures)

Soil:

Introduction to Soils – Soil formation: genesis and weathering. Soil physical properties – Soil colour, structure, texture, density and pore space soil water. Soil chemical properties – Soil acidity, Soil organic matter – Soil organism. Humus, influence of soil organic matter on soil physical and chemical properties. Soil nutrients – Primary, secondary and micronutrients, Soil conservation – soil erosion: types of erosion and method of conservation. (4 lectures)

Irrigation water management:

Irrigation: definition and objectives. Soil-plant-water relationships; Strategies of using limited water supply; factors affecting ET, control of ET by mulching and use of anti-transpirants; methods of soil moisture estimation, evapotranspiration and crop water requirement, effective root zone, Methods of irrigation: surface, sub-surface, sprinkler and drip irrigation; Irrigation efficiency and water use efficiency, conjunctive use of water. (4 lectures)

Manures and Fertilizers:

Arnon's criteria of essentiality of elements. Essential Plant nutrient elements (macro and micro) and their sources. FYM; compost, Vermocompost, Green manuring, Nitrogenous, Phosphatic, Potassic and complex fertilizers. Time & method of fertilizer application (4 lectures)

Farming systems, cropping system and maximising of crop production:

New concepts and approaches of farming systems and cropping systems
Farming systems: definition and importance; classification of farming systems according to type of rotation, intensity of rotation, Production potential of different components of farming systems; interaction and mechanism of different production factors; stability in different systems through research; eco-physiological approaches to intercropping.
Introduction to Organic Farming concepts, relevance in present day context; Organic production requirements Agro-physiological basis of variation in yield, recent advances in soil plant-water relationship.
Growth analysis: concept, CGR, RGR, NAR, LAI, LAD, LAR; validity and Limitations in interpreting crop growth and development; growth curves: sigmoid, polynomial and asymptotic; root systems; root-shoot relationship;
Principles involved in inter and mixed cropping systems; concept and differentiation of inter and mixed cropping; criteria in assessing the yield advantages, LER, AYL, ATER, CR, Crop Crowding Coefficient, Agressevity, MA. (12 lectures)

Practical:

Estimation of crop yield from yield attributing data; Fertilizers scheduling, Soil physical and chemical analysis like pH, conductivity, OC, N, P, K, etc (12 lectures)

Reference Texts

1. Manures And Fertilizers- Yawalker, Aggarwal , Bakle
2. Chemistry of Soil- Beaf.
3. Soil Conditions And Plant Growth-1961= Russal,- E.W.- Longman = Publishers- London
4. Fundamentals of Soil Sciences- 1943-Ruth and Turk-J. Wiley & Sons, Inc. -London

5. Micronutrients: Their Behaviour In Soils And Plants – 2001-Das Dilip Kumar-The Scientific World-Netherlands
6. Fertilizers – 2007-Basak Ranjan Kumar-Kalyani
7. The Earth and Its Atmosphere – 1953- D.R. Bates – Pergamon Press Ltd., London.
8. Introduction to Climatology for the Tropics – 1999- J.D.A. Yade- Springer Link Publishers-New York.
9. Agricultural Meteorology – 2008 – H.S. Mavi - www.niscair.res.in/science communication

Suggested Readings:

1. Sehgal J. 2002. Pedology- Concepts and Applications. Kalyan Publ.
2. Das Dilip Kumar 1997. Introductory Soil Science.
3. Brady NC & Weil RR. 2004. Elements of the Nature and Properties of Soils. 2nd Ed. Pearson/Prentice Hall Pub.
4. Oswal MC. 1994. Soil Physics. Oxford & IBH.

Project work

- ## Psychology

Objective: Objective of the course is to impart knowledge in "Measurement in Psychology" so that the students learn fundamental concepts and develop familiarity with some of the important problems of psychology, which call for statistical analysis along with corresponding techniques used. This will be useful later in their professional work like Human Resource Development, Marketing Research, School Education, Social Policy Formulation etc.

