Indian Statistical Institute

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Student's Brochure

B. Math. (Hons.) Programme
Effective from 2015-16 Academic Year

All rules are subject to change and approval by the Dean of Studies, Indian Statistical Institute, 203, B.T. Road, Kolkata 700108

Contents

1 General Information

1.1 Scope

The B. Math (Hons.) degree programme is a premier undergraduate programme in India that offers comprehensive instruction in mathematics along with courses in Probability, Statistics, Computer Science and Physics. It is so designed that after successfully completing this programme, a student will be able to pursue higher studies in areas of mathematical sciences including Mathematics, Statistics, Computer Science, Mathematical Physics and Applied mathematics. Students who successfully complete the requirements for the B. Math (Hons.) degree will automatically be admitted to the M. Math programme of the Indian Statistical Institute.

1.2 Duration

The total duration of the B. Math (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 am to 5:30 pm.

1.3 Centre

The B. Math (Hons.) programme is offered at the Bangalore centre only.

1.4 Course Structure

The B. Math (Hons.) programme has twenty eight one-semester credit courses and a non-credit course on Writing of Mathematics, as given in the curriculum below in Section 3.1

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 2.1 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 for Students

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, she/he may be asked by the invigilator to hand over the answer script and leave the examination hall (i.e., discontinue the examination).

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 examiner(s), 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 at the same time.

4. Students should ensure that the main answer booklet and any extra booklet 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 canceled, 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 1.8 in Students brochure, will continue to hold.)

6. Any student caught cheating or violating examination rules is not eligible for direct admission to the M. Math 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 twice or more will be asked to discontinue the programme and leave the Institute.

2 Academic Information

2.1 Attendance

Every student is expected to attend all the classes. If a student is absent, she/he must apply for leave to the Associate Dean or Students In-Charge. 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.

2.2 Class-Teacher

One of the instructors 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.

2.3 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 by the Students-in-charge or the Class Teacher, in consultation with the teacher concerned. 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 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 must take a backpaper examination to improve the score to a maximum of 45%. Such a back-paper is called a compulsory back-paper. At most one back-paper examination is allowed in a particular course.

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, 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.

Compensatory Examination: The following rule applies to a student who has failed a course (i.e obtained less than 35% in both the composite score and compulsory back paper examination) but scores 60% or more in all other courses: 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. However, she/he 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. Stipend may be restored after she/he successfully clears the examination, but not with retrospective effect. Also, she/he will not be eligible for any prizes or awards. All other terms and conditions related to the compensatory examination remain unchanged. 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.

Supplementary Examination: In the event of a student failing to take a mid-semestral, semestral, backpaper or compensatory examination due to medical or family emergencies, the Dean of Studies or the Students-in-charge, should be informed about this in writing, that is, through an e-mail or a letter, latest by the date of the examination. Subsequently, she/he should apply to the aforementioned authorities in writing for permission to take a supplementary examination, enclosing supporting documents. The supplementary semestral examination is held at the same time as the back-paper examinations for that semester and a student taking supplementary semestral examination is not allowed to take a backpaper examination in the course. When a student takes supplementary semestral (backpaper, compensatory) examination in a course, the maximum she/he can score in that examination is 60% (45%, 35% respectively). The score obtained in the supplementary semestral examination will be treated as the semestral exam score in the calculation of the composite score in that course.

2.4 Promotion

A student passes a semester of the programme only when she/he 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: the average composite score in all the credit courses taken in a year should be 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 the student is not eligible for promotion.

Subject to approval of the Teacher's committee: a student who fails can repeat any one of the first two years and the final year; a student who secures B. Math degree without Honours[1] 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

[1] See Section 2.6

will force the student to discontinue, then the student can appeal to the Dean of Studies or the Students-In-charge, 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. Math (Hons) course should undergo counseling by the Dean of Studies/Students-In-charge 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. The student is awarded the B. Math (Hons.) degree in one of the following categories according to the criteria she/he satisfies, provided his/her conduct is satisfactory, and she/he passes all the semesters.

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

  (i) The overall average score is at least 75%,

  (ii) average score in the sixteen core courses [2] is at least 60%, and

  (iii) the number of composite scores less than 45% is at most one.

[2] The 16 core courses are Algebra I, II, III, IV; Analysis I, II, III, IV; Probability I, II; Optimization, Complex Analysis, Graph Theory, Topology, Introduction to Differential Geometry and Introduction to Differential Equations. See Section 3.2 for detailed syllabi.

- **B. Math (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 sixteen core courses is at least 60%, and

  (iv) the number of composite scores less than 45% is at most four.

- **B. Math (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 sixteen 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 she/he is awarded the B. Math degree without Honours. A student fails if his/her composite score in any credit or non- credit course is less than 35%.

2.7 Award of Certificates

A student passing the B. Math degree examination is given a certificate which includes (i) the list of all the credit courses taken in the three-year programme along with their respective composite scores and (ii) the category (Hons. First Division with Distinction or Hons. First Division or Hons. Second Division or Pass) of his/her final result.

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

2.8 Fees, Stipend, and Contigency 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 Scholarships:* If a student is getting a scholarship from another government agency then the stipend will be discontinued. If during the B. Math (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 Associate Dean or Students-In-Charge 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.

