INDIAN STATISTICAL INSTITUTE

Student's Brochure

B. Stat. (Hons.) Programme

(Effective from 2016-17 Academic Year)

203 BARRACKPORE TRUNK ROAD

KOLKATA 700108

Contents

1. General Information

1.1. Scope

The B. Stat. (Hons.) degree programme offers comprehensive instruction in the theory, methods and application of Statistics, in addition to several areas of Mathematics and some basic areas of Computer Science. It also offers Elective Courses in some other subjects as given in Section 5. It is so designed that on successful completion, the students would be able to pursue higher studies in areas of Statistics and Mathematics, as well as Computer Science, Economics and allied fields, or take up careers as Statisticians in research institutions and scientific laboratories, government departments or industries. The students successfully completing the requirements for the B. Stat. (Hons.) degree will automatically be admitted to the M. Stat. programme.

1.2. Duration

The total duration of the B. Stat. (Hons.) programme is three years (six semesters). An academic year, consisting of two semesters with a recess in between, usually starts in July and continues till May. The classes are generally held only on the weekdays from 10:15 a.m. to 5:00 p.m. The time-table preferably will not have an off day in the beginning or the end of the week. There is a study-break of one week before the semestral examination in each semester.

1.3. Centre

The B. Stat (Hons.) programme is currently offered at Kolkata only.

1.4. Course Structure

The B. Stat. (Hons.) programme has 30 one-semester credit courses, five per semester, as given in the curriculum below in Section 4. Several groups of three elective courses in natural and social sciences are offered. Besides the above courses, a non-credit course on Remedial English is offered in the first semester of the first year. This course is compulsory for those who are found to have deficiency in English comprehension and writing, as determined through a test.

1.5. Satisfactory Conduct

The students shall observe all rules (inclusive of hostel and mess rules) of the Institute. Ragging is banned in the Institute and anyone found indulging in ragging will be given punishment such as expulsion from the Institute, or, suspension from the Institute/classes for a limited period and fine. The punishment may also take the shape of (i) withholding Stipend/Fellowship or other benefits, (ii)

withholding results, (iii) suspension or expulsion from hostel and the likes. Local laws governing ragging are also applicable to the students of the Institute. Incidents of ragging will be reported to the police.

Students shall not indulge in rowdyism or any other act of indiscipline or unlawful/unethical/indecent behavior. Attendance requirements in classes detailed in Section 2.2 should be met. Violations of the above will be treated as breach of discipline and unsatisfactory conduct. They will attract penalties ranging from: withholding promotion/award of degree, withdrawal of stipend and/or expulsion from the hostel/Institute.

1.6. Examination guidelines

1. Students are required to take their seats according to the seating arrangement displayed. If any student takes a seat not allotted to him/her, he/she may be asked by the invigilator to hand over the answer script (i.e., discontinue the examination) and leave the examination hall.
2. Students are not allowed to carry inside the examination hall any mobile phone with them, even in switched-off mode. Calculators, books and notes will be allowed inside the examination hall only if these are so allowed by the teacher(s) concerned, i.e., the teacher(s) of the course, or if the question paper is an open-note/book one. Even in such cases, these articles cannot be shared.
3. No student is allowed to leave the examination hall without permission from the invigilator(s). Further, students cannot leave the examination hall during the first 30 minutes of any examination. Under no circumstances, two or more students writing the same paper can go outside together.
4. Students should ensure that the main answer booklet and any extra loose sheet bear the signature of the invigilator with date. Any discrepancy should be brought to the notice of the invigilator immediately. Presence of any unsigned or undated sheet in the answer script will render it (i.e., the unsigned or undated sheet) to be cancelled, and this may lead to charges of violation of the examination rules.
5. Any student caught cheating or violating examination rules for the first time will get Zero in that paper. If the first offence is in a backpaper examination the student will get Zero in the backpaper. (The other conditions for promotion, as mentioned in Section 2.4 will continue to hold.)
6. Any student caught cheating or violating examination rules is not eligible for direct admission to the M. Stat programme.
7. Any student caught cheating or violating examination rules for the second time will be denied promotion in that year. This means that
   i) a student not already repeating, will have to repeat the corresponding year without stipend;
   ii) a student already repeating, will have to discontinue the programme. Any student caught cheating or violating examination rules more than two times will be asked to discontinue the programme and leave the Institute.

2. **Academic Information**

2.1. Class Teacher

One of the instructors of a class is designated as the Class Teacher. Students are required to meet their respective Class Teachers periodically to get their academic performance reviewed, and to discuss their problems regarding courses.

2.2. Attendance

Every student is expected to attend all the classes. If a student is absent, he/she must apply for leave to the Dean of Studies or Academic Coordinator. Failing to do so may result in disciplinary action. Inadequate attendance record in any semester would lead to reduction of stipend in the following semester; see Section 2.8.

A student is also required to furnish proper notice in time and provide satisfactory explanation if he/she fails to take an examination.

2.3. Examinations and Scores

There are two formal examinations in each course: mid-semestral (midterm) and semestral (final). The composite score in a course is a weighted average of the scores in the mid-semestral and semestral examinations, home-assignments, quizzes and the practical record book (and/or project work) in that course. The weights of examinations in a course are announced before the mid-term examination of the semester. In the case of courses involving field work, some weightage is given to the field reports also. The semestral examination has a weight of at least 50%.