Theory:

1. Introduction
    1.1. Definition, Scope, Branches (2 lectures)
    1.2. Schools of Psychology – Structural, Behavioural and Gestalt psychology (2 lectures)
    1.3. Relationship with other disciplines (2 lectures)
2. Biological basis of human behavior variation
    2.1. Heredity & environmental role on changes in behavior (1 lecture)
    2.2. Nervous system -neural and synaptic activity, brain localization (2 lecture)
    2.3. Endocrine gland and stress (2 lectures)
    2.4. Stages of sleep (1 lecture)
    2.5. Drugs and behavior (1 lecture)
3. Attention: Determinants, shift and fluctuation (2 lectures)
4. Perceptual process
    4.1. Perceptual organization (1 lecture)
    4.2. Experiments on distance, depth and time perception (2 lectures)
    4.3. Illusion and hallucination (1 lecture)
5. Memory
    5.1. Information processing model (2 lectures)
    5.2. Experiments in Short and Long term memory (2 lectures)
    5.3. Theories of forgetting (2 lectures)
6. Learning
    6.1. Experiments on classical conditioning (1 lecture)

6.2. Operant conditioning and reinforcement (1 lecture)
6.3. Laws of learning and learning curve (1 lecture)
6.4. Insight learning (1 lecture)
6.5. Teaching pedagogy (1 lecture)

7. Methods:
   7.1. Variables and Measurement Scales (1 lecture)
   7.2. Introspective, Observation and Case study (1 lecture)
   7.3. Experimental and Quasi-experimental Research Designs (1 lecture)
   7.4. Interviews and discourse analysis (1 lecture)
   7.5. Manual and Computer-assisted Testing (1 lecture)
   7.6. Characteristics of good questionnaire (2 lectures)
   7.7. Survey Research Techniques (3 lectures)

Practical:

(a) Designing research tool for collection and analysis of data on individual cognition as attention, perception, memory, intelligence (4 lectures)
(b) Analyzing social cognition data provided by the teacher or collected by students through field work (3 lectures)
(c) Designing aptitude tests for measurement of IQ and exceptional children (3 lectures)

Reference texts

1. Anastasi, A.: *Psychological Testing.*
2. Dutta Roy, D. – *Principles of questionnaire development with empirical studies.*
3. Eysenck, M.W - *Psychology: A student's handbook.*
4. Gregory, R.J. – *Psychological testing. Pearson Education.*
5. Morgan, C.T., King, R.A., Weisz, J.R., & Schopler, J. - *Introduction to Psychology.*
6. Munn, N.L., Fernald, L.D., and Ferhald, P.S. - *Introduction to Psychology.*

• Introduction to Anthropology

<u>Part-I</u>

1. Introduction: definition and scope, subdivisions of anthropology, interrelationships between anthropology and other biological and social science disciplines. (2 lectures)
2. Biocultural evolution of man : man's place in the animal kingdom, comparative anatomy of anthropoid apes, structural and functional specializations of man, evolution of man : his culture and technology. (8 lectures)
3. Man as a social animal: choice of mate, monogamy, exogamy, endogamy, inbreeding, family, clan, kin group, social stratification and society, role of social factors in influencing genetic and environmental variations. (6 lectures)

<u>Part II</u>

1. Racial anthropology to concepts and methods of Human Population Biology in Biological Anthropology. (2 lectures)
2. Human variation and adaptation to environment: causes of variation, short and long term adaptation to different climatic, biotic and sociocultural environments, genetic factors. (6 lectures)

3. Human biological processes: human physical growth; growth and development; aging and senescence (4 lectures)
4. Demographic studies in anthropology: basic concepts of demography (population structure, age and sex composition, fecundity, fertility, morbidity, mortality, life table, marriage, migration, population growth), environmental (climatic, biotic and socio-cultural) determinants of demographic measures, anthropological small scale demographic studies. (4 lectures)

Part III

1. Anthropometric measurements and observations: methods of measurement and computation. (4 lectures)
2. Quantitative estimation of hemoglobin or packed cell volume. (2 lectures)
3. Measuring blood pressure in man. (4 lectures)