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 twelve months in each academic year. The first stipend is given two months after admission with retrospective effect provided the student continues in the B. Math (Hons.) programme for at least two months.
An 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 B. Math (Hons.) Curriculum and Detailed Syllabi

3.1 Curriculum

Writing of Mathematics will be allocated two one hour lecture sessions per week. All other courses are allocated four one hour lecture sessions per week. Statistics, Physics, and Computer Science courses may be allocated an extra one hour session per week to facilitate Laboratory work.

First Year

Semester I	Semester II
1. Analysis I (Calculus of one variable)	1. Analysis II (Metric spaces and Multivariate Calculus)
2. Probability Theory I	2. Probability Theory II
3. Algebra I (Groups)	3. Algebra II (Linear Algebra)
4. Computer Science I (Programming)	4. Physics I (Mechanics of particles and Continuum systems)
5. Writing of Maths (non-credit half-course)	

Second Year

Semester I	Semester II
1. Analysis III (Vector Calculus)	1. Graph Theory
2. Algebra III (Rings and Modules)	2. Algebra IV (Field Theory)
3. Statistics I	3. Statistics II
4. Physics II (Thermodynamics and Optics)	4. Topology
5. Optimization	5. Computer Science II (Numerical Methods)

Third Year

Semester I	Semester II
1. Complex Analysis	1. Analysis IV (Introduction to Function Spaces)
2. Introduction to Differential Geometry	2. Introduction to Differential Equations
3. Physics III	3. Physics IV (Modern Physics and Quantum Mechanics)
4. Statistics III	4. Elective Subject II
5. Elective Subject I	5. Elective Subject III

3.2 Sixteen Core courses

Algebra I (Groups) : Basic set theory: Equivalence relations and partitions. Zorn's lemma. Axiom of choice. Principle of induction. Groups, subgroups, homomorphisms. Modular arithmetic, quotient groups, isomorphism theorems. Groups acting on sets. Sylow's theorems. Permutation groups. Semidirect products, Free groups.

Algebra II (Linear Algebra) : Matrices and determinants. Linear equations. Basics of Polynomial rings over real and complex numbers. Vector spaces over fields. Bases and dimensions. Direct sums and quotients of vector spaces. Linear transformations and their matrices. Eigenvalues and eigen vectors. Characteristic polynomial and minimal polynomial. Bilinear forms, inner products, symmetric, hermitian forms. Unitary and normal operators. Spectral theorems.

Algebra III (Rings and Modules) : Ring homomorphisms, quotient rings, adjunction of elements. Polynomial rings. Chinese remainder theorem and applications. Factorisation in a ring. Irreducible and prime elements, Euclidean domains, Principal Ideal Domains, Unique Factorisation Domains. Field of fractions, Gauss's lemma. Noetherian rings, Hilbert basis theorem. Finitely generated modules over a PID and their representation matrices. Structure theorem for finitely generated abelian groups. Rational form and Jordan form of a matrix.

Algebra IV (Field Theory) : Finite Fields. Field extensions, degree of a field extension. Ruler and compass constructions. Algebraic closure of a field. Transcendental bases. Galois theory in characteristic zero, Kummer extensions, cyclotomic extensions, impossibility of solving quintic equations. Time permitting: Galois theory in positive characteristic (separability, normality), Separable degree of an extension.

Reference Texts : 1. M. Artin: Algebra.

2. S. D. Dummit and M. R. Foote: Abstract Algebra.

3. I. N. Herstein: Topics in Algebra.

4. K. Hoffman and R. Kunze: Linear Algebra.

Analysis I (Calculus of one variable) : The language of sets and functions - countable and uncountable sets (see also Algebra 1). 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 $\mathbb{R}$. Series - convergence and divergence of series, absolute and conditional convergence. Various tests for convergence of series. (Integral test to be postponed till after Riemann integration is introduced in Analysis II.) Connection between infinite series and decimal expansions, ternary, binary expansions of real numbers, calculus of a single variable - continuity; attainment of supremum and infimum of a continuous function on a closed bounded interval, uniform continuity. Differentiability of functions. Rolle's theorem and mean value theorem. Higher derivatives, maxima and minima. Taylor's theorem - various forms of remainder, infinite Taylor expansions.

Analysis II (Metric spaces and Multivariate Calculus) : The existence of Riemann integral for sufficiently well behaved functions. Fundamental theorem of Calculus. Calculus of several variables: Differentiability of maps from $\mathbb{R}^m$ to $\mathbb{R}^n$ and the derivative as a linear map. Higher derivatives, Chain Rule, Taylor expansions in several variables, Local maxima and minima, Lagrange multiplier. Elements of metric space theory - sequences and Cauchy sequences and the notion of completeness, elementary topological notions for metric spaces i.e. open sets, closed sets, compact sets, connectedness, continuous and uniformly continuous functions on a metric space. The Bolzano - Weirstrass theorem, Supremum and infimum on compact sets, Rn as a metric space.

Analysis III (Vector Calculus) : Multiple integrals, Existence of the Riemann integral for sufficiently well-behaved functions on rectangles, i.e. product of intervals. Multiple integrals expressed as iterated simple integrals. Brief treatment of multiple integrals on more general domains. Change of variables and the Jacobian formula, illustrated with plenty of examples. Inverse and implicit functions theorems (without proofs). More advanced topics in the calculus of one and several variables - curves in $\mathbb{R}^2$ and $\mathbb{R}^3$. Line integrals, Surfaces in $\mathbb{R}^3$, Surface integrals, Divergence, Gradient and Curl operations, Green's, Strokes' and Gauss' (Divergence) theorems. Sequence of functions - pointwise versus uniform convergence for a function defined on an interval of $\mathbb{R}$, integration of a limit of a sequence of functions. The Weierstrass's theorem about uniform approximation of a continuous function by a sequence of polynomials on a closed bounded interval.

