Course of Study: B.Sc. (H) Mathematics

Semester – I

Algebra I	Calculus I	English / Literature	Phy / Eco / Comm/Chem I

Semester – II

Differential Equation I	Analysis I	Statistics I	Computer Science I

Semester – III

Algebra II	Analysis II	Statistics II	Computational Techniques

Semester – IV

Algebra III	Analysis III	Computer Science II	Phy. / Eco / Comm./Chem.II

Semester – V

Algebra IV	Calculus II	Metric Spaces	Differential Equation II

Semester – VI

Algebra V	Analysis IV	Differential Geometry	Optional

Semester I

I.1 Algebra I

Credits-6 : 6 Lectures and 1 Tutorial per week

Systems of linear equations, row reduction and echelon forms, the matrix equation Ax = b, solution sets of linear systems, linear independence, applications of linear systems, inverse of a matrix.

The fields R and C , vector spaces over R and C, subspaces, bases and coordinate systems, linear transformations, null space, the matrix of a linear transformation, change of basis, dimension, row rank, column rank and determinantal rank of a matrix, eigenvalues and eigenvectors.

De Moivre's theorem for rational indices and its applications, complex roots of unity, statement of the fundamental theorem of algebra and its consequences, results about occurrence of repeated roots, irrational roots and complex roots, Descarte's rule of signs, relation between roots and coefficients for any polynomial equation.

Use of computer aided software for example, Matlab/ Mathematica/ Maple/ MuPad/ wxMaxima for matrices, operations of matrices, determinant, rank, eigenvalue, eigenvector, inverse of a matrix,solution of system of equations.

The scope of this course is indicated from Chapters 1 (Sections 1.1-1.2, 1.4-1.9), 2 (Sections 2.1-2.2, 2.8-2.9), 4 (Sections 4.1-4.7), 5 (Sections 5.1) of [1] and relevant portion of [2].

References:

1. David C. Lay, *Linear Algebra and its Applications* (3rd Edition), Pearson Education Asia, Indian, Reprint, 2007.
2. T.Andreescu, D.Andrica, Complex numbers from A to --- Z, Birkhauser, 2006
3. *Theory of equations*, chapters on the website of the Institute of Life Long Learning, University of Delhi.

Paper I.2: Calculus I

Lectures: 5 hrs per week (including practical and period for students' presentation/group interactions)

Practical 1

Tutorial: 1 hr per week Credit -6

Max. Marks 100

(20 lectures)

Hyperbolic functions, Leibniz rule and its applications to problems of type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+\mathrm{b})^n \sin x$, $(ax+\mathrm{b})^n \cos x$, concavity and inflection points, asymptotes, curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, l'Hopital's rule, optimization procedure, Fermat's principle of optics and Snell's law, applications in business, economics and life sciences.

References:

[1]: Chapter 4 (Sections 4.3 – 4.5 (from page 124 – page 157), Section 4.6 (from page 164 – 165, Q 34, pg 169, Q 37, pg 170), Section 4.7).

[2]: Chapter 7 (Section 7.8), Chapter 11 (Section 11.1).

(18 lectures)

Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin^n x\, dx$, $\int \cos^n x\, dx$, $\int \tan^n x\, dx$, $\int \sec^n x\, dx$, $\int (\log x)^n\, dx$, $\int \sin^n x \cos^m x\, dx$, volumes by slicing, disks and washers methods, volumes by cylindrical shells, parametric equations, parameterizing a curve, arc length, arc length of parametric curves, area of surface of revolution, surface area, work, modeling fluid pressure and force.

References:

[2]: Chapter 8 (Sections 8.2-8.3 (pages 532-538)). Chapter 6 (Section 6.2-6.7(excluding arc length by numerical methods))

(18 lectures)

Graphs of spheres and cylinders in R^3, triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions, tangent and normal components of acceleration, modeling ballistics and planetary motion, Kepler's second law.

References:

[1]: Chapter 9 (Sections 9.1, 9.3 (from 468)), Chapter 10.

(Lectures 8)

Techniques of sketching conics, reflection properties of conics, rotation of axes and second degree equations, classification into conics using the discriminant, polar equations of conics.

References: [2]: Chapter 11 (Sections 11.4-11.6 (up to page 775 excluding sketching conics in polar coordinates)).

Practical/ Lab work to be performed on a computer using Mathematica/ Maple/ Matlab

(10 lectures)

(i) Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparing them.

(ii) Locating the inflexion point and region of concavity and convexity.

(iii) Finding higher derivatives of one variable functions.

(iv) Sketching parametric curves (Eg. Trochoid, cycloid, epicycloids, hypocycloid).

(v) Graphing a polar curve by converting into rectangular co-ordinates.

(vi) Obtaining surface of revolution of curves.

(vii) Finding volumes of solid generated by enclosed region about a given axes.

(viii) Finding the arc length of parametric curves.

(ix) Generating graphs of hyperbolic functions.

(x) Sketching graphs of vector functions.

References:

1. M. J. Strauss, G. L. Bradley and K. J. Smith, *Calculus* (3rd Edition), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.

2. H. Anton, I. Bivens and S. Davis, *Calculus* (7th Edition), John Wiley and Sons (Asia) Pte. Ltd., Singapore, 2002.

I.3 PAPER-3

TECHNICAL WRITING AND COMMUNICATION IN ENGLISH

Max. Marks 100

Unit 1
Communication: Language and communication, differences between speech and writing, distinct features of speech, distinct features of writing.

Unit 2
Writing Skills; Selection of topic, thesis statement, developing the thesis; introductory, developmental, transitional and concluding paragraphs, linguistic unity, coherence and cohesion, descriptive, narrative, expository and argumentative writing.

Unit 3
Technical Writing: Scientific and technical subjects; formal and informal writings; formal writings/reports, handbooks, manuals, letters, memorandum, notices, agenda, minutes; common errors to be avoided.

SUGGESTED READINGS

1. M. Frank. Writing as thinking: *A guided process approach, Englewood Cliffs,* Prentice Hall Reagents.
2. L. Hamp-Lyons and B. Heasely: Study Writing; *A course in written English.* For academic and professional purposes, Cambridge Univ. Press.
3. R. Quirk, S. Greenbaum, G. Leech and J. Svartik: *A comprehensive grammar of the English language*, Longman, London.
4. Daniel G. Riordan & Steven A. Panley: *"Technical Report Writing Today"* - Biztaantra.

Additional Reference Books

5. Daniel G. Riordan, Steven E. Pauley, Biztantra: *Technical Report Writing Today*, 8th Edition (2004).
6. *Contemporary Business Communication*, Scot Ober, Biztantra, 5th Edition (2004)

I.4 **Phy I**

Vector Calculus (Total Number of Lectures = 12)
Differentiation of a vector with respect to a scalar. Gradient, divergence, curl and Laplacian operations and their meanings. Idea of line, surface and volume integrals. Gauss's divergence theorem, Stokes theorem and Greens's theorem in a Plane.