Part IV

1. One week's training in field work

Reference Texts

1. Allan, A. 1980. *To Be Human*. John Wiley and Sons. Inc. New York.
2. Bogin, B. 1999. *Patterns of Human Growth*. Cambridge University Press, Cambridge.
3. Conroy, G.C. 1997. *Reconstructing Human Origins: A Modern Synthesis.* W. W. Norton & Company, New York.
4. Crews, D.E. 2003. *Human Senescence: Evolutionary and Biological Perspectives,* Cambridge Press.
5. Crews, D.E. and R.M. Garruto (eds.) 1994. *Biological Anthropology and Aging: Perspectives on Human Variation,* Oxford University Press, Now York.
6. Ember, C.R. and Ember, M. 1977. *Anthropology.* Prentice Hall, Inc. New Jersey.
7. Harris, M. 1975. *Culture, People, Nature.* Thomas Y. Crowell, New York.
8. Harrison, G.A., Tanner, J.M., Pilbeam, D.R. and Baker, P.T. 1990. *Human Biology: An Introduction to Human Evolution, Variation, Growth and Adaptability* (3rd Ed). Oxford University Press. Oxford.
9. Hauspie, R.C., Cameron, N., Molinari, L. 2004. *Methods in Human Growth Research.* Cambridge University Press. Cambridge.
10. Jurmain, R., Kilgore, L., Trevathan, W., Ciochon, R.L. 2011. *Physical Anthropology: An Introduction,* International Edition. Warsworth Cengage Learning.
11. Mascie-Taylor, C.G.N., Lasker, G.W. 1991. *Applications of Biological Anthropology to Human Affairs.* Cambridge University Press, Cambridge.
12. Mielke, J. H., Konigsberg, L. W., Relethford, J. H. 2006. *Human Biological Variation.* Oxford University Press, Oxford.
13. Molnar, S. 1983. *Human Variation.* Prentice Hall Inc. New Jersey.
14. Park, M.A. 2008. *Biological Anthropology* (5th Ed.). Central Connecticut State University.
15. Scupin, R., DeCorse, C.R. 2009. *Anthropology: A Global Perspective* (6th Ed.). Prentice Hall. Inc. New Jersey
16. Stein, P., Rowe, B. 2005. *Physical Anthropology* (9th Ed.). McGraw-Hill.
17. Weiner, J.S., Lourie, J.A. 1981. *Practical Human biology*, Academic Press, New York.

- **Introduction to Sociology**

(A) Sociological Thought

1. Origin of Sociology: (a) Contribution of Industrial Revolution
2. Auguste Comte**:** (a) Positivism
   (b) The Law of Three Stages of Social Development
   (c) Social Statics and Social Dynamics
3. Emile Durkheim: (a) Division of Labour
   (b) Suicide
4. Max Weber : (a) Types of Authority with Special Reference to Bureaucracy
5. Karl Marx : (a) Class and Class Struggle
   (b) Alienation
6. Andre Beteille : (a) Caste, Class and Politics
7. Binay Kumar Sarkar: (a) Progress
   (b) Positivism

(B) Sociological Theory:

(a) Introduction with definition and characteristics of Modern Sociological Theory
(b) Concept of Micro and Macro-level Theory.

(C) Indian Society: Perspectives and Structures,

(D) Gender studies:

(a) Nature and Scope of Sociology of Gender
(b) Biology, Sex and Gender
(c) Socialization and Gender Socialization
(d) Gender, Crime and Violence
(e) Gender and Politics

(E) Agrarian Sociology

(a) Basic characteristics of peasant and agrarian society
(b) Debates on mode of production and agrarian relations including tenancy
(c) Rural poverty, migration and landless labour
(d) Globalisation and its impact on agriculture

(F) Methods of Social Research:

1. Definition and meaning of Social Research.
2. Types of Social Research: (a) Pure and (b) Applied
3. Facts, Concepts, Hypothesis and Theory, Research Methodology
4. Social Survey, differences between social survey and social research, Case Study, Experimental methods- Statistical methods.
5. Data collection: Tools of Data collection – Observation Schedules – Questionnaire, Interview, Focus Group of Discussion,
6. Sampling : Types of sampling
   (a) Random
   (b) Snow ball
   (c) Stratified
   (d) Systematic
   (e) Cluster
   (f) Judgment

- **Physics-I**

Classical Mechanics (34 lectures):

1. Survey of the elementary principles (2 lectures)
   Mechanics of a particle, Mechanics of a system of particles and conservation laws, Conservative force field.
2. Lagrange's formulation (15 lectures)
   The basic problem with the constraint forces, Principle of virtual work, D'Alembert's Principle, Degrees of Freedom, Generalised Coordinates, Lagrange's equations of motion of the second kind, Velocity Dependent potentials and the dissipation function, Simple applications of the Lagrange's formulation.
3. Two Body Central Force Problems (5 lectures)
   The problem, Centre of Mass and Relative Coordinates; reduced Mass, The Equations of motion, The equivalent one dimensional problem, The equation of the orbit, The Kepler orbits.
4. Variational Principle and Hamiltonian Mechanics (12 lectures)
   Some techniques of the calculus of variations, Hamilton's principle, Derivation of Lagrange's equations from Hamilton's principle, Concept of symmetry: Homogeneity and Isotropy, Conservation Theorems and Symmetry properties. Hamilton's equations for one dimensional system.