The minimum composite score to pass a credit or non-credit course is 35%.

Back Paper Examination: If the composite score of a student in a course (other than the Statistics Comprehensive) is above 35% but falls short of 45%, she/he will have an option to take a back-paper examination to improve the score to a maximum of 45%. This is called an optional back-paper. However, a student with composite score less than 35% in any course (other than the Statistics Comprehensive) must take a backpaper examination to improve the score to a maximum of 45%. Such a back-paper is called a compulsory back-paper. When a student takes back-paper examination in a course, his/her new composite score in that course will be the higher of the back-paper score and the earlier composite score, subject to a maximum of 45%.

At most one back-paper examination is allowed in any course other than the Remedial English Course. If the score of a student in the back-paper examination

of Remedial English is below 35%, he/she is allowed to repeat the course in the following year along with the new first year students. A student is not allowed to continue in the B. Stat. (Hons.) programme if he/she fails the Remedial English course even after these three attempts.

The ceiling on the total number of backpaper examinations a student can take is as follows: *4 in the first year, 3 in the second year, and 3 in the final year*. Note that this ceiling is for the entire academic year. If a student takes more than the allotted quota of backpaper examinations in a given academic year, then at the end of that academic year the student should decide which of the optional back-paper examination scores should be disregarded. In such a case, the marks of those particular courses will be reverted to their original scores.

The semestral examination of the Statistics Comprehensive course is conducted in the form of a viva voce, where questions are asked on materials from the various Statistics courses taken by the students in the first five semesters. The viva voce is conducted by a panel of at least five teachers (at a time) who taught Statistics courses to the group of students concerned. *No back-paper examination is allowed in this course.*

Compensatory Examination: The following rule applies to a student who obtains less than 35% in at most one course even after the compulsory back paper examination, but scores 60% or more in average in the remaining courses of that academic year: If such a student is not in the final year of the programme, she/he may be provisionally promoted without stipend or contingency grant to the following year, subject to the requirement that the paper is cleared through the so-called compensatory examination, which is a regular (semestral) examination in the corresponding semester of the following year, along with the regular courses for that semester in the current year. Only the score in the semestral examination need be considered for the purpose of evaluation. The student is not expected to attend the course, or to take the mid-semestral examination or to do assignments, projects, etc. even if these are prescribed for the course in that semester. The student can score at most 35% in such an examination. A student scoring less than 35% in this examination will have to discontinue the programme, regardless of the year of study in the programme. If a student successfully clears the examination, then the stipend may be restored but not with retrospective effect. Also, she/he will not be eligible for any prizes or awards. In case the student in question is in the final year of the programme, the Dean of Studies, in consultation with the Teachers Committee, may decide on the mechanism of conducting a special examination of that particular course along the lines suggested above, within six months of the end of that academic year.

A student can appear in at most one compensatory paper every academic year. The student can either appear in the compensatory paper, if the conditions stated above are met, or repeat the year if the existing rules so allow; and not do both.

The student must inform the Dean of Studies in writing in advance regarding his/her choice. No compensatory paper will be allowed in a course where backpaper is not allowed, that is, Statistics Comprehensive. The compensatory examinations for all subjects will be held once in an academic year.

Supplementary Examination: If a student misses an examination due to medical or family emergencies, he/she can appear in the supplementary examination. Supplementary examinations will be held for mid-semestral, semestral, back-paper and compensatory examinations within a month of the examination. The student should submit a written application to the Dean of Studies for appearing in the supplementary examination, enclosing supporting documents. On receipt of such application from a student with supporting documents, the Dean of Studies will decide, in consultation with the relevant Teachers' Committee, on whether such examination will be allowed. The student can score at most 60% in the supplementary examinations to mid-semestral and semestral examinations. For the back-paper or the compensatory papers, the maximum the student can score in the supplementary examination, is 45% or 35% respectively.

2.4. Promotion

A student passes a semester of the programme only when he/she secures composite score of 35% or above in every course AND his/her conduct has been satisfactory. If a student passes both the semesters in a given year, the specific requirements for promotion to the following year are as follows:

Average composite score in all the credit courses taken in a year should be at least 45%, and that the score(s) in non-credit course(s) should be at least 35%.

2.5. Repeating a year

A student fails a year if he/she is not eligible for promotion. If a student fails a year then he/she can repeat the year subject to approval of the Teachers committee. However, a student can repeat only one of the first two years and the final year. A student, who secures B. Stat degree without Honours and has at most eight composite scores (in credit courses) less than 45% in the first two years, is allowed to repeat the final year. The repeat year must be the academic year immediately following the year being repeated. A repeating student will not get any stipend or contingency grant or prizes during the repeat year. However, if the student is from such an economically underprivileged background that this step will force the student to discontinue, then the student can appeal to the Dean of Studies for financial support. A student repeating a year must be assessed for all courses even if the student has passed them in the original year, and the student must obtain a minimum of the respective pass marks in such courses in the repeat year. The final score in a course being repeated will be the maximum

of the scores obtained in the respective two years. A student who is going to repeat the first year of the B. Stat (Hons) course should undergo counseling by the Dean of Studies in the presence of his/ her parents/guardians, to assess whether the student has an aptitude for the programme.