Mechanics (Total Number of Lectures = 24)
Dynamics of a system of particles, Centre of mass. Conservation of momentum . Newton's laws, Galilean invariance, Linear Momentum, Impulse. Work–Energy theorem, Potential energy, Conservative and non-conservative forces.

Angular momentum of a particle and system of particles. Torque, Conservation of angular momentum. Rotation about a fixed axis. Moment of inertia and its calculation for rectangular, spherical and cylindrical bodies. Kinetic energy of rotation.
Motion of a particle in a central force field. Kepler's Laws (Only statement).
Elasticity: Hook's Law, Stress, Strain, Elastic Constants, Twisting torque on a wire.
Special Theory of Relativity (Total Number of Lectures = 12)
Constancy of speed of light, The Michelson-Morley Experiment, Postulates of Special theory of Relativity, Lorentz transformations, Lorentz contraction and time dilation, Relativistic velocity addition ,Velocity dependence of mass and equivalence of mass and energy, Doppler effect, Red shift.

REFERENCES:

1. Schaum's Outline of Vector Analysis, 2ed By Murray Spiegel, Seymour Lipschutz (McGraw-Hill, 2009)
2. Mechanics by D.S. Mathur, (S. Chand & Company Ltd., 2000).
3. Mechanics Berkeley physics course, v.1: By Charles Kittel,Walter Knight, Malvin Ruderman,Carl Helmholz,Burton Moyer, (Tata McGraw-Hill, 2007)
4. Physics, Volume I and Vol II by Robert Resnick, David Halliday and Kenneth S. Krane, (John Wiley and Sons Inc., Fifth Edition,1992).
5. Physics for Scientists and Engineers By Raymond A. Serway, John W. Jewett, John W. Jewett, Jr. (Brooks/Cole, 2009)

Semester II

II.1

Differential Equations and Mathematical Modeling I

5 Lectures (including period for students' presentation/group interactions)

Practical 1

Tutorial 1(per week per student) Credit-6

Total marks: 100

Theory: 70

Internal assessment: 30 (15 for theory and 15 for practicals)

(22 lectures)

Differential equations and mathematical models, order and degree of a differential equation, exact differential equations and integrating factors of first order differential equations, reducible second order differential equations, general solution of homogeneous equation of second order, principle of superposition for a homogeneous equation, wronskian, its properties and applications, application of first order differential equations to acceleration-velocity model, growth and decay model, applications of second order differential equations to mechanical vibrations.

References:

[2]: Chapter 1 (Sections 1.1, 1.4, 1.6), Chapter 2 (Section 2.3), Chapter 3 (Sections 3.1, 3.2, 3.4).
[3]: Chapter 2.

(14 lectures)

Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters.

References:

[2]: Chapter 3 (Sections 3.3, 3.5-3.6).

(16 lectures)

Equilibrium points, interpretation of the phase plane, predator-prey model and its analysis, competing species and its analysis, epidemic model of influenza and its analysis, battle model and its analysis.

References:

[1]: Chapter 5 (Sections 5.3-5.4, 5.6-5.7), Chapter 6.

(10 lectures)

Practical/ Lab work to be performed on a computer:

Modeling of the following problems using *Mathematica/ Maple/ Matlab etc.*

(i) Plotting second and third order solution families
(ii) Growth and decay model
(iii) Lake pollution model
(iv) Case of a single cold pill and a course of cold pills
(v) Case study of alcohol in the bloodstream
(vi) Limited growth of population
(vii) Discrete population growth and chaos
(viii) Logistic equation with time lag
(ix) Automated variation of parameters
(x) Predator prey model
(xi) Epidemic model of influenza
(xii) Battle model

References:

1. Belinda Barnes and Glenn R. Fulford, *Mathematical Modeling with Case Studies, A Differential Equation Approach Using Maple*, Taylor and Francis, London and New York, 2002.

2. C. H. Edwards and D. E. Penny, *Differential Equations and Boundary Value Problems: Computing and Modeling*, Pearson Education, India, 2005.

3. S. L. Ross, *Differential Equations*, John Wiley and Sons, India, 2004.

II.2

Analysis I

Total marks: 100

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student) Credit-6

(20 lectures)

The algebraic and order properties of R, suprema and infima, the completeness property of R, the Archimedean property, density of rational numbers in R, characterization of intervals, neighborhoods, open sets, closed sets, limit points of a set, isolated points, closure, complements, nested intervals, Cantor intersection theorem for nested intervals, uncountability of R.

References:

[1]: Chapter 2 (Sections 2.1-2.4, 2.5 (up to 2.5.4)), Chapter 11 (Section 11.1 (up to 11.1.6 and 11.1.8)).

(24 lectures)

Sequences, limit of a sequence, convergent sequences, limit theorems, monotone sequences, monotone convergence theorem, subsequences, convergence and divergence criteria, existence of monotonic subsequences, Bolzano-Weierstrass theorem for sequences and sets, definition of Cauchy sequence, Cauchy's convergence criterion, limit superior and limit inferior of a sequence.

References:

[1]: Chapter 3 (Sections 3.1-3.2).

[3]: Chapter 2 (Sections 10.6-10.7).

(16 lectures)

Definition of infinite series, sequence of partial sums, convergence of infinite series, Cauchy criterion, absolute and conditional convergence, convergence via boundedness of sequence of partial sums, tests of convergence: comparison test, limit comparison test, ratio test, Cauchy's nth root test (proof based on limit superior), integral test (without proof), alternating series, Leibniz test. Arbitrary term series,rearrangements of series.

References:

[2]: Chapter 9 (Sections 9.1, 9.18).

[3]: Chapter 2 (Sections 14.9-14.10, 15).

Practical/ Lab work to be performed on a computer using Mathematica/ Maple/ Matlab etc.

1. To find numbers between two real numbers.
2. Plotting subsets of **R** to study boundedness /unboundedness and bounds (if they exist).
3. Plotting of sets on **R** to discuss the idea of cluster points, lim sup, lim inf.
4. Plotting of recursive sequences.
5. Study the convergence of sequences through plotting.
6. Verify Bolzano Weiestrass theorem through plotting of sequences and hence identify convergent subsequences from the plot.

7. Studying the convergence /divergence of infinite series by plotting their sequences of partial sum.

8. Cauchy's root test by plotting n-th roots.

9. Ratio test by plotting the ratio of nth and n+1 th term.

References:

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

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

3. K. A. Ross, *Elementary analysis: the theory of calculus*, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

II.3 Statistics I

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student) Credit-6

Random Variables : Discrete and continuous random variables, p.m.f. , p.d.f. , c.d.f. illustrations of random variables and its properties.