References:

1. Classical Mechanics- H. Goldstein
2. Introduction to Classical Mechanics – R. Takwale and P. Puranik

Electromagnetic Theory - I (16 lectures):

1. Vector Analysis (4 lectures)
   Vector Algebra, Vector calculus.
2. Electrostatics (6 lectures)
   The Electric Field, Divergence and Curl of electrostatic fields, Electric Potential, Work and Energy in Electrostatics, Conductors, The method of images, Polarization, The electric displacement, Linear dielectrics .
3. Magneto-statics (6 lectures)
   The Lorentz Force Law, The Biot-Savart Law, Divergence and Curl of B, Magnetic Vector Potential, Magnetization, The Auxiliary Field H, Magnetic susceptibility and permeability.

References:

1. Introduction to Electrodynamics- D. J. Griffiths
2. Feynman Lectures on Physics- Volume II
3. Classical Electricity and Magnetism-W.K. H. Panofsky and M. Phillips

- **Physics II**

Thermodynamics and Statistical Mechanics (25 lectures):

1. Thermodynamics (5 lectures)
   Laws of thermodynamics, Maxwell's relations and thermodynamic functions, kinetic theory of ideal gases, non-ideal (Van der Waals) gas.
2. Statistical formulation of mechanical problems (10 lectures)

State of a system, ensembles, postulates, Probability calculations, partition function, its properties and its connection with thermodynamic quantities, Ideal gas, non-ideal (Van der Waals) gas, Para-magnetism, System of quantum harmonic oscillators.

3. Quantum Statistical Mechanics (10 lectures)
   Blackbody radiation, Debye's Theory, Ideal Bose Gas, Ideal Fermi Gas, Gibbs paradox, Maxwell-Boltzmann statistics, Bose-Einstein statistics, Fermi-Dirac statistics, Classical limits, specific heat of solids (Einstein approximation).

References:

1. Thermodynamics – E. Fermi
2. Statistical Mechanics – R. K. Pathria
3. Fundamentals of Statistical and Thermal Physics – F. Reif

Electromagnetic Theory - II (25 lectures)

1. Electrodynamics (6 lectures)
   Electromotive Force, Electromagnetic Induction, Maxwell's equations.
2. Conservation Laws (2 lectures)
   Conservation of Charge and Energy, Conservation of momentum.
3. Electromagnetic waves (12 lectures)
   Waves in One dimension, Electromagnetic Waves in Vacuum, Electromagnetic waves in Matter, Electromagnetic waves in Conductor, Wave Guides.
4. Potentials and Fields (5 lectures)
   Scalar and Vector potentials, Gauge Transformations, Coulomb gauge and Lorentz Gauge.

References:

Introduction to Electrodynamics- D. J. Griffiths

- **Physics-III**

Special Theory of Relativity (13 lectures):

1. Principle of relativity (5 lectures)
   Galilean Relativity, Significance of Michelson-Morley experiment, The Postulates of special Relativity, The Lorentz Transformation.
2. Relativistic effects (6 lectures)
   Time dilatation, Length Contraction, The relativistic velocity addition formula, Mass formula, Mass energy equations.
3. Four vector formalism (2 lectures)
   Minkowskian four- Dimensional Space Time, Four velocity and Four momentum and their interpretation.

Quantum Mechanics (37 lectures):

1. Introduction to Quantum Theory (3 lectures)
   The Photoelectric Effect, The Compton Effect, De Broglie relation, The Diffraction of matter waves, The Statistical Interpretation of matter waves, The Superposition Principle.
2. The Mathematical Foundations of Quantum Mechanics (11 lectures)

Hilbert Space, Operators, Eigen value, Eigen function, Bra and Ket notation, state and Observables, Born probability Interpretation, The Heisenberg's Uncertainty Principle, Principle of complementarity, Dynamics; The Schrodinger picture, The Heisenberg picture.