Analysis IV (Introduction to Function Spaces) : Review of compact metric spaces. $C([a,b])$ as a complete metric space, the contraction mapping principle. Banach's contraction principle and its use in the proofs of Picard's theorem, inverse and implicit function theorems. The Stone-Weierstrass theorem and Arzela-Ascoli theorem for $C(X)$. Periodic functions, Elements of Fourier series - uniform convergence of Fourier series for well behaved functions and mean square convergence for square integrable functions.

Reference Texts :

1. T. M. Apostol: Mathematical Analysis.
2. T. M. Apostol: Calculus
3. S. Dineen: Multivariate Calculus and Geometry.
4. R. R. Goldberg: Methods of Real Analysis.
5. T. Tao: Analysis I.
6. Bartle and Sherbert: Introduction to Real Analysis.
7. H. Royden: Real Analysis.

Introduction to Differential Equations : Ordinary differential equations - first order equations, Picard's theorem (existence and uniqueness of solution to first order ordinary differential equation), Second order linear equations - second order linear differential equations with constant coefficients, Systems of first order differential equations, Equations with regular singular points, Introduction to power series and power series solutions, Special ordinary differential equations arising in physics and some special functions (eg. Bessel's functions, Legendre polynomials, Gamma functions). Partial differential equations - elements of partial differential equations and the three equations of physics i.e. Laplace, Wave and the Heat equations, at least in 2-dimensions. Lagrange's method of solving first order quasi linear equations.

Reference Texts :

1. G.F. Simmons: Differential Equations.
2. R. Haberman: Elementary applied partial differential equations.
3. R. Dennemeyer: Introduction to partial differential equations and boundary value problems.

Complex Analysis : Holomorphic functions and the Cauchy-Riemann equations, Power series, Functions defined by power series as holomorphic functions, Complex line integrals and Cauchy's theorem, Cauchy's integral formula. Representations of holomorphic functions in terms of power series. Zeroes of analytic functions, Liouville's theorem, The fundamental theorem of algebra, The maximum modulus principle, Schwarz's lemma, The argument principle, The open mapping property of holomorphic functions. The calculus of residues and evaluation of integrals using contour integration.

Reference Texts :

1. D. Sarason: Notes on Complex Function Theory.
2. T. W. Gamelin: Complex Analysis.
3. J. B. Conway: Functions of one complex Variable.

Topology : Topological spaces, quotient topology. Separation axioms, Urysohn lemma. Connectedness and compactness. Tychonff's theorem, one point compactification.

Reference Texts :

1. J. Munkres: Topology a first course.
2. M. A. Armstrong: Basic Topology.
3. G. F. Simmons: Introduction to Topology and Modern Analysis.
4. K. Janich: Topology.

Introduction to Differential Geometry : Curves in two and three dimensions, Curvature and torsion for space curves, Existence theorem for space curves, Serret-Frenet formula for space curves, Inverse and implicit function theorems, Jacobian theorem, Surfaces in $\mathbb{R}^3$ as two dimensional manifolds, Tangent space and derivative of maps between manifolds, First fundamental form, Orientation of a surface, Second fundamental form and the Gauss map, Mean curvature and scalar curvature, Integration on surfaces, Stokes formula, Gauss-Bonnet theorem.

Reference Texts : 1. M.P. do Carmo: Differential Geometry of Curves and Surfaces.

2. A. Pressley: Elementary Differential Geometry.

Graph Theory : Graphs, Hamilton Cycles and Euler Cycles, Planar Graphs, vector spaces and matrices associated with Graphs, Flows in Directed Graphs, Connectivity and Menger's Theorem, Matching, Tutte's 1-Factor Theorem.

Reference Texts : 1. B. Bollobas: Graph Theory (Chapters I - III).

2. P. J. Cameron and J.H. Van Lint: Graphs, codes and designs.

Optimization : Systems of linear equations: Gaussian elimination, LU, QR decompositions, Singular values, SVD, Inner product spaces, Projections onto subspaces, Perron- Frobenius, Fundamental theorem of LP, The simplex algorithm, Duality and applications, LP and Game theory.

Reference Texts : 1. Harry Dym: Linear algebra in action, AMS Publications 2011.

2. A. R. Rao and Bhimasankaram: Linear Algebra
3. G. Strang: Applied linear algebra.
4. C. R. Rao: Linear statistical inference.
5. H. Karloff: Linear programming.
6. S-C Fang and S.Puthenpura: Linear optimization and extensions.

Probability I : Orientation, Combinatorial probability and urn models, Independence of events, Conditional probabilities, Random variables, Distributions, Expectation, Variance and moments, probability generating functions and moment generating functions, Standard discrete distributions (uniform, binomial, Poisson, geometric, hypergeometric), Independence of random variables, Joint and conditional discrete distributions. Univariate densities and distributions, standard univariate densities (normal, exponential, gamma, beta, chi-square, cauchy). Expectation and moments of continuous random variables. Transformations of univariate random variables. Tchebychev's inequality and weak law of large numbers.