Expectation of random variable and its properties. Moments and cumulants, moment generating function. Cumulant generation function and characteristic function.

Correlation and regression, Karl Pearson's Coefficient of Correlation, Coefficient of determinations, lines of regression, Spearman's Rank Correlation Coefficient, Intraclass correlation coefficient, Correlation Ratio. Multiple and partial correlation coefficients (for three variates only).

Standard discrete distributions: Degenerate, Binomial, Poisson, Geometric, Negative Binomial, Hypergeometric, Multinomial.

Practicals should broadly cover the following areas:

(i) Fitting of Binomial, Poisson, Negative Binomial, Normal Distributions.
(ii) Tracing of standard distributions
(iii) Calculation of correlation coefficient, Rank Correlation, etc.
(iv) Fitting of polynomials and regression curves.

SUGGESTED READINGS:

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2003): An Outline of Statistical Theory, Vol. I, 4th Edn. World Press, Kolkata.
2. Gupta, S.C. and Kapoor, V.K. (2007): Fundamentals of Mathematical Statistics, 11th Edn., (Reprint), Sultan Chand and Sons.
3. Hogg, R.V. and Tanis, E.A. (2009): A Brief Course in Mathematical Statistics. Pearson Education.
4. Mood, A.M., Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edn. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
5. Johnson, N.L., Kotz, S. and Balakrishnan, N. (1994): Discrete Univariate Distributions, John Wiley.
6. Ross, S. M. (2007): Introduction to Probability Models, 9th Edn., Indian Reprint, Academic Press.
7. Rohatgi, V. K. and Saleh, A. K. Md. E. (2009): An Introduction to Probability and Statistics, 2nd Edn. (Reprint). John Wiley and Sons.

II.4 Paper 4 **CS-1 Programming Fundamentals**

4 Lectures (including period for students' presentation/group interactions)

Practical -2 per week

Tutorial 1(per week per student) Credit-6

Basic Computer Organization: Functional Units, basic I/O devices and storage devices; Representation of integers, real (fixed and floating point), characters (ASCII and Unicode); Basic operations of a programming environment.

Problem Solving Approaches: Notion of an algorithm, problem solving using top-down design and decomposition into sub-problems, stepwise methodology of developing an algorithm, methodology of developing an algorithmic solution from a mathematical specification of the problem, use of recursion for problems with inductive characterization.

Programming using C++: basic data types; constants and variables, arithmetic and logical expressions, assignment; input-output interface; control structures in conditionals, loops; procedural abstractions; strings and arrays; command line arguments; file handling; error handling.

Introduction to the object-oriented programming paradigms; data abstraction and encapsulation — objects and classes; inheritance; polymorphism;

Practicals

1. Read floating point numbers and computes two averages: the average of negative numbers and the average of the positive numbers.
2. Logical (i.e. Boolean) valued function which takes a single integer parameter and returns " True " if and only if the integer is a prime number between 1 and 1000.
3. User defined function to find the absolute value of an integer.
4. Using two dimensional arrays, write c ++ function (and corresponding program to test it) which multiplies an m x n matrix of integers by an n x r matrix of integers.
5. To create employee data base using two dimensional arrays.
6. Enter 100 integers into an array and sort them in an ascending order.
7. Enter 10 integers into an array and then search for a particular integer in the array.
8. Read from a text file and write to a text file.
9. Find roots of a second degree polynomial.
10. Enter 10 integers into an array and print the largest of them.

Recommended Books:

1. B. A. Forouzan and R. F. Gilberg, Computer Science, A structured Approach using C++, Cengage Learning, 2004.

2. R.G. Dromey, How to solve it by Computer, Pearson Education

3. E. Balaguruswamy, Object Oriented Programming with C++ , 4th ed., Tata McGraw Hill

4. G.J. Bronson, A First Book of C++ From Here to There, 3rd ed., Cengage Learning.

Semester – III

III.1 Algebra II

Credits-6: 6 Lectures and 1 Tutorial per week

Binary relations, equivalence relations, congruence relation between integers, statement of well-ordering property of positive integers, statement of fundamental theorem of arithmetic.

Definition and examples of groups, elementary properties of groups, subgroups and examples of subgroups, centralizer, normalizer, center of a group, cyclic groups, generators of cyclic groups, classification of subgroups of cyclic groups.

Permutations, even and odd permutations, alternating group, product (HK) of two subgroups, definition and properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem, an application of cosets to permutation groups, definition and examples of the external direct product of a finite number of groups, normal subgroups, factor groups, applications of factor groups to the alternating group A_4, commutator subgroup.

The scope of this course is indicated from Chapters 1, 2, 3 (including Exercise 20 on page 66 and Exercise 2 on page 86), 4, 5 (till the end of Example 3), 5 (till the end of Theorem 5.7), 7 (till the end of Theorem 7.2 and including Exercises 3, 6 and 7 on page 168), 8 (till the end of Corollary 2 of Theorem 8.2), 9 (till the end of Theorem 9.3 and including Exercise 52 on page 188) of [2] and Chapter 1 of [3].

References:

1. David S. Dummit and Richard M. Foote, *Abstract Algebra* (2nd Edition), John Wiley and Sons (Asia) Pte. Ltd, Singapore, 2003.

2. Joseph A. Gallian, *Contemporary Abstract Algebra* (4th Edition), Narosa Publishing House, New Delhi, 1999.

3. I.N. Herstein, *Topics in Algebra,* 2nd Edition, John Wiley and Sons, 2003.

III.2 Analysis II

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student)   Credit-6

(24 lectures)

Limits of functions, sequential criterion for limits, divergence criteria, review of limit theorems and one-sided limits, continuous functions, sequential criterion for continuity, discontinuity criterion, Dirichlet's nowhere continuous function (illustrations), combinations of continuous functions and compositions of continuous functions, continuous functions on intervals, boundedness theorem, the maximum-minimum theorem, location of roots theorem, Bolzano's intermediate value theorem, intermediate value property, preservation of interval property.

References:

[1]: Chapter 4 (Sections 4.1-4.3), Chapter 5 (Sections 5.1-5.3).

(15 lectures)

Uniform continuity, uniform continuity theorem, differentiation, derivative, combinations of differentiable functions, Caratheodory theorem, chain rule, derivative of inverse functions, interior extremum theorem, intermediate value property for derivatives (Darboux's theorem), review of Rolle's theorem, mean value theorem, Cauchy's mean value theorem.

References:

[1]: Chapter 5 (Section 5.4 up to 5.4.3), Chapter 6 (Sections 6.1-6.2, 6.3.2).