2.6. Final Result

At the end of the third academic year the overall average of the percentage composite scores in all the credit courses taken in the three-year programme is computed for each student. Each of the credit courses carries a total of 100 marks, while Statistics Comprehensive carries 200 marks. The student is awarded the B. Stat. (Hons.) degree in one of the following categories according to the criteria he/she satisfies, provided his/her conduct is satisfactory, and he/she passes all the years.

B. **Stat. (Hons.) - First Division with distinction**

(i) The overall average score is at least 75%,
(ii) average score in the eighteen core[1] courses is at least 60%, and
(iii) the number of composite scores less than 45% is at most one.

B. **Stat. (Hons.) - First Division**

(i) Not in the First Division with distinction
(ii) the overall average score is at least 60%,
(iii) average score in the eighteen core courses is at least 60%, and
(iv) the number of composite scores less than 45% is at most four.

B. **Stat. (Hons.) - Second Division**

(i) Not in the First Division with distinction or First Division,
(ii) the overall average score is at least 45%,
(iii) average score in the eighteen core courses is at least 45%, and
(iv) the number of composite scores less than 45% is at most six.

If a student has satisfactory conduct, passes all the courses but does not fulfill the requirements for the award of the degree with Honours, then he/ she is awarded the B. Stat. degree without Honours. A student fails if his/ her composite score in any credit or non-credit course is less than 35%.

[1] 1The eighteen core courses in which a student must have a minimum average score in order to be placed in a particular division are: Analysis I- III, Probability Theory I - III, Statistical Methods I - IV, Vectors and Matrices I - II, Linear Statistical Models, Parametric Inference, Sample Surveys, Nonparametric and Sequential Methods, Design of Experiments, Statistics Comprehensive.

2.7. Award of Certificates

A student passing the B. Stat. degree examination is given a certificate which includes (i) the list of all the credit courses taken in the three-year programme along with the respective composite scores, (ii) the list of all non-credit courses passed and (iii) the category (Hons. First Division with Distinction or Hons. First Division or Hons. Second Division or without Honours) of his/her final result.

The Certificate is awarded in the Annual Convocation of the Institute following the last semestral examination.

2.8. Stipend and Contingency Grant

Other than refundable Library and Hostel deposit and the recurring mess fees there are no fees charged by the institute. A monthly stipend of Rs. 3000 is awarded at the time of admission to each student. This is valid initially for the first semester only. A repeating student will not get any stipend or contingency grant or prizes during the repeat year. However, if she/he is from such an economically underprivileged background that this step will force him/her to discontinue, then she/he can appeal to the Dean of Studies or the Students In-charge, for financial support. The amount of stipend to be awarded in each subsequent semester depends on academic performance, conduct, and attendance, as specified below, provided the requirements for continuation in the academic programme (excluding repetition) are satisfied; see Sections 2.3 and 1.5.

1. *Students having other Scholarships:*
   If a student is getting a scholarship from another government agency then the stipend will be discontinued. If during the B. Stat (Hons.) programme the student obtains any scholarship with retrospective effect then the student should return the stipend given by the institute. Failure to do so will be deemed as unsatisfactory conduct and corresponding rules shall apply.

2. *Performance in course work*
   If, in any particular semester, (i) the composite score in any course is less than 35%, or (ii) the composite score in more than one course (two courses in the case of the first semester of the first year) is less than 45%, or (iii) the average composite score in all credit courses is less than 45%, no stipend is awarded in the following semester.

   If all the requirements for continuation of the programme are satisfied, the average composite score is at least 60% and the number of credit course scores less than 45% is at most one in any particular semester (at most two in the first semester of the first year), the full value of the stipend is awarded in the following semester.

If all the requirements for continuation of the programme are satisfied, the average composite score is at least 45% but less than 60%, and the number of credit course scores less than 45% is at most one in any particular semester (at most two in the first semester of the first year), the stipend is halved in the following semester.

All composite scores are considered after the respective back-paper examinations. Stipend is fully withdrawn as soon as the requirements for continuation in the academic programme are not met.

3. *Attendance*
   If the overall attendance in all courses in any semester is less than 75%, no stipend is awarded in the following semester.

4. *Conduct*
   The Dean of Studies or the Class Teacher, at any time, in consultation with the respective Teachers' Committee, may withdraw the stipend of a student fully for a specific period if his/her conduct in the campus is found to be unsatisfactory.

Note: Once withdrawn, stipends may be restored in a subsequent semester based on improved performance and/or attendance, but no stipend is restored with retrospective effect.

Stipends are given after the end of each month for eleven months in each academic year. The first stipend is given two months after admission with retrospective effect provided the student continues in the B. Stat. (Hons.) programme for at least two months.

A yearly contingency grant of Rs 3000 is given to students at the time of admission. Contingency grants can be used for purchasing a scientific calculator (or calculator) and other required accessories for the practical class, text books and supplementary text books and for getting photocopies of required academic material. All such expenditure should be approved by the Students-In-Charge. Contingency grants can be utilised after the first two months of admission. Every student is required to bring a scientific calculator for use in the practical classes.