Probability II : Joint densities and distributions. Transformation of variables (assuming Jacobian formula). Distributions of sum, maxima, minima, order statistics, range etc. Multivariate normal (properties, linear combinations) and other standard multivariate distributions (discrete and continuous) as examples. Standard sampling distributions like t, χ^2 and F. Conditional distributions, Conditional Expectation. Characteristic functions: properties, illustrations, inversion formula, continuity theorem (without proof). Central Limit Theorem for i.i.d. case with finite variance. Elements of modes of convergence of random variables and the statement of the strong law of large numbers.

Reference Texts : 1. K. L. Chung: Elementary Probability Theory.

2. P. G. Hoel, S. C. Port and C. J. Stone : Introduction to Probability Theory.
3. R. Ash : Basic Probability Theory.
4. W. Feller : Introduction to Probability Theory and its Applications, Volume 1.
5. W. Feller : Introduction to Probability Theory and its Applications, Volume 2.
6. P. Billingsley : Probability and Measure.
7. V. K. Rohatgi: Probability theory.

3.3 Statistics courses

Statistics I : Introduction to Statistics with examples of its use; Descriptive statistics; Graphical representation of data: Histogram, Stem-leaf diagram, Box-plot; Exploratory statistical analysis with a statistical package; Basic distributions, properties; Model fitting and model checking: Basics of estimation, method of moments, Basics of testing, interval estimation; Distribution theory for transformations of random vectors; Sampling distributions based on normal populations: t, χ^2 and Fx distributions. Bivariate data, covariance, correlation and least squares

Suggested References: 1. Lambert H. Koopmans: An introduction to contemporary statistics

2. David S Moore and William I Notz: Statistics Concepts and Controversies
3. David S Moore, George P McCabe and Bruce Craig: Introduction to the Practice of Statistics

4. Larry Wasserman: All of Statistics. A Concise Course in Statistical Inference
5. John A. Rice: Mathematical Statistics and Data Analysis

Statistics II : Theory and Methods of Estimation and Hypothesis testing, Sufficiency, Exponential family, Bayesian methods, Moment methods, Maximum likelihood estimation, Criteria for estimators, UMVUE, Large sample theory: Consistency; asymptotic normality, Confidence intervals, Elements of hypothesis testing; Neyman-Pearson Theory, UMP tests, Likelihood ratio and related tests, Large sample tests.

Suggested References : 1. George Casella and Roger L Berger: Statistical Inference

2. Peter J Bickel and Kjell A Doksum: Mathematical Statistics
3. Erich L Lehmann and George Casella: Theory of Point Estimation
4. Erich L Lehmann and Joseph P Romano: Testing Statistical Hypotheses

Statistics III : Multivariate normal distribution, Transformations and quadratic forms; Review of matrix algebra involving projection matrices and matrix decompositions; Linear models; Regression and Analysis of variance; General linear model, Matrix formulation, Estimation in linear model, Gauss-Markov theorem, Estimation of error variance, Testing in the linear model, Regression, Partial and multiple correlations, Analysis of variance, Multiple comparisons; Stepwise regression, Regression diagnostics.

Suggested References: 1. Sanford Weisberg: Applied Linear Regression

2. C R Rao: Linear Statistical Inference and Its Applications
3. George A F Seber and Alan J Lee: Linear Regression Analysis

3.4 Computer Science Courses

Computer Science I (Programming) Recommended Language: C Basic abilities of writing, executing, and debugging programs. Basics: Conditional statements, loops, block structure, functions and parameter passing, single and multi-dimensional arrays, structures, pointers. Data Structures: stacks, queues, linked lists, binary trees. Simple algorithmic problems: Some simple illustrative examples, parsing of arithmetic expressions, matrix operations, searching and sorting algorithms.

Computer Science II (Numerical Methods) Introduction to Matlab (or appropriate package) and Numerical Computing: Number representations, finite precision arithmetic, errors in computing. Convergence, iteration, Taylor series. Solution of a Single Non-linear Equation: Bisection method. Fixed point methods. Newton's method. Convergence to a root, rates of convergence. Review of Applied Linear algebra: Vectors and matrices. Basic operations, linear combinations, basis, range, rank, vector norms, matrix norms. Special matrices. Solving Systems of equations (Direct Methods): Linear systems. Solution of triangular systems. Gaussian elimination with pivoting. LU decomposition, multiple right-hand sides. Nonlinear systems. Newton's method. Least Squares Fitting of Data: Fitting a line to data. Generalized least squares. QR decomposition. Interpolation: Polynomial interpolation by Lagrange polynomials. Alternate bases: Monomials, Newton, divided differences. Piecewise polynomial interpolation. Cubic Hermite polynomials and splines. Numerical Quadrature: Newton - Cotes Methods: Trapezoid and Simpson quadrature. Gaussian quadrature. Adaptive quadrature. Ordinary Differential Equations: Euler's Method. Accuracy and Stability. Trapezoid method. Runge - Kutta method. Boundary value problems and finite differences.

Reference Texts:

1. B. Kernighan and D. Ritchie: The C Programming Language.
2. J. Nino and F. A. Hosch: An Introduction to Programming and Object Oriented Design using JAVA.
3. G. Recketenwald: Numerical Methods with Matlab.
4. Shilling and Harries: Applied Numerical methods for engineers using Matlab and C.
5. S. D. Conte and C. De Boor: Elementary Numerical Analysis: An Algorithmic Approach.
6. S. K. Bandopadhyay and K. N. Dey: Data Structures using C.
7. J. Ullman and W. Jennifer: A first course in database systems.