(15 lectures)

Taylor's theorem with Lagrange and Cauchy form of remainders, binomial series theorem, Taylor series, Maclaurin series, expansions of exponential, logarithmic and trigonometric functions, convex functions, applications of mean value theorems and Taylor's theorem to monotone functions.

References:

[1]: Chapter 6 (Sections 6.4 (up to 6.4.6)), Chapter 9 (Section 9.4 (page 271)).

[3]: Chapter 5 (Sections 31.6-31.8).

(10- Lectures)

Power series, radius of convergence, Properties of exponential, logarithmic and trigonometric functions, Cauchy-Hadamard theorem,

[1]: Chapter 9 (Sections 9.4.7-9.4.13)

Use of computer aided software for example, Matlab/ Mathematica/ Maple/ MuPad/ wxMaxima for Taylor and Maclaurin series of sin x, cos x, log (1+*x*), e^x, $(1+x)^n$, *maxima and minima, inverse of graphs.*

References:

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

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

3. K. A. Ross, *Elementary analysis: the theory of calculus*, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

III.3 Statistics II

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student) Credit-6

Bivariate and Multivariate Distributions : Discrete and continuous type, c. d. f., p. d. f., marginal and conditional distributions, independence, expectation and conditional expectation, characteristic function and its properties, Inversion Theorem (without proof).

Transformation of variates, Univariate and bivariate distributions, standard continuous probability distributions: Normal, uniform, exponential, beta, gamma, Cauchy, Laplace. Bivariate normal distribution and its properties.

Order Statistics: distribution of r^{th} order Statistic, Joint distribution of r^{th} and s^{th} order Statistics. Distribution of Sample Range.

Limit Laws: Convergence in probability, almost sure convergence, convergence in mean square and convergence in distribution. Chebyshev's inequality, WLLN, SLLN applications, De-Moivre-Laplace theorem, central limit theorem (C.L.T.) for i. i. d. variates, Liapunov theorem (without proof) and applications of C.L.T.

Practicals based on above course.

SUGGESTED READINGS:

1. David, H.A. and Nagaraja, H.N. (2003): Order Statistics, 3rd Edn., John Wiley and Sons.
2. Hogg, R.V., Craig, A.T. and Mckean, J.W. (2009): Introduction to Mathematical Statistics, 6th Edn., (6th Impression). Pearson Education.
3. Johnson, N.L., Kotz, S. and Balakrishnan, N. (1994): Continuous Univariate Distributions, Vol. I, 2nd Edn. John Wiley.
4. Johnson, N.L., Kotz, S. and Balakrishnan, N. (1994): Continuous Univariate Distributions, Vol. II, 2nd Edn. John Wiley.
5. Goon, A.M., Gupta, M.K. and Dasgupta. B. (2003): An Outline of Statistical Theory, Vol. I, 4th Edn. World Press, Kolkata.

6. Gupta, S.C. and Kapoor, V.K. (2007): Fundamentals of Mathematical Statistics, 11^{th} Edn., (Reprint), Sultan Chand and Sons.

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

8. Ross, S. M. (2007): Introduction to Probability Models, 9^{th} Edn., Indian Reprint, Academic Press.

III.4 Computational Techniques

Total marks: 100 (50 for theory + 50 for practical)

Theory: 35

Practical: 40

Internal assessment: 25 (15 for theory and 10 for practical)

5 Lectures (including period for students' presentation/group interactions)

Practical 2

Credit-6

Note:

1. **Practical (Lab): Maximum number of students allowed per batch for the practical throughout the semester shall be as per the rules of B.Sc. (H) courses.**
2. **Practical Examination: Maximum number of students allowed per batch for the practical shall be 25. There will be one external examiner and one internal examiner for the practical examination. The duration of the practical examination will be 4 hours.**

Theory: 55 Lectures

Convergence, Rate of Convergence, Bisection method, false position method, Newton's method, secant method, error estimate and condition number, LU decomposition, Cholesky methods, error analysis, ill conditioned system, Gauss-Jacobi, Gauss-Seidel and SOR iterative methods. 25L

References:
[1]: Chapter 1 (Section 1.2), Chapter 2 (Sections 2.1-2.2, 2.4-2.5), Chapter 3 (Sections 3.4-3.5, 3.7-3.8, pages 164-166).

Lagrange and Newton interpolation: linear and higher order, finite difference operators and interpolating polynomials using finite differences. 15L

References:

[3]: Chapter 4 (Sections 4.3, 4.4 up to Gregory Newton Backward interpolation).
[1]: Chapter 5 (Sections 5.1, 5.3).

Numerical differentiation: forward difference, backward difference and central difference.
Integration: trapezoidal rule, Simpson's rule IVP of ODE: Euler's method. 15L

References:

[1]: Chapter 6 (Sections 6.2, 6.4), Chapter 7 (Section 7.2).

Practical: 24 labs

Programs using C++ based on each of the above method and the following (and similar) types have to be done:

1. Development of programs for the above methods with applications to electrical circuits, input-output model for a simple economy.
2. Development of programs for the above methods with applications to properties of water and spread of an epidemic.
3. Root finding methods - Newton and secant Method.
4. LU decomposition and Cholesky methods.
5. Gauss-Jacobi and Gauss-Siedel method.
6. Lagrange and Newton Interpolation
7. Gregory Newton Backward and forward interpolation.
8. Simpson's rule.
9. Euler's method.
10. SOR iterative methods.
11. Trapezoidal rule.

References:

1. **B. Bradie, A friendly introduction to Numerical Analysis, Pearson Education, India, 2006.**
2. **C. F. Gerald and P. O. Wheatly, Applied Numerical Analysis, Pearson Education, India, 2005.**
3. **M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical methods for scientific and engineering computation, New age International Publisher, India, 2003.**

SEMESTER IV

IV.1 Algebra III

Credits-6: 6 Lectures and 1 Tutorial per week

Definition and examples of fields. Vector spaces, subspaces, algebra of subspaces, direct sums and quotient spaces, linear combinations and systems of linear equations, linear span, linear independence, basis and dimension, dimension of a subspace, linear transformations, null space, range, rank and nullity of linear transformations, matrix of a linear transformation, algebra of linear transformations, isomorphism, Isomorphism theorems, invertibility and isomorphisms, change of basis. Dual spaces, dual basis, double dual, transpose and its matrix in the dual basis, annihilators. Eigenvalues and eigenvectors, characteristic polynomial, diagonalizability, invariant subspaces and the Cayley-Hamilton theorem, the minimal polynomial for a linear transformation. Inner product spaces and norms, Gram-Schmidt orthogonalisation process, orthogonal complements, Bessel's inequality. Invariant subspaces, primary decomposition theorem, theorem on decomposition into sum of diagonalizable and nilpotent operator, Rational and Jordan forms.