3. **Miscellaneous**

3.1. Prizes and Medals

ISI Alumni Association awards Mrs. M. R. Iyer Memorial Gold Medal to the outstanding B. Stat. (Hons.) student. Prof. J. M. Sengupta Gold Medal is awarded for an outstanding performance in B. Stat. (Hons.).

3.2. Library Rules

Every student is allowed to use the reading room facilities in the library and allowed access to the stacks. B. Stat. (Hons.) students have to pay a security deposit of Rs. 250 in order to avail of the borrowing facility. A student can borrow at most three books at a time.

Any book from the Text Book Library (TBL) collection may be issued out to a student only for overnight or week-end reference provided at least one copy of that book is left in the TBL. Only one book is issued at a time to a student. Fine is charged if any book is not returned by the due date stamped on the issue-slip.

The library rules and other details are posted in the library.

3.3. Hostel Facilities

The Institute has hostels for male and female students in its Kolkata campus. However, it may not be possible to accommodate all students in the hostels. The students have to pay Rs. 605 as caution deposit and Rs. 50 per month as room rent. Limited medical facilities are available free of cost at Kolkata campuses.

3.4. Field Training Programme

All expenses for the necessary field training programmes are borne by the Institute, as per the Institute rules.

3.5. Change of Rules

The Institute reserves the right to make changes in the above rules, course structure and the syllabi as and when needed.

4. B. Stat. (Honours) Curriculum

All the courses listed below are allocated three lecture sessions and one practical/tutorial session per week. The practical/tutorial session consists of two periods in the case of Statistics, Computer and Elective courses, and one period in case of Mathematics and Probability courses. The periods are meant to be used for discussion on problems, practicals, computer outputs, assignments, for special lectures and self-study, etc. All these need not be contact hours.

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 Stochastic Processes
Probability Theory III (C)	Discrete Mathematics
Statistical Methods III (C)	Statistical Methods IV (C)
Elements of Algebraic Structures	Differential Equations
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)
Economic and Official Statistics and Demography	Statistical Quality Control and Operations Research
Design and Analysis of Algorithms	Optional Course

5. **Elective Courses**

5.1. Objectives of the Elective Courses

The primary objective is to impart knowledge in natural and social sciences so that the students may learn the language of the scientists and the fundamental concepts in these fields, and develop familiarity with some of the basic and important problems in these fields which call for statistical analysis along with the corresponding techniques used. The secondary objective is to enrich the general scientific knowledge which may be of use later in professional work.

5.2. Elective Groups

For Elective I, each student has to choose one course from the following list.

(a) Physics I
(b) Microeconomics
(c) Molecular Biology
(d) Geology
(e) Introduction to Sociology

For Elective II, each student has to choose one course from the following list.

(a) Physics II
(b) Macroeconomics
(c) Agricultural Science
(d) Introduction to Anthropology
(e) Psychology

5.3. Choice of Electives

A Student has to choose one elective course for credit in the beginning of each semester of the second year. The choice has to be given in writing to the Dean of Studies within the first four weeks of the semester. Once the choice has been made, it cannot be altered.

5.4. Use in Advanced Courses

The electives 'Physics I and Physics II' are desirable for the Probability specialization; 'Microeconomics and Macroeconomics' and 'Molecular Biology and Agricultural Science' are desirable respectively for the Finance track and the Biostatistics track under the Applied Statistics specialization in M. Stat. Anthropological and sociological data may be used in courses on multivariate statistical analysis and analysis of categorical data. Geological data may be used

in the courses on multivariate statistical analysis and analysis of directional data. Examples from natural and social sciences would generally be discussed in all methodological and modelling courses in statistics.

Note: The B. Stat. (Hons.) curriculum has been designed as a part of the five-year programme leading to the M. Stat. degree. It may be helpful to know the M. Stat. curriculum along with the list of specialization courses in order to make decision on the choice of elective courses. The Class Teacher may be consulted in order to know the scope of the different specializations offered in the M. Stat. programme.

6. **Optional Courses**

In the final semester (Semester VI), a number of courses will be offered from the following list of Optional Courses.

(a) Random Graphs
(b) Number Theory
(c) Special topics on Algorithm
(d) Statistical Methods in Genetics
(e) Quantum Physics

Not all courses can be offered in a particular semester and a student will have to choose one course only from the offered ones.

7. Detailed Syllabi of the B. Stat. (Hons.) Courses

7.1. Statistics Courses

- **Statistical Methods I**

History of statistics. Concepts of population, sample, statistical experiments and observational studies. Various kinds of statistical problems.
Collection and summarization and presentation of different types of univariate and bivariate data.
Descriptive statistics: measures of location, spread, skewness, kurtosis; various properties of these measures and their utility.
Summarization and analysis of different types of bivariate data. Correlation, measures of associations, simple linear regression and properties.
Illustration with specific examples and numerical exercises using statistical packages, preferably R.

- **Statistical Methods II**

Summarization and analysis of different types of multivariate data. Multiple regression. Partial and multiple correlation.
Simulation of probability distributions and stochastic models. Applications of simulation techniques.
Methods of estimation: method of moments, maximum likelihood estimation.
Fitting probability distributions and stochastic models to observed data. Goodness of fit using Pearson's $\chi 2$ and Q-Q plots (applications only).
Illustration with specific examples and numerical exercises using statistical packages, preferably R.