3.5 Physics Courses

Physics I (Mechanics of Particles and Continuum Systems): Newton's laws of motion; Concept of inertial frames of reference. Conservation laws (energy, linear momentum, angular momentum) for a single particle and a system of particles; Motion of system with variable mass; Frictional forces; Center of mass and its motion; Simple collision problems; Torque; Moment of Inertia (parallel and perpendicular axis theorem) and Kinetic energy of a rotating rigid body; Central forces; Newtons laws of gravitation; Keplers laws; Elements of Variational calculus and Lagrangian formulation; Introduction to mechanics of continuum systems; Elastic deformation and stress in a solid; Hookes law; 9 interrelations of elastic constants for an isotropic solid; elastic waves; basic elements of fluid dynamics; equation of continuity; Eulers equation for ideal fluid; Streamline flow; Bernoullis equation +5 experiments (10 hours)

Suggested Text Books:

1. Mechanics - Keith Symon :
2. Classical Mechanics- R. Douglas Gregory
3. Classical Mechanics - J. R. Taylor

Physics II (Thermal physics and Optics): Kinetic theory of Gases; Ideal Gas equation; Maxwells Laws for distribution of molecular speeds. Introduction to Statistical mechanics; Specification of state of many particle system; Reversibility and Irreversibility ; Behavior of density of states; Heat and Work; Macrostates and Microstates; Quasi static processes; State function; Exact and Inexact differentials; First Law of Thermodynamics and its applications; Isothermal and Adiabatic changes; reversible, irreversible, cyclic processes; Second law of thermodynamics; Carnots cycle. Absolute scale of temp; Entropy; Joule Thomson effect; Phase Transitions; Maxwells relations; Connection of classical thermodynamics with statistical mechanics; statistical interpretation of entropy.; Third law of Thermodynamics

Optics:

Light as a scalar wave; superposition of waves and interference; Youngs double slit experiment; Newtons rings; Thin films; Diffraction; Polarization of light; transverse nature of light waves

Texts:

1. F. Reif: Statistical and Thermal physics
2. Kittel and Kroemer: Thermal Physics
3. Zeemansky and Dittman: Heat and Thermodynamics
4. Jenkins and White: Optics

Physics III (Electromagnetism and Electrodynamics) Vectors, Vector algebra, Vector Calculus (Physical meaning of gradient, divergence and curl); Gauss's divergence theorem; Theorems of gradients and curls. Electrostatics, Coulomb's law for discrete and continuous charge distribution; Gauss's theorem and its applications; Potential and field due to simple arrangements of electric charges; work and energy in electrostatics; Dilectrics, Polarization; Electric displacement; Capacitors (Paralleleplates); Electrical images. Magnetostatics: Magnetic field intensity (H), Magnetic induction (B), Biot-Savart's law; Ampere's law; comparison of electrostatics and magnetostatics. Electro- dynamics: Ohm's law, Electromotive force, Faraday's law of electro- magnetic induction; Lorentz force, Maxwell's equations. Electromagnetic theory of light and wave optics. Electronics: Semiconductors; pn junctions; transistors; zenor diode, IV characteristics. +5 experiments (10 hours)

Reference Texts:

1. D. J. Giffths: Introduction to Electrodynamics.
2. J. R. Reitz, F. J. Milford and W. Charisty: Foundations of Electromagnetic theory. 10
3. D. Halliday and R. Resnick: Physics II.

Physics IV (Modern Physics and Quantum Mechanics): Special theory of Relativity: Michelson-Morley Experiment, Einstein's Postulates, Lorentz Transformations, length contraction, time dilation, velocity transformations, equivalence of mass and energy. Black body Radiation, Planck's Law, Dual nature of Electromagnetic Radiation, Photoelectric Effect, Compton effect, Matter waves, Wave-particle duality, Davisson-Germer experiement, Bohr's theory of hydrogen spectra, concept of quantum numbers, Frank-Hertz experiment, Radioactivity, X-ray spectra (Mosley's law), Basic assumptions of Quantum Mechanics, Wave packets, Uncertainty principle, Schrodinger's equation and its solution for harmonic oscillator, spread of Gaussian wave packets with time.

A list of possible physics experiments:

1. Determination of the coefficient of viscosity of water by Poiseuille's method (The diameter of the capillary tube to be measured by a travelling vernier microscope).
2. Determination of the surface tension of water by capillary rise method.

3. Determination of the temp. coefficient of the material of a coil using a metric bridge.
4. To draw the frequency versus resonant length curve using a sonometer and hence to find out the frequency of the given tuning fork.
5. Study of waves generated in a vibrating string and vibrating membrane.
6. Determination of wave length by Interference and Diffraction.
7. One experiment on polarized light.
8. Experiments on rotation of place of polarization - chirality of media.
9. Elasticity: Study of stress-strain relation and verification of Hooke's law of elasticity, Measurement of Young's modulus.
10. Faraday Experiment: Pattern in fluid and granular materials under parametric oscillation.
11. Determination of dispersion rotation of Faraday waves in liquid (water/glucerol) and to compute the surface tension of the liquid.
12. Determination of the moment of a magnet and the horizontal components of Earth's magnetic field using a deflection and an oscillation magnetometer.
13. Familiarization with components, devices and laboratory instruments used in electronic systems.
14. To study the characteristics of a simple resistor-capacitor circuit.
15. Transistor Amplifier: To study a common emitter bipolar junction transistor amplifier.
16. Diodes and Silicon controlled rectifiers: To study the operational characteristics of diodes and silicon controlled rectifier.
17. Logic circuits: Combinational logic and binary addition.