The scope of this course is indicated from Chapters 1 (sections 1.2-1.6), 2 (sections 2.1-2.6), 5 (sections 5.1-5.2, 5.4, 7.3), 6 (sections 6.1-6.2) of [1]; and Chapters 6 (section 6.8) and 7 of [2].

References:

1. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra* (4th Edition), Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.

2. Kenneth Hoffman and Ray Kunze, *Linear Algebra* (2nd edition), Pearson Education Inc., India, 2005.

3. David C. Lay, *Linear Algebra and its Applications* (3rd Edition), Pearson Education Asia, Indian Reprint, 2007.

IV.2 Analysis III

Total marks: 100

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student) Credit-6

(18 lectures)

Riemann integral, basic inequality of Riemann integral, Riemann condition of integrability, Riemann sum, algebraic and order properties of the Riemann integral, Riemann integrability for continuous functions, monotonic functions and functions with finite number of discontinuities, the fundamental theorem of calculus, consequences of the fundamental theorem of calculus: integration by parts and change of variables, mean value theorem of calculus.

References:

[4]: Chapter 6 (Articles 32-34).

(20 lectures)

series of functions, Weierstrass M-test, Weierstrass approximation theorem (statement only). Pointwise and uniform convergence of sequence of functions, uniform norm, uniform convergence and continuity, uniform convergence and differentiation.Uniform convergence and integration.

References:

[1]: Chapter 8 (Sections 8.3-8.4), Chapter 9 (Sections 9.1, 9.4.1-9.4.6).

References:

[1]: Chapter 8 (Sections 8.1, 8.2.1-8.2.3)

(10 lectures)

improper integrals, convergence of improper integrals, tests of convergence for improper integrals, Abel's and Dirichlet's tests for improper integrals, Beta and Gamma functions and their relations.

References:

[1]: Chapter 9 (Sections 9.4.7-9.4.13)

[2]: Chapter 9 (Sections 9.4-9.6).

(16 Lectures)

Piecewise continuous functions, Fourier cosine and sine series, Fourier series, property of Fourier coeffcients, Fourier theorem, discussion of the theorem and its corollary.

References: [3].

Use of computer aided software for example, Matlab/ Mathematica/ Maple/ MuPad/ wxMaxima for power series of analytic functions, Fourier series.

References:

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

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

3. *J.W.Brown, R.V.Churchill, Fourier Series and Boundary value problems* , Tata Mcgraw Hill 2008.

4. K. A. Ross, *Elementary analysis: the theory of calculus*, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

IV.3 Computer Science II

Introduction: Security, Attacks, Computer Criminals, Security Services, Security Mechanisms.

Cryptography: Substitution ciphers, Transpositions Cipher, Confusion, diffusion, Symmetric, Asymmetric Encryption. DES Modes of DES.,Uses of Encryption.,Hash function,key exchange, digital signatures,Digital Certificates.

Program Security: Secure programs,Non malicious Program errors, Malicious codes virus,trap doors,salami attacks, covert channels,Control against program

Threats.Protection in OS: Memory and Address Protection, Access control, File Protection, User Authentication.

Database Security: Requirements, Reliability, Integrity, Sensitive data, Inference, Multilevel Security.

Security in Networks: Threats in Networks s Networks security Controls, firewalls, Intusion detection systems, Secure e-mails

Administrating Security: Security Planning, Risk Analysis, Organisational Security Policy, Physical Security. Ethical issues in Security:

Protecting Programs and data. Information and law.

Recommended Books:

1. C. P. Pfleeger, S. L. Pfleeger; Security in Computing, Prentice Hall of India, 2007

2. W. Stallings ; Network Security Essentials: Applications and Standards, 4/E, 2007

IV.4 Phy II

Waves & Optics
Oscillations and Waves (Total Number of Lectures =24)
Simple Harmonic Motion: Simple Harmonic Oscillator, Motion of simple and compound pendlum,
Loaded spring, Energy in simple harmonic motion. Superposition of two SHM: (i) collinear SHM of
same frequency (ii) collinear SHM of different frequencies – phenomenon of Beats (iii) SHM of

same frequency but perpendicular to each other and (iv) Lissajous figures.
Damped Harmonic Motion: Equation of motion, Dead beat motion, Critically damped system, Lightly damped system: relaxation time, logarithmic decrement, quality factor.
Forced Oscillations: Equation of motion, Complete solution, Steady state solution, Resonance, Sharpness of resonance, Quality factor.
Coupled Oscillator: Degrees of freedom, Coupled oscillator with two degrees of freedom; Normal
modes; General method of finding normal modes for a system of two degrees of freedom.
Wave Optics (Total Number of Lectures =24)

Interference: Essential conditions for observing interference; Division of wave front; Young's double
slit experiment , colour of thin films, Division of amplitude: Newton's rings.
Diffraction: Fresnel and Fraunhofer diffraction; Fraunhofer Diffraction – single slit (intensity distribution, position of maxima and minima), circular aperture (qualitative). plane diffraction grating,
resolving power of grating, Rayleigh's criterion, Fresnel diffraction: half period zone, rectilinear propagation of light, zone plate.
Polarization: Polarization of light (plane polarized light), Malus Law, Polarizing materials, Polarizer,
Analyzer.
REFERENCES
1. Fundamentals of optics By Francis Arthur Jenkins and Harvey Elliott White (McGraw-Hill, 1976)
2. Optics by Ajoy Ghatak (Tata McGraw Hill, 2008)
3. Contemporary optics by A.K.Ghatak & K.Thyagarajan.(Plenum Press,1978).
4. Introduction to Optics by Khanna and Gulati
5. The physics of waves and oscillations by N.K. Bajaj (Tata McGraw-Hill, 1988)
6. Vibrations and waves by A.P.French.(CBS Pub. & Dist., 1987).

Semester V

V.1 Algebra IV

Credits-6: 6 Lectures and 1 Tutorial per week

Definition and examples of homomorphisms, properties of homomorphisms, definition and

examples of isomorphisms, Cayley's theorem, properties of isomorphisms, Isomorphism theorems I, II and III, definition and examples of automorphisms, inner automorphisms, group of automorphisms of cyclic groups, internal direct products, fundamental theorem of finite abelian groups.

Definition and examples of group actions, stabilizers and kernels of group actions. Applications of group actions: Cauchy's theorem, Index theorem, conjugacy relation, class equation and consequences, conjugacy in S_n, *p*-groups, Sylow's theorems and consequences, Cauchy's theorem for finite groups.

Adjoint of an operator, unitary operators, unitary diagonalization of Hermitian operators. Conic sections.