- **Statistical Methods III**

Point estimation: Criteria for good estimates: Unbiasedness, minimum variance, mean square error.
Maximum Likelihood Estimation: Fisher's scoring method, EM algorithm. Iteratively Reweighted Least Squares Estimation (IRLS), Least Absolute Deviation Estimation. Probit and Logit Analyses, Logistic Regression.
Tests of hypotheses: Different types of statistical hypotheses. Level of significance, power of a test, p-value, test for for parameters of normal distributions based on single and two populations. Large sample tests for parameters in Binomial and Poisson
distributions. Conditional tests. Non-central $\chi 2$, t and F distributions.
Confidence intervals: relationship with tests of hypothesis, criteria for goodness.
Illustration with specific examples and numerical exercises using statistical packages, preferably 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.
Likelihood ratio and large-sample tests and confidence intervals. Variance stabilizing transformations. χ2-tests for independence and homogeneity.
Sample quantiles and their properties.
Elements of Time Series analysis: Trend/secular, seasonal/cyclic and random components of a time series, moving averages, autocorrelation function, correlogram and periodogram.
Introduction to Resampling Techniques: Jackknife, Bootstrap and Cross-Validation as data analytic tools.
Illustration with specific examples and numerical exercises using statistical packages, preferably 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. I and II.
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. C. 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.*
12. L. Wasserman: All of Statistics: *A Concise Course in Statistical Inference*.
13. C. Casella and R. L. Berger: *Statistical Inference*, 2nd Edition.
14. B. Efron and R. J. Tibshirani: *An Introduction to the Bootstrap*.
15. P. McCullagh and J. A. Nelder: *Generalized Linear Models.*

- **Linear Statistical Models**

Introduction to stochastic models; formulation and illustrations. Linear statistical models; illustrations.
Least square estimation, estimable linear functions, Normal equations, Best Linear Unbiased Estimates (BLUEs). Gauss - Markov Theorem.
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.
Introduction to random effect models
Illustration with specific examples and numerical exercises using statistical packages, preferably 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 and its Applications*
7. D. Sengupta and S. R. Jammalamadaka: *Linear Models, An Integrated Approach.*

- **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.
Analysis of income and allied size distributions: Pareto and log-normal distributions, genesis, specification and estimation, Lorenz curve, Gini coefficient.
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.
Production analysis: Profit maximization, cost minimization, returns to scale, Cobb-Douglas and ACMS production functions.

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.

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.

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.

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

Use of Control Chart: Introduction to control chart, control chart for variables and attributes - X-MR chart, X-R chart, X-s chart, p-chart, np-chart and c-chart; u-chart, CUSUM chart, EWMA chart; process capability analysis.

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.

Operations Research (OR):

Introduction to Operations Research:

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.

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.

Concluding remark: Synthesizing Statistical Quality Control and Operations Research.

Reference Texts

1. E. L. Grant & R. S. Leavenworth: *Statistical Quality Control*, McGraw-Hill, N. Y.
2. A. J. Duncan: *Quality Control and Industrial Statistics*, Irwin, Homewood, Ill
3. D. C. Montgomery: *Introduction to Statistical Quality Control*, Wiley, N. Y.
4. J. W. Tukey: *Exploratory Data Analysis*, Addison-Wesley
5. Jerry Banks: *Principles of Quality Control*, John Wiley
6. Defect Prevention - Victor E Kane, Marcel Dekker, New York

7. J. M. Juran & F. M. Gryne: *Juran's Quality Control Handbook*, McGraw Hill.
8. D. Bertsimas and J. N. Tsitsiklis: *Introduction to Linear Optimization*, Athena, Scientific, Belmont, Massachusetts, 1999.
9. D. G. Luenberger: *Linear and Nonlinear Programming*, Second Edition, Addison-Wesley, Reading, MA, 1984.
10. G. Hadley: *Linear Programming*, Addison Wesley.
11. K. G. Murty: *Linear Programming*, John Wiley
12. M. S. Bazaraa and J. J. Jarvis: *Linear Programming and Network Flows*, John Wiley & Sons, Inc., New York.
13. M. S. Bazaraa, H. D. Sherali, and C. M. Shetty: *Nonlinear Programming: Theory and Algorithms,* New York, NY: John Wiley & Sons Inc.
14. Hillier and Lieberman: *Introduction to Operations Research*, McGraw-Hill, Boston., MA.
15. S. Chandra, Jayadeva and Aparna Mehra, *Numerical Optimization with Applications*, 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.
Bayesian techniques, priors, posteriors, Bayes' estimators and Bayesian credible regions.
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.

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.
Nonparametric function estimation: histogram, frequency polygon, kernel density estimation and regression.
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.

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.
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. 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.
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.

