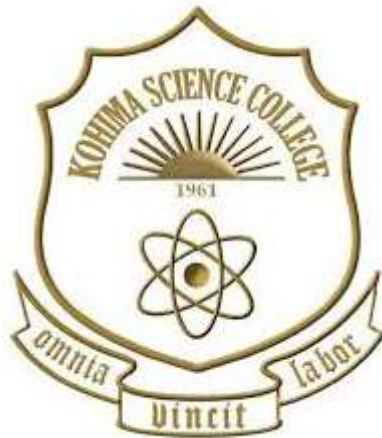# FOUR YEAR UNDERGRADUATE PROGRAMME

(Effective from Academic Session July 2024)

KOHIMA SCIENCE COLLEGE (AUTONOMOUS), JOTSOMA

DEPARTMENT OF MATHEMATICS

Four -Year Under-Graduate Programme with Multiple Exit Options Curriculum

The overall structure

SEMESTER	DISCIPLINE SPECIFIC COURSES-CORE	MINOR	MULTI-DISCIPLINARY COURSES	AECC (LANGUAGE)	SKILL ENHANCEMENT COURSES / INTERNSHIP/ DISSERTATION	COMMON VALUE ADDED COURSES	TOTAL CREDITS
I	MJ-1 (4-CREDITS)	MN-1 (4-CREDITS)	IN-1 (3-CREDITS)	AEC-1 (3-CREDITS)	SEC-1 (3-CREDITS)	VAC-1 (3-CREDITS)	20
II	MJ-2 (4-CREDITS)	MN-2 (4-CREDITS)	IN-2 (3-CREDITS)	AEC-2 (3-CREDITS)	SEC-2 (3-CREDITS)	VAC-2 (3-CREDITS)	20
EXIT WITH UG CERTIFICATE							
III	MJ-3 MJ-4 (8-CREDITS)	MN-3 (4-CREDITS)	IN-3 (3-CREDITS)	AEC-3 (2-CREDITS)	SEC-3 (3-CREDITS)		20
IV	MJ-5 MJ-6 MJ-7 MJ-8 (16-CREDITS)	MN-4 (4-CREDITS)					20
EXIT WITH UG DIPLOMA							
V	MJ-9 MJ-10 MJ-11 (12-CREDITS)	MN-5 (4-CREDITS)			INTERNSHIP (4-CREDITS)		20
VI	MJ-12 MJ-13 MJ-14 MJ-15 (16-CREDITS)	MN-6 (4-CREDITS)					20
EXIT WITH UG DEGREE							
VII	MJ-16 MJ-17 MJ-18 MJ-19 (16-CREDITS)	MN-7 (4-CREDITS)					20
VIII	MJ-20 (4-CREDITS)	MN-8 (4-CREDITS)			MJ-21 MJ-22 MJ-23 (12-CREDITS) OR RESEARCH PROJECT / DISSERTATION (12-CREDITS)		20
AWARDED UG DEGREE(HONS) / WITH RESEARCH							

Course Structure for Four-Year Under-Graduate Programme in Mathematics

Semester	Major (Credit: 4)	Minor (Credit:4)	Multi-Disciplinary Courses (Credit:3)	AECC (Language)	Skill Enhancement Courses (Credit:3)	Common Value Added Courses (Credit:3)
I	1. Calculus (T+P)	Algebra (T+P)	Introductory Mathematics	AEC-1 (**Credit:3**)	Foundation Course in Mathematics (T+P)	Environmental Science
II	2. Algebra (T+P)	Calculus (T+P)	Quantitative Aptitude	AEC-2 (**Credit:3**)	Programming in C (T+P)	Mathematics for Competitive Examinations / Vedic Mathematics
III	3. Differential Equations (T+P) 4. Real Analysis-I	Group Theory	Vector Algebra / SWAYAM Courses	AEC-3 (**Credit:2**)	Introduction to LaTeX (T+P)	
IV	5. PDE and Systems of ODE (T+P) 6. Group Theory-I 7. Elementary Number Theory 8. Real Analysis-II	Differential Equations (T+P)				
V	9. Numerical Analysis (T+P) 10. **Optional** 11. **Optional**	Complex Variable				
VI	12. Linear Algebra-I (T+P) 13. Real analysis -III 14. Ring Theory 15. Complex Analysis -I	Numerical Analysis (T+P)				
VII	16. ODE (T+P) 17. Complex Analysis-II 18. Linear Algebra-II 19. Topology	Linear Algebra (T+P)				
VIII	20. PDE (T+P) and **Dissertation** **or** (The following three papers) 21. **Optional** 22. **Optional** 23. **Optional**	ODE (T+P)				

NB: 1. **T:** Theory**; P:** Practical
2. **Major** papers will be offered to those students who choose Mathematics as their main subject.
3. **Minor** papers will be offered to students of other disciplines who qualified Mathematics in HSSLC examination.
4. **Multi-Disciplinary** papers will be offered to those students from any discipline who didn't take Mathematics in HSSLC.
5. **Skill Enhancement Courses** will be offered to Mathematics students only.
6. **Common Value Added Courses** will be offered to Mathematics students only.