The scope of this course is indicated from Chapters 6, 9 (Theorems 9.4-9.5 and section on internal direct products), 10, 11 of [3]; Chapters 1 (Section 1.7), 2 (Section 2.2), 4 (Sections 4.2-4.3, 4.5-4.6) of [1], and Chapter 6 (sections 6.4-6.5) of [2].

References:

1. David S. Dummit and Richard M. Foote, *Abstract Algebra* (2nd Edition), John Wiley and Sons (Asia) Pte. Ltd, Singapore, 2003.

2. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra* (4th Edition), Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.

3. Joseph A. Gallian, *Contemporary Abstract Algebra* (4th Edition), Narosa Publishing House, New Delhi, 1999.

V.2 Calculus II

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student) Credit-6

(Lectures 25)

Functions of several variables, level curves and surfaces, graphs of functions of two variables, limits and continuity of functions of two and three real variables, partial differentiation (two variables), partial derivative as a slope, partial derivative as a rate, higher order partial derivatives (notion only), equality of mixed partials, tangent planes, approximations and differentiability, sufficient condition for differentiability (statement only), chain rule for one and two independent parameters, illustration of chain rule for a function of three variables with three independent parameters, directional derivatives and the gradient, extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems, Lagrange multipliers with two parameters.

References: [1]: Chapter 11.

(Lectures 18)

Double integration over rectangular region, double integration over nonrectangular region, double integrals in polar co-ordinates, triple integrals, cylindrical and spherical co-ordinates, change of variables.

References: [1]: Chapter 12.

(Lectures 18)

Divergence and curl, line integrals, The Fundamental Theorem and path independence, Green's Theorem, surface integrals, Stoke's Theorem, The Divergence Theorem.

References: [1]: Chapter 13.

References:

1. M. J. Strauss, G. L. Bradley and K. J. Smith, *Calculus* (3rd Edition), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.

2. H. Anton, I. Bivens and S. Davis, *Calculus* (7th Edition), John Wiley and Sons (Asia) Pte. Ltd., Singapore, 2002.

V.4 Metric Spaces

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student) Credit-6

Total marks: 100

Definition and examples of metric spaces, isometries, diameter, isolated points, accumulation and boundary points, closure and interior, open and closed sets, Cantor's intersection theorem, open and closed balls, convergence, Cauchy sequence and boundedness.

References:

[1]: Chapter 1 (Sections 1.1 (up to example 1.1.17), 1.3-1.4, 1.6-1.7), Chapter 2 (Sections 2.1-2.3, 2.5-2.6), Chapter 3 (Sections 3.1, 3.6-3.7), Chapter 4 (Sections 4.1-4.4, 4.7), Chapter 5 (Sections 5.1-5.3), Chapter 6 (Sections 6.1-6.2, 6.4-6.8), Chapter 7 (Sections 7.1, 7.4, 7.6-7.8).

Continuity and uniform continuity, completeness, contraction mapping theorem, Baire's category theorem.

References:

[1]: Chapter 8 (Sections 8.1-8.3, 8.5, 8.9-8.10), Chapter 9 (Sections 9.1 (up to Subsection 9.1.3), 9.2 (Theorem 9.2.1 with 1st two criteria), 9.4, 9.9), Chapter 10 (Sections 10.2 (only Cauchy criterion), 10.3, 10.8, 10.10).

Connectedness, connected subsets, connected components, pathwise connectedness.

References:

[1]: Chapter 11 (Sections 11.1 – 11. 8)

Compactness, compact subsets, compactness of products.

References:

[1]: Chapter 12 (Sections 12.1 – 12. 5).

References :

1. Mícheál Ó Searcóid, *Metric Spaces*, Springer Undergraduate Mathematics Series, Springer-Verlag

London Limited, London, 2007.

2. G.F.Simmons, Introduction to Topology and Modern Analysis, Mcgraw-Hill Editions, 2004.

V.4 Differential Equation II

Total marks: 100
Theory: 50
Practical: 25
Internal assessment: 25(15 for theory and 10 for practicals)
6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student) Credit-6

Introduction, classification, construction and geometrical interpretation of first order partial differential equations (PDE), method of characteristic and general solution of first order PDE, canonical form of first order PDE, method of separation of variables for first order PDE.

References:

[2]: Chapter 2.

Classification of second order PDE, reduction to canonical forms, equations with constant coefficients, general solution.

References:

[2]: Chapter 4.

Cauchy problem for second order PDE, homogeneous wave equation, initial boundary value problems, non-homogeneous boundary conditions, finite strings with fixed ends, non-homogeneous wave equation, Riemann problem.
References:

[2]: Chapter 5.

Method of separation of variables for second order PDE, vibrating string problem, existence and uniqueness of solution of vibrating string problem, heat conduction problem, existence and uniqueness of solution of heat conduction problem, Laplace and beam equation, non-homogeneous problem.

References:

[2]: Chapter 7.

Practical/ Lab work to be performed on a computer:
Modeling of the following problems using *Matlab/ Mathematica/ Maple*

(i) Finding the characteristics for the first order PDE
(ii) Vibrating string
(iii) Vibrating membrane
(iv) Conduction of heat in solids
(v) Gravitational potential
(vi) Cauchy problem for homogeneous wave equation
(vii) Telegraph equation
(viii) Oscillating soil temperatures
(ix) Detecting lake mines
(x) Transient lake pollution
(xi) Transverse vibration of a beam

References:

1. Belinda Barnes and Glenn R. Fulford, *Mathematical Modeling with Case Studies, A Differential Equation Approach Using Maple*, Taylor and Francis, London and New York, 2002.
2. Tyn Myint-U and Lokenath Debnath, *Linear Partial Differential Equation for Scientists and Engineers*, Springer, Indian reprint, 2006.

Semester VI

VI.1 Algebra V

Credits-6: 6 Lectures and 1 Tutorial per week

Definition and examples of rings, properties of rings, subrings, integral domains,

characteristic of a ring, ideals, factor rings, ideal generated by a subset in a commutative ring with unity, operations on ideals, prime ideals and maximal ideals, homomorphisms, isomorphisms, Isomorphism theorems I, II and III, field of quotients.

Polynomial rings over commutative rings, the division algorithm and consequences, principal ideal domains, factorization of polynomials, reducibility tests, Eisenstein criterion, unique factorization in Z[x]. Noetherian rings, Hilbert basis theorem. Divisibility in integral domains, irreducibles, primes, unique factorization domains, Euclidean domains.

Extension fields, Kronecker's theorem, finite extensions, algebraic extensions, properties of algebraic extensions, construction with straight edge and compass.