Reference Texts

1. W. G. Cochran: *Sampling Techniques*.
2. M. N. Murthy: *Sampling Theory and Methods*.
3. A. Chaudhuri: *Essentials of Survey Sampling*.
4. A. S. Hedayat and B. K. Sinha: *Design and Inference in Finite Population Sampling.*
5. C. M. Cassel, C. E. Sarndal and J. H. Wretman: *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.
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.
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.
Missing plot technique.
Use of concomitant variables in orthogonal designs and related analysis. General full factorial designs, their use, advantage and analysis; confounding and partial confounding in 2n designs and relative efficiencies of the effects; experiments with factors at 3 levels, useful designs using confounding in 32, 33 experiments.
Split-plot designs, their use and analysis. 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

7.2. 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.
Fluctuations in coin tossing and random walks, Combination of events.
Composite experiments, conditional probability, Polya's urn scheme, Bayes theorem, independence.
Discrete random variables. Standard discrete distributions. Expectation/mean, variance, moments, functions of discrete random variables, moment generating

functions, probability generating functions.
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.

- **Probability Theory II**

Uncountable sample spaces and concept of events and random variables, properties of probability
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
Expectation, Variance and moments of random variables with densities, Expectation of functions of random variables with densities as integral, Moment generating function with properties and illustrations
Bivariate continuous distributions, bivariate CDFs, independence, distribution of sums, products and quotients for bivariate continuous distributions, Student-t, x2, F densities, Bivariate Normal distribution.
Multivariate distributions and properties. Multivariate densities and multivariate singular distributions. Distributions of functions of random vectors and Jacobian formula. Examples of multivariate densities. Conditional and marginal distributions, Independence, Conditional expectation, Examples.
Multivariate Normal distribution, properties; Sampling distribution for mean and sample variance; Distributions of linear and quadratic forms; Dirichlet density, properties

- **Probability Theory III**

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.
Review of conditional distribution and conditional expectation, General definition, Examples
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.
Characteristic functions, properties, Inversion formula and Levy continuity theorem (statements only)
CLT in i.i.d. finite variance case. Slutsky's Theorem. δ-method. Multivariate CLT, Cramer-Wald device.
Brief introduction to Poisson process on $[0,\infty)$ and some basic properties.

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*.

- **Introduction to Stochastic Processes**

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.
Classification of states, recurrence and transience; absorbing states, irreducibility, decomposition of state space into irreducible classes, Examples.
Absorbing chains, absorption probabilities and mean absorption time, fundamental matrix
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.
Introduction to MCMC, perfect sampling
Review of Poisson process and its properties, non-homogeneous and compound Poisson processes, Simple birth and death processes, a brief introduction to general continuous time Markov chains, Kolmogorov equations

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. J. G. Kemeny, J. L. Snell and A. W. Knapp: *Finite Markov Chains*.

7.3. 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.

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. L'Hospital's rule, Maxima and minima of functions.

- **Analysis II**

Riemann integration, Fundamental theorem of calculus, Computation of definite integrals, improper integrals.
Sequences and Series of functions, Double sequences, Pointwise and uniform convergence, Term- by-term differentiation and integration, Power series, Weierstrass approximation theorem. Fourier series.

- **Analysis III**

Functions of several variables, Continuity, Partial derivatives, Differentiability, Taylor's theorem, Maxima and minima.

Multiple integrals, Repeated integrals, The Jacobian theorem, Line, surface and volume integrals, Differential forms, Theorems of Green and Stokes.

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*.

- **Differential Equations**

Illustration of setting up differential equations: radio-active decay, the tractrix, the catenary, the L-C-R circuit, the Brachistochrome, etc.
First and second order linear differential equations with constant and variable coefficients, 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.
Solutions of exact differential equations, integrating factors.
Power Series Solutions of differential equations with analytic coefficients, special functions.
Existence and uniqueness of solution of $x' = f(x; t)$. Picard's method.
System of first order equations. Nonlinear equations. Introduction to chaos. Calculus of variations. Euler's differential equation. Laplace transform and

convolution.

Introduction to partial differential equations.

Reference Texts

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

- **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.
Linear transformation and its matrix with respect to a pair of bases, properties of matrix operations, use of partitioned matrices.
Column space and row space, rank of a matrix, nullity, rank of AA*.
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.
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.
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.

- **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.
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.
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.
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.
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.
Rings. Ideals and quotient rings. Prime ideals and Integral domains. Maximal ideals, PID, UFD. Polynomial rings (over commutative rings). Gauss' theorem. Fields. Roots of polynomials. Field extensions. Splitting fields. Finite fields.
Applications to elementary number theory.

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, Pigeon-hole 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.

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.
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.
Graph Theory: Definition of graph and directed graph, definition of degree, subgraph, induced sub-graph, paths and walk, connectedness of a graph, connected components.
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.
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).
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).
Flows-definitions and examples, max-flow min-cut theorem.

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.*

7.4. Computer Science Courses

- **Introduction to Programming and Data Structures**

Introduction to number system: binary, octal, hexadecimal;
Introduction to digital computers: CPU, main memory, peripherals, I/O devices,

algorithm, storage, flow-charts;
Imperative languages: Introduction to imperative language - syntax and constructs of a specific language (preferably C); variables, assignment, expressions, input/output, conditionals and branching, iteration;
Data handling: arrays and pointers, structures, dynamic allocation, Files;
Functions and Recursion: Function - parameter passing, procedure call, call by value, call by reference; Recursion.
Data Structures: Queue, Stack, Linked lists, Trees.