3. The Schrodinger Equation and its application (6 lectures)
   Stationary States, The Harmonic Oscillator, The Free particle, Particle in a Box, The finite square well, The potential barrier.
4. Operator Formalism (12 lectures)
   Creation and annihilation operators, Harmonic oscillators, Angular momentum. Addition of Angular Momentum, Details of Spin-1/2 system.
5. Symmetry in Quantum Mechanics (5 lectures)
   Symmetries, Conservation Laws, Degeneracy, Discrete Symmetries, Parity or Space Inversion.

References:

1. Special Theory of Relativity –R. Resnick
2. Modern quantum mechanics - J.J.Sakurai
3. Quantum mechanics – J.L. Powell and B. Crasemann

6. Optional Courses

6.1 Optional courses in Statistics

• Resampling Techniques

Introduction: what is resampling and its purpose? examples from estimating variance, sampling distribution and other features of a statistic, shortcomings of analytic derivations. (3 lectures)

Different resampling schemes: jackknife, bootstrap, half-sampling, etc. (5 lectures)

Bootstrap in the i.i.d. case: parametric and non-parametric bootstrap, Bayesian bootstrap, consistency and inconsistency of bootstrap, comparison between bootstrap approximation and normal approximation. (15 lectures)

Jackknife in the i.i.d. case: consistency and inconsistency issues, comparison with non-parametric bootstrap. (10 lectures)

Resampling in non-i.i.d. models: need for other resampling schemes, introduction to estimating equation bootstrap and generalized bootstrap. (7 lectures)

Resampling in linear models: special emphasis on residual bootstrap and weighted bootstrap, concept of robust and efficient resampling schemes. (10 lectures)

Reference Texts

1. Davidson A.C. and Hinkley D.V. (1997): *Bootstrap methods and their applications*.
2. Efron B. and Tibshirani R.J. (1993): *An introduction to the bootstrap*.
3. Hall P. (1992): *The bootstrap and Edgeworth expansion*.
4. Politis D.N., Romano J.P. and Wolf M. (1999): *Subsampling*.
5. Shao J. and Tu D. (1995): *The jackknife and bootstrap*.
6. Barbe P. and Bertail P (1995): *The weighted bootstrap*. (Lecture Notes in Statistics, Vol 98)
7. Efron B. (1982): The *jackknife, the bootstrap and other resampling plans*. (CBMS-NSF Regional Conference Series in Applied Mathematics, No 38)
8. Gine E. (1997): *Lectures on some aspects of the bootstrap*. (Lecture Notes in Mathematics, Vol 1665)

9. Mammen E. (1992): *When does bootstrap work? Asymptotic results and simulations*. (Lecture Notes in Statistics, Vol 77)

- ### Statistical Methods in Genetics

Mendel's Laws (2 lectures)
Random Mating, Hardy-Weinberg Equilibrium (6 lectures)
Inheritance of the X-chromosome (2 lectures)
Estimation of allele frequencies from genotype and phenotype data (with applications of the EM algorithm) (8 lectures)
Inbreeding, Mutation, Selection (10 lectures)
Joint genotype distributions of relatives using I-T-O matrices (3 lectures)
Segregation Analyses (3 lectures)
Basic Quantitative Trait Locus Model (5 lectures)
Tests for Genotype and Allelic Association for Population-based data on Binary Traits and Quantitative Traits (12 lectures)
Adjustment of covariates in population-based association analyses (5 lectures)

Reference Texts

1. Statistics in Human Genetics: Pak Sham
2. A Statistical Approach to Genetic Epidemiology: Andreas Ziegler and Inke Konig

6.2 Optional Courses in Probability

- ### Random Graphs

Some basic probabilistic tools: First and second moment methods and their variations. The methods of moments. Concentration inequalities for sum of independent Bernoulli variables, binomial and general case. Azuma's inequality (statement only). The FKG inequality for finitely many variables, probability of non-existence. (8 lectures)
Two basic models of random graphs (Erdös-Rényi random graphs): binomial random graphs and uniform random graphs. Monotonicity property of these graphs. Asymptotic equivalence of the two models. (6 lectures)
Concept of thresholds and proof of every monotone property has a threshold. Thresholds for subgraph containment. Connectivity threshold. Basic idea of sharp thresholds. (8 lectures)
Dense and sparse random graphs. (2 lectures)
The evolution of the sparse random graph, the emergence of the giant component, phase transition. Sub-critical, critical and super-critical phases. (10 lectures)
Sub-graph counts and its asymptotic distribution. (6 lectures)
Chromatic number of dense and sparse random graphs. (6 lectures)
Random regular graphs, the configuration model. Asymptotic of small cycles. (6 lectures)
Other models of random graphs: Albert-Barabaśi model of *preferential attachment*, *geometric random graphs*. Properties and illustration with examples. (4 lectures)