The scope of this course is indicated from Chapters 12, Chapter 13, 14, 15, 16, 17 (till the end of Theorem 17.6), 18, 20 (till the end of Example 3), 21 (Extensions till the end of Example 6, Theorem 21.7 and its Corollary), 23 of [2].

References:

1. David S. Dummit and Richard M. Foote, *Abstract Algebra* (2nd Edition), John Wiley and Sons (Asia) Pte. Ltd, Singapore, 2003.

2. Joseph A. Gallian, *Contemporary Abstract Algebra* (4th Edition), Narosa Publishing House, New Delhi, 1999.

3. I.N. Herstein, *Topics in Algebra,* 2nd Edition, John Wiley and Sons, 2003.

4. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra* (4th Edition), Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.

VI.2 Analysis IV

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student) Credit-6

(18 lectures)

Review of complex plane, sequences and series, connected sets and polygonally connected sets in the complex plane, stereographic projection, analytic polynomials, power series, analytic functions, Cauchy-Riemann equations, functions e^z , sin z , and cos z .

References:

[1]: Chapter 1, Chapter 2, Chapter 3.

(18 lectures)

Line integrals and their properties, closed curve theorem for entire functions, Cauchy integral formula and Taylor expansions for entire functions, Liouville's theorem and the fundamental theorem of algebra.

References:

[1]: Chapter 4, Chapter 5.

(16 lectures)

Power series representation for functions analytic in a disc, analyticity in an arbitrary open set, uniqueness theorem, definitions and examples of conformal mappings, bilinear transformations.

References:

[1]: Chapter 6 (Sections 6.1-6.2, 6.3 (up to theorem 6.9), Chapter 9 (Sections 9.2, 9.7-9.8, 9.9 (statement only), 9.10, 9.11 (with examples), 9.13), Chapter 13 (Sections 13.1, 13.2 (up to Theorem 13.11 including examples).

Practical / Lab work to be performed on a computer using Mathematica/Maple/ Matlab etc.

1. Declaring a complex number.
e.g. Z_1 =3 + 4i, Z_2 = 4 – 7i
2. Program to discuss the algebra of complex numbers.
e.g., if Z_1 =3 + 4i, Z_2 = 4 – 7i, then find $Z_1 + Z_2$, $Z_1 - Z_2$, $Z_1 * Z_2$,and Z_1 / Z_2
3. To find conjugate, modulus and phase angle of an array of complex numbers.
e.g., Z = [2+ 3i 4-2i 6+11i 2-5i]

4. To compute the integral over a straight line path between the two specified end points.

e. g., $\int_C \sin Z\, dz$, where C is the straight line path from -1+i to 2-i.

5. To perform contour integration

e.g., (i) $\int_C (Z^2-2Z+1)dz$

where C is the Contour given by x = y^2 +1; $-2 \le y \le 2$.

(ii) $\int_C (Z^3+2Z+1)dz$

, where C is the contour given by $x^2 + y^2 = 1$, which can be parameterized by x = cos (t), y = sin (t) for $0 \le y \le 2\pi$.

6. To plot the complex functions.

e.g., (i) f(z) = Z

(ii) f(z)=Z^3

(iii) f(z) = $(Z^4-1)^{1/4}$

7. To perform the Taylor series expansion of a given function f(z) around a given point z. The number of terms that should be used in the Taylor series expansion is given for each function. Hence plot the magnitude of the function and magnitude of its Taylors series expansion.

e.g., (i) f(z) = exp(z) around z = 0, n =40.

(ii) f(z)=exp(z^2) around z = 0, n = 160.

8. To perform Laurents series expansion of a given function f(z) around a given point z

e.g., (i) f(z)= (sin z -1)/z^4 around z = 0

(ii) f(z) = cot (z)/z^4 around z = 0.

9. To perform Conformal Mapping and Bilinear Transformations.

References:

1. Joseph Bak and Donald J. Newman, *Complex analysis* (2^{nd} Edition), Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., New York, 1997.

VI.3 Differential Geometry

Credits 6 : 6 lectures and 1 tutorial

Curves (parametrized) in R^2 and R^3 , reparametrization, closed curves, level curves, curvature, signed curvature for plane curves, principal normal, binormal, torsion, Serret-Frenet formaulas. The isoperimetric inequality, Wirtinger's inequality, the four vertex theorem.

Surfaces, smooth surfaces, smooth maps, derivatives and tangent spaces, orientable surfaces, level surfaces, quadric surfaces. Surfaces of revolution, compact surfaces, first fundamental form, isometries of surfaces, tangent developables, conformal mappings of surfaces, equiareal maps, second fundamental form, Gauss and Weingarten maps, normal curvature, geodesic curvature, principal curvatures, elliptic, hyperbolic and parabolic points, Gaussian and mean curvature, Gaussian curvature of compact surfaces.

The scope of this course is indicated from Chapters 1--5, 6 (sections 6.1-6.4), 7(sections 7.1-7.3) and 8 (sections 8.1-8.2, and8.6) of [1].

References:

1. Andrew Pressley : Elementary differential geometry; 2nd edition, Springer, 2010.
2. J.A. Thorpe : Elementary topics in differential geometry, Springer, 2004.

VI.4 Optional Papers

Optional Paper 1: Discrete Mathematics

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student) Credit-6

Definition, examples and basic properties of ordered sets, maps between ordered sets, duality principle, lattices as ordered sets, lattices as algebraic structures, sublattices, products and homomorphisms.

L 14

References:

[1]: Chapter 1 (till the end of 1.18), Chapter 2 (Sections 2.1-2.13), Chapter 5 (Sections 5.1-5.11).

[3]: Chapter 1 (Section 1).

Definition, examples and properties of modular and distributive lattices, Boolean algebras, Boolean polynomials, minimal forms of Boolean polynomials, Quinn-McCluskey method, Karnaugh diagrams, switching circuits and applications of switching circuits. L 24

References:

[1]: Chapter 6.

[3]: Chapter 1 (Sections 3-4, 6), Chapter 2 (Sections 7-8).

Definition, examples and basic properties of graphs, pseudographs, complete graphs, bi-partite graphs, isomorphism of graphs, paths and circuits, Eulerian circuits, Hamiltonian cycles, the adjacency matrix, weighted graph, travelling salesman's problem, shortest path, Dijkstra's algorithm, Floyd-Warshall algorithm. L18

References:

[2]: Chapter 9, Chapter 10.

References:

1. B A. Davey and H. A. Priestley, *Introduction to Lattices and Order,* Cambridge University Press, Cambridge, 1990.

2. Edgar G. Goodaire and Michael M. Parmenter, *Discrete Mathematics with Graph Theory* (2nd Edition), Pearson Education (Singapore) Pte. Ltd., Indian Reprint 2003.