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.
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.
Numerical integration: Newton-Cotes; Orthogonal polynomials and Gaussian quadrature. Accuracy of quadrature formulae.
Numerical differentiation.
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.
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.
Computation in Linear Algebra: Numerical solution of system of linear equations and matrix inversion: Gaussian elimination, square Root, L-U methods.
Reduction to bidiagonal/tridiagonal form: Householder transformation, Given's transformation. Numerical computation of eigenvalues and eigenvectors: Jacobi's method, power method.

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. Searching algorithms: Binary search, balanced binary search tree, hashing.
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.
Graph Algorithms: Basic definitions, connectivity and traversals (Breadth First Search and Depth First Search), directed acyclic graphs and topological ordering.
Computational Geometry: Convex hull, diameter of a point set.
Greedy Algorithms: Shortest paths in a graph, minimum spanning trees, clustering.
Divide and Conquer: Closest pair of points, integer multiplication, matrix multiplication, Fast Fourier Transform.
Dynamic Programming: Subset sum, knapsack, all pair shortest paths in a graph.

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.*

7.5. Elective Courses

- **Microeconomics**

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

Reference Texts

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

- **Macroeconomics**

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

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.
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.
Time in Geology: Geological time scale, absolute and relative time, fossils and their usage, succession of the through time, organic evolution.
Important Geologic Principles.
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.

Quantitative aspects of Geology: Nature and source of geologic data, possible applications of various statistical and mathematical tools, example of such usage.

Practical: Identification of minerals, rocks and fossils. Introducing topsheets and simple geological maps. Measurement and graphical representation of grain-size and paleocurrent data. Field Work: basic geologic mapping, collection of scalar and vector data, mine visits, etc.

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**

Distinguishing characteristics of living and non-living things Cell structure and functions

Metabolism of protein, carbohydrate and fat Structure and function of DNA and RNA

Replication, transcription, translation, cell division (mitosis, meiosis) Definition of gene and genetic code; relationship between them Mendel's Law of genetics and application in human population

Practical

Reference Texts

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

- **Agricultural Science**

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.

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).

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.

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.

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

Farming systems, cropping system and maximizing 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.

Practical: Estimation of crop yield from yield attributing data; Fertilizers scheduling, Soil physical and chemical analysis like pH, conductivity, OC, N, P, K, etc.

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
   - 1.2. Schools of Psychology - Structural, Behavioural and Gestalt psychology
   - 1.3. Relationship with other disciplines
2. Biological basis of human behavior variation
   - 2.1. Heredity and environmental role on changes in behavior
   - 2.2. Nervous system - neural and synaptic activity, brain localization

2.3. Endocrine gland and stress
2.4. Stages of sleep
2.5. Drugs and behavior

3. Attention: Determinants, shift and fluctuation
4. Perceptual process
   4.1. Perceptual organization
   4.2. Experiments on distance, depth and time perception
   4.3. Illusion and hallucination
5. Memory
   5.1. Information processing model
   5.2. Experiments in Short and Long term memory
   5.3. Theories of forgetting
6. Learning
   6.1. Experiments on classical conditioning
   6.2. Operant conditioning and reinforcement
   6.3. Laws of learning and learning curve
   6.4. Insight learning
   6.5. Teaching pedagogy
7. Methods:
   7.1. Variables and Measurement Scales
   7.2. Introspective, Observation and Case study
   7.3. Experimental and Quasi-experimental Research Designs
   7.4. Interviews and discourse analysis
   7.5. Manual and Computer-assisted Testing
   7.6. Characteristics of good questionnaire
   7.7. Survey Research Techniques

Practical:

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

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**

Part I

1. Introduction: definition and scope, subdivisions of anthropology, interrelationships between anthropology and other biological and social science disciplines.
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.
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 environ- mental variations.

Part II

1. Racial anthropology to concepts and methods of Human Population Biology in Biological Anthropology.
2. Human variation and adaptation to environment: causes of variation, short and long term adaptation to different climatic, biotic and sociocultural environments, genetic factors.
3. Human biological processes: human physical growth; growth and development; aging and senescence.
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.

Part III

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

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, New 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) Globalization 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

1. Survey of the elementary principles: Laws of Mechanics, Mechanics of a system of particles, Conservation laws, Vector Algebra, Conservative force.
2. Lagrange's formulation: The basic problem with the constraint forces, Principle of virtual work, D'Alembert's principle, Degree of freedom, Lagrange's equation of motion, Velocity dependent potential, Simple applications of Lagrange's formulation.
3. Two body central force problems: Centre of mass and relative coordinates, Reduced mass, Kepler's laws and their derivations.
4. Hamiltonian mechanics: Some techniques of calculus of variation, Hamilton's principle, Derivation of Lagrange's equation of motion from Hamilton's principle, Concept of symmetry, Conservation theorems, Hamilton's equation of motion.

References:

1. H. Goldstein: *Classical Mechanics*
2. N.C. Rana and P.S. Joag: *Classical Mechanics*

Thermodynamics and Statistical Mechanics

1. Thermodynamics: Laws of thermodynamics, Concept of entropy, Maxwell relations and thermodynamic functions, Ideal and non-ideal gases.
2. Statistical mechanics: State of a system, Basic postulates, Ensemble (Micro-Canonical, Canonical and grand Canonical), Partition function, Maxwell-Boltzmann statistics.