Reference Texts

1. S. Janson, T. Łuczak and A. Riciński: *Random Graphs.*
2. B. Bollobás: *Random Graphs.*

3. M. Penrose: *Random Geometric Graphs.*
4. R. van der Hofstad: *Random Graphs and Complex Networks* (lecture notes: http://www.win.tue.nl/~rhofstad/NotesRGCN.pdf)

- **Percolation Theory**

Basic notion of percolation. Bond and site percolation on infinite lattice. Percolation function, phase transition and critical probability. (6 lectures)
Increasing events. The FKG inequality. Concept of pivotal variable, Russo's formula. (12 lectures)
Percolation on d-dimensional integer lattice. Bond percolation in two dimensions: planar duality, proof that critical probability is ½. (14 lectures)
The sub-critical phase, asymptotic behavior of the radius of an open cluster. (6 lectures)
The super-critical phase, uniqueness of infinite open cluster. (6 lectures)
Percolation on trees. Differences with percolation on integer lattices. (6 lectures)
Basic idea of amenable and non-amenable graphs. Differences in percolation properties (statements only). (6 lectures)

References Texts

1. G. Grimmett: *Percolation.*
2. B. Bollobás and O. Riordan: *Percolation*.

6.3 Optional Courses in Mathematics

- **Differential Equations**

Review of First and second order linear differential equations with constant and variable coefficients. Oscillation Theory and boundary value problems. (14 lectures)
Power series solutions and special functions. (14 lectures)
Existence and uniqueness of solution of $x' = f(x; t)$. Picard's method. (6 lectures)
System of first order equations. Nonlinear equations. Introduction to chaos. Calculus of variation. Euler's differential equation. Laplace transforms and convolution. (12 lectures)
Introduction to Partial Differential Equations. (10 lectures)

Reference Texts

1. George F. Simmons: *Differential Equations.*
2. E.A. Coddington: *An Introduction to Ordinary Differential Equations.*

- **Number Theory**

The ring structure and the order relation on Z; Induction and well-ordering; Division algorithm; Prime numbers, infinitude of primes (Euclid's proof); Unique factorization of integers; GCD and LCM; Euclid's algorithm for computing GCD; Application to linear Diophantine equations. (3 lectures)
Notion of congruence and residues; Application to non-solvability of Diophantine equations; Structure of Z/nZ; The group of units of Z/nZ; The Euler φ-function; Fermat's “little” theorem, Wilson's theorem and Euler's theorem; Linear congruences and the Chinese Remainder Theorem; *Applications to RSA and other cryptosystems* (8 lectures)
Pythagorean triplets and their geometric interpretation (rational points on circles); Rational points

on conics; Fermat's method of infinite descent and application to simple Diophantine equations like $x^4 + y^4 = z^2$; *The Hasse principle for conics, Rational points on cubics and the failure of the Hasse principle*. (5 lectures)
Polynomial congruences and Hensel's Lemma; Quadratic residues and non-residues, Euler's criterion. (4 lectures)
Detailed study of the structure of the group of units of Z/nZ, Primitive roots; *Dirichlet characters and how to construct them*. (8 lectures)
Definition and properties of the Legendre symbol, Gauss's lemma, Law of quadratic reciprocity for Legendre symbols; *Extension to Jacobi symbols*. (7 lectures)
Arithmetical functions and their convolutions, multiplicative and completely multiplicative functions, examples like the divisor function $d(n)$, the Euler function $\varphi(n)$, the Möbius function $\mu(n)$ etc.; The Möbius inversion formula; Sieve of Eratosthenes; Notion of “order of magnitude" and asymptotic formulae; Statement of the Prime Number Theorem; Elementary estimates of $\pi(X)$ — the number of primes up to X; Euler and Abel summation formulae and average order of magnitude of various arithmetical functions. (7 lectures)
Review of algebraic numbers and algebraic integers; Arithmetic in Z[i]—the ring of Gaussian integers; Examples of failure of unique factorization; Arithmetic in the ring of integers in number fields, explicit examples for quadratic fields. (7 lectures)
Sum of two and four squares, Lagrange's four square theorem. (4 lectures)
The topics in italics are supplementary and depending on the inclination of the instructor and the students, some of them may be chosen for brief discussions. Topics like *Gauss sums, Brun's sieve, Group law on cubics, transcendence of e and π* etc., may also be covered if time is available.