3. Rudolf Lidl and Günter Pilz, *Applied Abstract Algebra* (2nd Edition), Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

Optional paper 2 : Number Theory

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student) Credit-6

Linear Diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues, Chinese remainder theorem, Fermat's little theorem, Wilson's theorem.
L 10

References:

[1]: Chapter 2 (Section 2.5), Chapters 3 (Section 3.3), Chapter 4 (Sections 4.2 and 4.4), Chapter 5 (Section 5.2 excluding pseudoprimes, Section 5.3).

[2]: Chapter 3 (Section 3.2).

Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Möbius inversion formula, the greatest integer function, Euler's phi-function, Euler's theorem, reduced set of residues, some properties of Euler's phi-function. L 20

References:

[1]: Chapter 6 (Sections 6.1-6.3), Chapter 7.

[2]: Chapter 5 (Section 5.2 (Definition 5.5-Theorem 5.40), Section 5.3 (Theorem 5.15-Theorem 5.17, Theorem 5.19)).

Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, Euler's criterion, the Legendre symbol and its properties, quadratic reciprocity, quadratic congruences with composite moduli. Public key encryption, RSA encryption and decryption, the equation $x^2 + y^2 = z^2$, Fermat's Last Theorem.
L 20

References:

[1]: Chapters 8 (Sections 8.1-8.3), Chapter 9, Chapter 10 (Section 10.1), Chapter 12.

References:

1. David M. Burton, *Elementary Number Theory* (6th Edition), Tata McGraw-Hill Edition, Indian reprint, 2007.

2. Neville Robinns, *Beginning Number Theory* (2nd Edition), Narosa Publishing House Pvt. Limited, Delhi, 2007.

Optional Paper 3 Mathematical Finance

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student) Credit-6

Basic principles: comparison, arbitrage and risk-aversion, Interest (simple and compound, discrete and continuous), time value of money, inflation, net present value, internal rate of return (calculation by bisection and Newton-Raphson methods), comparison of NPV and IRR. Bonds, bond prices and yields, Macaulay and modified duration, term structure of interest rates: spot and forward rates, explanations of term structure, running present value, floating-rate bonds, Fisher-Weil and Quasi-modified duration, immunization, convexity, putable and callable bonds.

References:[1]: Chapter 1, Chapter 2, Chapter 3, Chapter 4.

Asset return, short selling, portfolio return, (brief introduction to expectation, variance, covariance and correlation), random returns, portfolio mean return and variance, diversification, portfolio diagram, feasible set, Markowitz model (review of Lagrange multipliers for 1 and 2 constraints), Two fund theorem, risk free assets, One fund theorem, capital market line, Sharpe index. Capital Asset Pricing Model (CAPM), betas of stocks and portfolios, security market line, use of CAPM in investment analysis and as a pricing formula, Jensen's index, Harmony theorem, data and statistics.

References:[1]: Chapter 6, Chapter 7, Chapter 8 (Sections 8.5-8.8).

[3]: Chapter 1 (for a quick review/description of expectation etc.)

Forwards and futures, marking to market, value of a forward/futures contract, replicating portfolios, futures on assets with known income or dividend yield, currency futures, hedging (short, long, cross, rolling), optimal hedge ratio, hedging with stock index futures, interest rate futures, swaps. Lognormal distribution, Lognormal model/ Geometric Brownian Motion for stock prices, Binomial Tree model for stock prices, parameter estimation, comparison of the models.

References:[1]: Chapter 10 (except 10.11, 10.12), Chapter 11 (except 11.2 and 11.8)

[2]: Chapter 3, Chapter 5, Chapter 6, Chapter 7 (except 7.10 and 7.11) [3]: Chapter 3

References:1. David G. Luenberger, *Investment Science*, Oxford University Press, Delhi, 1998.

2. John C. Hull, *Options, Futures and Other Derivatives* (6th Edition), Prentice-Hall India, Indian reprint, 2006.

3. Sheldon Ross, *An Elementary Introduction to Mathematical Finance* (2nd Edition), Cambridge University Press, USA, 2003.

Optional paper 4 Linear Programming and Theory of Games

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student) Credit-6

Introduction to linear programming problem, Theory of simplex method, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method, Big-M method and their comparison.

Reference:[1]: Chapter 3 (Sections 3.2-3.3, 3.5-3.8), Chapter 4 (Sections 4.1-4.4).

Duality, formulation of the dual problem, primal-dual relationships, economic interpretation of the dual.

Reference:[1]: Chapter 6 (Sections 6.1- 6.3).

Transportation problem and its mathematical formulation, northwest-corner method least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem.

Reference:[3]: Chapter 5 (Sections 5.1, 5.3-5.4).

Game theory**:** formulation of two person zero sum games, solving two person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solution of games.

Reference:[2]: Chapter 14.

References:

1. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, *Linear Programming and Network Flows* (2nd edition), John Wiley and Sons, India, 2004.

2. F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research* (9th Edition), Tata McGraw Hill, Singapore, 2009.

3. Hamdy A. Taha, *Operations Research, An Introduction* (8th edition), Prentice-Hall India, 2006.

Suggested Reading:

G. Hadley, Linear Programming, *Narosa Publishing House*, *New Delhi*, 2002.

Optional Paper 5 Mechanics

6 Lectures (including practical and period for students' presentation/group interactions)

Tutorial 1(per week per student)   Credit-6

Moment of a force about a point and an axis, couple and couple moment, Moment of a couple about a line, resultant of a force system, distributed force system, free body diagram, free body involving interior sections, general equations of equilibrium, two point equivalent loading, problems arising from structures, static indeterminacy.

References:

[1]: Chapter 3, Chapter 4, Chapter 5.

Laws of Coulomb friction, application to simple and complex surface contact friction problems, transmission of power through belts, screw jack, wedge, first moment of an area and the centroid, other centers, Theorem of Pappus-Guldinus, second moments and the product of area of a plane area, transfer theorems, relation between second moments and products of area, polar moment of area, principal axes.

References:

[1]: Chapter 6 (Sections 6.1-6.7), Chapter 7

Conservative force field, conservation for mechanical energy, work energy equation, kinetic energy and work kinetic energy expression based on center of mass, moment of momentum equation for a single particle and a system of particles, translation and rotation of rigid bodies, Chasles' theorem, general relationship between time derivatives of a vector for different references, relationship between velocities of a particle for different references, acceleration of particle for different references.

References:

[1]: Chapter 11, Chapter 12 (Sections 12.5-12.6), Chapter 13.

References:

1. I.H. Shames and G. Krishna Mohan Rao, *Engineering Mechanics: Statics and Dynamics* (4th Edition), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2009.
2. R.C. Hibbeler and Ashok Gupta, *Engineering Mechanics: Statics and Dynamics* (11th Edition), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.