References

1. F. Reif: *Fundamentals of Statistical and Thermal Physics*

- **Physics II**

Electromagnetic Theory

1. Vector analysis: Introduction to vector calculus
2. Electrostatics: Electric field and potential, Gauss theorem and its application, Work and energy in electrostatics, Conductors, Polarization, Electric displacement, Linear dielectrics.
3. Magneto-statistics: Lorentz force law, Biot-Savart's law, Magnetic vector potential, Magnetization, Magnetic susceptibility and permeability.
4. Electrodynamics: Electromotive force, Electromagnetic induction, Maxwell's equations, Conservation of momentum, energy and charge.
5. Electromagnetic wave: Waves in one-dimension, Electromagnetic wave in vacuum and its significance.

References

1. D.J. Griffith: *Introduction to Electrodynamics*

Special Theory of Relativity

1. Principle of Relativity: Galilean relativity, Significance of Michelson-Morley experiment, Postulates of special relativity, Lorentz transformation
2. Relativistic effects: Time dilation, Length contraction, Relativity of simultaneity, Relativistic addition of velocity, Mass formula, Mass-energy equation.
3. Four vector formalism: Minkowskian four-dimensional space-time, Four velocity and four momentum and their interpretations.

References

1. R. Resnick: *Introduction to Special Relativity*
2. R.A. Mould: *Basic Relativity*

7.6. Optional Courses

Optional Course in Statistics

- **Statistical Methods in Genetics**

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

Reference Texts

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

Optional Course 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.
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.
Concept of thresholds and proof of every monotone property has a threshold. Thresholds for sub-graph containment. Connectivity threshold. Basic idea of sharp thresholds.
Dense and sparse random graphs.
The evolution of the sparse random graph, the emergence of the giant component, phase transition. Sub-critical, critical and super-critical phases.
Sub-graph counts and its asymptotic distribution. Chromatic number of dense and sparse random graphs.

Random regular graphs, the configuration model. Asymptotic of small cycles.
Other models of random graphs: Albert-Barabaśi model of preferential attachment, geometric random graphs. Properties and illustration with examples.

Reference Texts

1. S. Janson, T. Łuczak and A. Ricínski: *Random Graphs.*
2. B. Bollobs: *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)

Optional Course in Mathematics

- **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.
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.*
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.*
Polynomial congruences and Hensel's Lemma; Quadratic residues and non-residues, Euler's criterion.
Detailed study of the structure of the group of units of Z/nZ, Primitive roots; Dirichlet characters and how to construct them.
Definition and properties of the Legendre symbol, Gauss's lemma, Law of quadratic reciprocity for Legendre symbols; Extension to Jacobi symbols.
Arithmetical functions and their convolutions, multiplicative and completely multiplicative functions, examples like the divisor function d(n), the Euler function ϕ(n), the Möbius function μ(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 π(X) - the number of primes up to X; Euler and Abel summation formulae and average order of magnitude of various arithmetical functions.
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.
Sum of two and four squares, Lagrange's four square theorem.
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.*

Optional Course in Computer Science

- **Special topics on Algorithm**

Graph algorithm: Optimal graph traversal, shortest path, minimum spanning tree, planarity algorithms.
Geometric algorithm: Convex hull, point location, Voronoi diagram, Delaunay triangulations, arrangements and duality.
Combinatorial algorithms: Simplex algorithms, network flows, matching.
NP and Computational Intractability: Polynomial-time reductions, the definition of NP, NP-complete problems.
Combinatorial geometry: Convexity, Radon's lemma and Helly's theorem, ham sandwich cuts, Ramsey number, Erdos-Szekeres theorem, arrangement, cutting lemma.
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.
Randomized Algorithms: Random variables and their expectations. Examples of randomized algorithms.

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. Vaek Chvtal, *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.

Optional Course in Physics

- **Quantum Physics**

Pre-requisites: Physics I and Physics II

Quantum mechanics

4. Introduction to quantum theory: Photoelectric effect, Compton effect, de Broglie relation, Diffraction of matter waves, Superposition principle.
5. Mathematical foundation of quantum mechanics: Hilbert space, Hermitian operator and spectral representation, Unitary operator, Kinematical Postulates of quantum mechanics, Heisenberg uncertainty relation and its interpretation, Principle of Complementarity, Quantum dynamics; Schroedinger and Heisenberg picture.
6. Solving Schroedinger equation in some simple cases: Particle in a box, Finite square well, Potential barrier, Introduction to Semi-conductor band theory.
7. Operator formalism: Creation and annihilation operators, Harmonic oscillator, Angular momentum, Ladder operator and its application, Details of spin-1/2 system.

Quantum Statistical Mechanics

8. Quantum statistical mechanics: Law of Black body radiation, Bose-Einstein Statistics, Fermi-Dirac statistics, Classical limit.

References Texts

1. J.J.Sakurai, *Modern Quantum Mechanics*
2. A. Ghatak and S. Lokanathan, *Quantum Mechanics: Theory and Applications*
3. F. Reif, *Fundamentals of Statistical and Thermal Physics*

7.7. 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 course will have two sessions of two periods in a week. 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.