Reference Texts

1. Z. I. Borevich & I. R. Shafarevich, *Number Theory.*
2. G. H. Hardy & E. M. Wright, *An Introduction to the Theory of Numbers.*
3. K. Ireland & M. Rosen, *A Classical Introduction to Modern Number Theory.*
4. I. Niven, H. S. Zuckerman, & H. L. Montgomery, *The Theory of Numbers.*

6.4 Optional Course in Computer Science

• Special topics on Algorithm

Graph algorithm: Optimal graph traversal, shortest path, minimum spanning tree, planarity algorithms. (5-7 lectures)
Geometric algorithm: Convex hull, point location, Voronoi diagram, Delaunay triangulations, arrangements and duality. (8 lectures)
Combinatorial algorithms: Simplex algorithms, network flows, matching. (8 lectures)
NP and Computational Intractability: Polynomial-time reductions, the definition of NP, NP-complete problems. (5-7 lectures)
Combinatorial geometry: Convexity, Radon's lemma and Helly's theorem, ham sandwich cuts, Ramsey number, Erdos- Szekeres theorem, arrangement, cutting lemma. (9 lectures)
Approximation Algorithms: Approximation algorithms design techniques for a variety of combinatorial and graph optimization problems: greedy-method, linear programming relaxation, divide and conquer, primal-dual methods, etc. Examples of approximation algorithms. (6 lectures)
Randomized Algorithms: Random variables and their expectations. Examples of randomized

algorithms. (5 lectures)

Reference Texts

1. M. de Berg et.al, *Computational Geometry: Algorithms and Applications*, 3rd ed., Springer-Verlag, 2000.
2. S.L. Devadoss and J. O'Rourke, *Discrete and Computational Geometry*, Princeton University Press, 2011.
3. N. Alon and J. Spencer, *The Probabilistic Method*, 3rd edition, Wiley, 2008.
4. Matousek, *Lectures on Discrete Geometry*, Springer, May 2002.
5. Vijay Vazirani, *Approximation Algorithms*, Springer-Verlag.
6. Douglas West, *Introduction to Graph Theory*, Prentice Hall, 470pp, Aug 2000.
7. Reinhard Diestel, *Graph Theory*, Springer-Verlag, 2nd edition, April 2000.
8. Vašek Chvátal, *Linear Programming*, W. H. Freeman, 1983.
9. Dorit Hochbaum (Editor), *Approximation Algorithms for NP-Hard Problems*, Brooks/Cole Pub Co; 1996.
10. Alexander Schrijver, *Theory of Linear and Integer Programming*, Wiley, John & Sons, 1998.
11. Michael R. Garey and David S. Johnson, *Computers and Intractability: A Guide to the Theory of NP-Completeness*, W. H. Freeman Company, November 1990.
12. Ravindra K. Ahuja, Thomas L. Magnanti, and James B. Orlin, *Network Flows: Theory, Algorithms, and Applications*, Prentice Hall, February 1993.
13. Rajeev Motwani, Prabhakar Raghavan, *Randomized Algorithms*, Cambridge University Press.

7. Remedial English Course

• Remedial English

Just after the admission to the B. Stat. (Hons.) programme all students are required to take a test in English language (comprehension and ability in writing). The students who fail this test are required to take the non-credit course in Remedial English. The syllabus of this course will help the students to improve their English reading, comprehension and verbal ability. It will also include an exposure to usual mistakes in mathematical/statistical English (for example: 'let we consider', 'the roots of the equation is', 'we now discuss about', 'stationery process') and their corrections. This course will have three lecture-hours and one tutorial session per week. If a student fails this course, even after the back-paper examination, he/she would be allowed to repeat the course in the following year along with the new first year students. A student will not be allowed to continue the B. Stat. (Hons.) programme if he/she fails the course even after these three chances. (Two sessions of two periods each in a week.)