3.6 Non Credit Courses

Writing of Mathematics (non-credit half-course) The aim of this (non-credit) course is to improve the writing skills of students while inculcating an awareness of mathematical history and culture. The instructor may choose a book, like the ones listed below, and organize class discussions. Students will then be assigned five formal writing assignments (of 8 to 10 pages each) related to these discussions. These will be corrected, graded and returned.

Reference Texts: 1. J. Stillwell: Mathematics and Its History, Springer UTM.

2. W. Dunham, Euler: The Master of Us All, Mathematical Association of America.
3. W. Dunham: Journey Through Genius, Penguin Books.
4. M. Aigner and M. Ziegler: Proofs From The Book, Springer.
5. A. Weil: Number Theory, An Approach Through History from Hammurapi to Legendre.

3.7 Elective Courses

Introduction to Representation Theory: Introduction to multilinear algebra: Review of linear algebra, multilinear forms, tensor products, wedge product, Grassmann ring, symmetric product. Representation of finite groups: Complete reducibility, Schur's lemma, characters, projection formulae. Induced representation, Frobenius reciprocity. Representations of permutation groups.

Reference Texts: 1. W. Fulton and J. Harris: Representation Theory, Part I.

2. J-P Serre: Linear representations of finite groups.

Introduction to algebraic geometry: Prime ideals and primary decompositions, Ideals in polynomial rings, Hilbert basis theorem, Noether normalisation theorem, Hilbert's Nullstellensatz, Projective varieties, Algebraic curves, Bezout's theorem, Elementary dimension theory.

Reference Texts: 1. M. Atiyah and I.G. MacDonald: Commutative Algebra.

2. J. Harris: Algebraic Geometry.
3. I. Shafarervich: Basic Algebraic Geometry.
4. W. Fulton: Algebraic curves.
5. M. Ried: Undergraduate Commutative Algebra.

Introduction to Algebraic Number Theory: Number fields and number rings, prime decomposition in number rings, Dedekind domains, definition of the ideal class group, Galois theory applied to prime decomposition and Hilbert's ramification theory, Gauss's reciprocity law, Cyclotomic fields and their ring of integers as an example, the finiteness of the ideal class group, Dirichlet's Unit theorem.

Reference Texts: 1. D. Marcus: Number fields.

2. G. J. Janusz: Algebraic Number Theory.

Differential Geometry II: Manifolds and Lie groups, Frobenius theorem, Tensors and Differential forms, Stokes theorem, Riemannian metrics, Levi-Civita connection, Curvature tensor and fundamental forms.

Reference Texts: 1. S. Kumaresan: A course in Differential Geometry and Lie Groups.

2. T. Aubin: A course in Differential Geometry.

Introduction to Differential Topology: Manifolds. Inverse function theorem and immersions, submersions, transversality, homotopy and stability, Sard's theorem and Morse functions, Embedding manifolds in Euclidean space, manifolds with boundary, intersection theory mod 2, winding numbers and Jordan- Brouwer separation theorem, Borsuk-Ulam fixed point theorem.

Reference Texts: 1. V. Guillemin and Pollack: Differential Topology (Chapters I, II and Appendix 1, 2).

2. J. Milnor: Topology from a differential viewpoint.

Topics in Optimization: Constrained optimization problems, Equality constraints, Lagrange multipliers, Inequality constraints, Kuhn-Tucker theorem, Convexity. If time permits :-

Calculus of variations, Optimal control, Game theory.

References Texts: 1. R. K. Sundaram, A first course in Optimization theory.

2. S. Tijs, Introduction to game theory.

3. Fleming and Rishel, Deterministic and stochastic optimal control.

Combinatorics: Review of finite fields, Mutually orthogonal Latin squares and finite projective planes, Desargues's theorem, t-designs and their one-point extensions, Review of group actions - transitive and multiply transitive actions, Mathieu groups, Witt designs, Fisher's inequality, Symmetric designs.

Reference Texts: 1. D. R. Hughes and F. Piper: Projective planes, Graduate texts in Mathematics 6.

2. P.J.Cameron and J.H.van Lint, Graphs, codes and designs.

Topics in Applied Stochastic Processes: Discrete parameter martingales (without conditional expectation w.r.t. σ algebras!), Branching processes, Markov models for epidemics, Queueing models.

Notes: (i) Measure theory to be avoided. Of course, use of DCT, MCT, Fubini, etc. overtly or covertly permitted. (ii) Relevant materials concerning Markov chains, including continuous time MC's, may be reviewed. If this course runs concurrently with Prob. III (where Markov chains are taught), some concepts/facts needed may be stated with proofs deferred to Prob. III. (iii) Genetic models may also be included, but then at least two topics from the above may have to deleted, as the background material from genetics may be formidable.

References: 1. A. Goswami and B. V. Rao: A Course in Applied Stochastic Processes. Hindustan Book Agency

2. S. Karlin and H. M. Taylor: A First and Second Course in Stochastic Processes. Academic Press, 1975 and 1981.

3. S. M. Ross: Introduction to Probability Models. 8th edition. Academic Press/Elsevier, Indian reprint, 2005. (Paperback)

4. S. M. Ross: Stochastic Processes. 2nd edition. Wiley Student Edition, 2004. (Paperback)

Introduction to Dynamical systems: Linear maps and linear differential equation: attractors, foci, hyperbolic points; Lyapunov stability criterion, Smooth dynamics on the plane: Critical points, Poincare index, Poincare- Bendixon theorem, Dynamics on the circle: Rotations: recurrence, equidistribution, Invertible transformations: rotation number, Denjoy construction, Conservative systems: Poincare recurrence. Newtonian mechanics.

Reference Texts: 1. B. Hasselblatt and A. Katok: A first course in dynamics.

2. M. Brin and G. Stuck: Introduction to dynamical systems.

3. V. I. Arnold: Geometrical methods in the theory of Ordinary Differential Equations.

Introduction to Stochastic Processes: Discrete Markov chains with countable state space. Classification of states - recurrence, transience, periodicity. Stationary distributions, reversible chains. Several illustrations including the Gambler's Ruin problem, queuing chains, birth and death chains etc. Poisson process, continuous time markov chain with countable state space, continuous time birth and death chains.

Reference Texts: 1. P. G. Hoel, S. C. Port and C. J. Stone: Introduction to Stochastic Processes.

2. S. M. Ross: Stochastic Processes.

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

4. D. L. Isaacsen and R. W. Madsen: Markov Chains, Theory and Applications.

Stochastic Models in Insurance: 1. Review of Markov chains, Poisson processes

2. Renewal processes (Basics, Renewal equations; Blackwell's renewal theorem may be stated without proof)

3. Claim size distributions

4. Cramer-Lundberg and Renewal risk models.

5. Ruin problems

6. Markov chain methods in life-insurance

7. Some discussion on statistical methods

Reference Texts: 1. T. Mikosch: Non-life insurance mathematics. Springer(India), 2004. (Paperback)

2. H. U. Gerber: Life-insurance mathematics. Springer (India), 2010. (Paperback)

3. W. Feller: An introduction to probability theory, vol.II. Wiley-Eastern. (Paperback)

4. T.Rolski, Tomasz Rolski, Hanspeter Schmidli, Volker Schmidt, Jozef Teugels, Stochastic Processes for insurance and finance. Wiley. 1999

5. P.Boland: Statistical and probabilistic methods in actuarial science. Chapmen and Hall, 2007.

6. R.Hogg and S.Klugman: Loss distributions. Wiley. 1984.

Elements of Statistical Computing: Examples and use of computational techniques in data analysis; Simulations; Monte-Carlo sampling; E-M algorithm; Markov chain Monte-Carlo methods, Gibbs sampling, Hastings algorithm, reversible jump MCMC; Resampling methods: Jackknife, Bootstrap, Cross-validation.

Reference Texts:

1. Christian P Robert and George Casella: Monte Carlo Statistical Methods
2. Brian D Ripley: Stochastic Simulation
3. Geoffrey J McLachlan and T Krishnan: The EM Algorithm and Extensions
4. Sheldon Ross: Simulation
5. B Efron: The Jackknife, the Bootstrap, and Other Resampling Plans.

Statistics IV : Analysis of Discrete data: Nonparametric methods: Decision theory, Goodness of fit tests, Multiway contingency tables, Odds ratios, Logit model, Wilcoxon test, Wilcoxon signed rank test, Kolmogorov test. Elements of decision theory : Bayes and minimax procedures.

Reference Texts:

1. G. K. Bhattacharya and R. A. Johnson: Statistics : Principles and Methods.
2. P. J. Bickel and K. A. Doksum: Mathematical Statistics.
3. E. J. Dudewicz and S. N. Mishra: Modern Mathematical Statistics.
4. V. K. Rohatgi: Introduction to Probability Theory and Mathematical Statistics.

Statistics V: Sample Surveys (1/2 Semester): Scientific basis of sample surveys. Complete enumeration vs. sample surveys. Principal steps of a sample survey; illustrations, N.SS., Methods of drawing a random sample. SRSWR and SRSWOR: Estimation, sample size determination. Stratified sampling; estimation, allocation, illustrations. Systematic sampling, linear and circular, variance estimation. Some basics of PPS sampling, Two-stage sampling and Cluster sampling. Nonsampling errors. Ration and Regression methods.

Reference Texts:

1. W. G. Cochran: Sampling Techniques.
2. M. N. Murthy: Sampling Theory and Methods.

3. P. Mukhopadhyay: Theory and Methods of Survey Sampling.

Design of Experiments (1/2 semester): The need for experimental designs and examples, basic principles, blocks and plots, uniformity trials, use of completely randomized designs. Designs eliminating heterogeneity in one direction: General block designs and their analysis under fixed effects model, tests for treatment contrasts, pairwise comparison tests; concepts of connectedness and orthogonality of classifications with examples; randomized block designs and their use. Some basics of full factorial designs. 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.

Mathematics of Computation: Models of computation (including automata, PDA). Computable and non-computable functions, space and time complexity, tractable and intractable functions. Reducibility, Cook's Theorem, Some standard NP complete Problems: Undecidability.

Computer Science III (Data Structures): Fundamental algorithms and data structures for implementation. Techniques for solving problems by programming. Linked lists, stacks, queues, directed graphs. Trees: representations, traversals. Searching (hashing, binary search trees, multiway trees). Garbage collection, memory management. Internal and external sorting.

Computer Science IV (Design and Analysis of Algorithms): Efficient algorithms for manipulating graphs and strings. Fast Fourier Transform. Models of computation, including Turing machines. Time and Space complexity. NP-complete problems and undecidable problems.

Reference Texts: 1. A. Aho, J. Hopcroft and J. Ullmann: Introduction to Algorithms and Data Structures.

2. T. A. Standish: Data Structure Techniques.
3. S. S. Skiena: The algorithm Design Manual.
4. M. Sipser: Introduction to the Theory of Computation.
5. J.E. Hopcroft and J. D. Ullmann: Introduction to Automata Theory, Languages and Computation.
6. Y. I. Manin : A Course in Mathematical Logic.

Mathematical Morphology and Applications Introduction to mathematical morphology: Minkowski addition and subtraction, Structuring element and its decompositions. Fundamental morphological operators: Erosion, Dilation, Opening, Closing. Binary Vs Greyscale morphological operations. Morphological reconstructions: Hit-or-Miss transformation, Skeletonization, Coding of binary image via skeletonization, Morphological shape decomposition, Morphological thinning, thickening, pruning. Granulometry, classification, texture analysis: Binary and greyscale granulometries, pattern spectra analysis. Morphological Filtering and Segmentation: Multiscale morphological transformations, Top-Hat and Bottom-Hat transformations, Alternative Sequential filtering, Segmentation. Geodesic transformations and metrics: Geodesic morphology, Graph-based morphology, City-Block metric, Chess board metric, Euclidean metric, Geodesic distance, Dilation distance, Hausdorff dilation and erosion distances. Efficient implementation of morphological operators. Some applications of mathematical morphology.

Reference Texts: 1. J. Serra, 1982, Image Analysis and Mathematical Morphology, Academic Press London, p. 610.

2. J. Serra, 1988, Image Analysis and Mathematical Morphology: Theoretical Advances, Academic Press, p. 411
3. L. Najman and H. Talbot (Eds.), 2010, Mathematical Morphology, Wiley, p. 507.
4. P. Soille, 2003, Morphological Image Analysis, Principles and Applications, 2nd edition, Berlin: Springer Verlag.
5. N. A. C. Cressie, 1991, Statistics for Spatial Data, John Wiley.

Economics 1: Introduction to Economics: Micro and Macro Economics *Micro Economics:*Welfare Economics: Supply and Demand, Elasticity; Consumption and Consumer behaviour;Production and Theory of costs. Market Organisation: Competition, Monopoly.

*Macro Economics:*National income accounting, demand and supply. Simple Keynesian model and extensions. Consumption and Investment. Inflation and Unemployment. Fiscal policy Money, banking and finance.

Reference Texts 1. Intermediate Microeconomics by Hal Varian.

2. Microeconomic Theory by Richard Layard and A.A. Walters
3. Microeconomics in Context by N. Goodwin, J. Harris, J. Nelson, B. Roach and M. Torras
4. Microeconomics: behavior, institutions, and evolution by Bowles S.
5. Macroeconomics by N. G. Mankiw.
6. Macroeconomics by R Dornbusch and S Fisher.
7. Macroeconomics in context by N Goodwin, J Harris, J Nelson, B Roach and M Torras,

Economics 2: Themes in Development Theory and Policy Topics from:

Theories of growth: historical pattern, classical models, structural models, neo-classical and contemporary approaches. Concept of development: beyond growth (basic needs, capabilities, freedom). Agricultural transformation. Strategies of industrial development. Unemployment, underemployment and poverty. Population and demographic transition. Migration and urbanisation.Trade theory and development experience. Environment and sustainable development

Reference Texts 1. Development Economics by Michael P Todaro.

2. Leading Issues in Economic Development by G. M Meier and J E Rauch.
3. International Economics: Theory and Policy by Paul Krugman and M Obstfeld.
4. Halting Degradation of Natural Resources by J. M. Baland and J. P. Platteau.
5. Chapters 1-3 of Book I of Adam Smith s The Wealth of Nations.
6. Development economics. Princeton University Press by Ray D.
7. Increasing returns and economic progress. The Economic Journal 38, 527 542, Young A.A. (1928).

8. Industrialization and the Big Push. The Journal of Political Economy 97, 1003 1026 by Murphy K.M., A. Shleifer, and R.W. Vishny.
9. Why Poverty Persists in India: A Framework for Understanding the Indian Economy. OUP Catalogue by Eswaran M., and A. Kotwal.

Economics 3: Poverty and Inequality: theory and empirics Topics from: Concept and measurement of inequality in incomes. Concentration of wealth. Intra-household inequality Poverty, relatively speaking. Definition and measurement of poverty. Poverty and undernutrition. Trends in poverty and inequality in India

Reference Texts 1. Measurement of Inequality and Poverty, Oxford University Press, 1997, by S Subramanian (ed).

2. Measuring Inequality by Frank Cowell.
3. On Economic Inequality by Amartya Sen.
4. Why Poverty Persists in India: A Framework for Understanding the Indian Economy. OUP Catalogue by Eswaran M., and A. Kotwal.
5. Growing public: Volume 1, the story: Social spending and economic growth since the eighteenth century by Lindert P.H.
6. The Haves and the Have-Nots: A brief and idiosyncratic history of global inequality by Milanović B.

4 Miscellaneous

4.1 Library Rules

Any student is allowed to use the reading room facilities in the library and allowed access to the stacks. B. Math (Hons.) students have to pay a security deposit of Rs.2000/- in order to avail 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 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.

4.2 Hostel Facility

The Institute has hostel for students in the Bangalore campus. However, it may not be possible to accommodate all degree/diploma students in the hostels. Limited medical facilities are available free of cost at Bangalore campus.

4.3 Expenses for the Field Training Programmes

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

4.4 Change of Rules

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