Options for Semester V (Any two):

1. Group Theory-II
2. Multivariate Calculus
3. Portfolio Optimization
4. Industrial Mathematics
5. Probability and Statistics
6. Theory of computation
7. Econometrics
8. Three Dimensional Geometry
9. Research Methodology

Options for Semester VIII (Any three):

1. Mechanics
2. Differential Geometry
3. Number Theory
4. Graph Theory
5. Operations Research-I
6. Finite Element Methods
7. Advanced LaTeX (T+P)
8. Bio-Mathematics
9. Discrete Mathematics

Multi-Disciplinary Course Papers

1. Introductory Mathematics (MD-I)
2. Quantitative Aptitude (MD-II)
3. Vector Algebra / SWAYAM Courses (MD-III)

Skill Enhancement Course Papers

1. Foundation Course in Mathematics (T+P) (SEC-I)
2. Programming in C (T+P) (SEC-II)
3. Introduction to LaTeX (T+P) (SEC-III)

Common Value Added Course Papers

1. Environmental Science (VAC-I)
2. Mathematics for Competitive Examinations / Vedic Mathematics (VAC-II)

SYLLABUS OF MATHEMATICS COURSES

MAJOR PAPERS
Calculus (MJ-1)
Credit: 3(Theory) +1(Practical)

Unit I L'Hospital's rule. Higher order derivatives, Leibniz rule and its applications to problems of type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n \sin x$, $(ax+b)^n \cos x$. Concavity and inflection points; applications of derivatives in business, economics and life sciences.

Curve tracing in Cartesian coordinates, introduction to polar coordinates and curve tracing in polar coordinates of standard curves (cycloid, cardioid, other simple curves).

Unit II Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin^n x\, dx$, $\int \cos^n x\, dx$, $\int \sin^n x \cos^n x\, dx$, $\int \tan^n x\, dx$, $\int \sec^n x\, dx$, $\int x^m (\log x)^n dx$.

Volumes by slicing; disks and washers' methods, volumes by cylindrical shells, volumes by parametric equations, arc length, arc length of parametric curves, area of surface of revolution.

Unit III Hyperbolic functions, Introduction to vector-valued functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions, tangent and normal components of acceleration, modelling ballistics and planetary motion.

List of Practicals (using any software)
1. Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and studying the nature of the curve.
2. Obtaining the volume and surface of revolution of curves.
3. Plotting of parametric curves (E.g. Trochoid, cycloid, epicycloids, hypocycloid)
4. Plotting of graphs of function e^{ax+b}, $\log(ax+b)$, $\frac{1}{ax+b}$, $\sin(ax+b)$, $\cos(ax+b)$, $|ax+b|$ and to illustrate the effects of a and b on the graph.

Recommended Books and References:
1. G.B. Thomas and R.L. Finney, *Calculus,* 9th Ed., Pearson Education, Delhi, 2005.
2. M.J. Strauss, G.L. Bradley and K.J. Smith, *Calculus,* 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
3. H. Anton, I. Bivens and S. Davis, *Calculus,* 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
4. James Stewart, *Calculus: Early Transcendentals*, 7th Ed, Cengage India Private Limited, 2017
5. R. Courant and F. John, *Introduction to Calculus and Analysis* (*Vol. I & II*), Springer Verlag, New York, Inc., 1989.

Algebra (MJ-2)
Credit: 3(Theory) +1(Practical)

Unit I Polynomial functions: Division algorithm, Synthetic division, Remainder Theorem, Factor Theorem. Polynomial equations, Relation between roots and Coefficients of a polynomial equation, Symmetric function of the roots of an equation, sum of powers of the roots, Solution of cubic and bi-quadratic equations.

Unit II   Matrix introduction, matrix operations, types of matrices (symmetric, skew-symmetric, Hermitian and skew-Hermitian matrices, idempotent, nilpotent, involuntary, orthogonal and unitary matrices, singular and non-singular matrices), elementary operations on matrices, adjoint, inverse of a matrix.

Unit III   Trace of a matrix, rank of a matrix, invariance of rank through elementary transformations, normal form of a matrix, elementary matrices and inverse of a non-singular matrix through elementary row transformations.

Recommended Books and References:

1. M.K. Singal, Asha Rani Singal, *Algebra,* 31st Ed., R Chand & Co, New Delhi. 2020.
2. Chandrika Prasad, *Text Book on Algebra and Theory of Equations,* Pothishala Pvt. Ltd, 1963.

Algebra (Practical)

Problems from Algebra (Theory) may be solved with the help of any software.

Differential Equations (MJ-3)
Credit: 3 (Theory) +1 (Practical)

Unit I   General, particular, singular, explicit and implicit solution of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors.

Unit II   Introduction to compartmental model, exponential decay model, lake pollution model (case study of Lake Burley Griffin), exponential growth of population, limited growth of population, limited growth with harvesting.

Unit III General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications. Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Method of undetermined coefficients, method of variation of parameters.

Equilibrium points, Interpretation of the phase plane. Predatory-prey model and its analysis, epidemic model of influenza and its analysis, battle model and its analysis.

List of Practicals (using any software)
1. Finding solutions of separable equations, exact, and first order linear equations.
2. Finding solutions and plotting of second order solution family of differential equation.
3. Finding solutions and plotting of third order solution family of differential equation.
4. Growth model (exponential case only).
5. Decay model (exponential case only).
6. Lake pollution model.
7. Limited growth of population.
8. Predatory-prey model.
9. Epidemic model of influenza.
10. Battle model.

Recommended Books and References:

1. Belinda Barnes & Glenn R Fulford, *Mathematical Modelling with Case Studies, Using Maple and MATLAB,* 3rd Ed., CRC Press, Taylor & Francis Group, 2015.
2. Shepley L. Ross, *Differential Equations,* 3rd Ed., John Wiley & Sons. India, 2004.

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Real Analysis–I (MJ-4)
Credit: 4

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Unit I Review of Algebraic and Order Properties of R, neighbourhood of a point in R, Idea of countable sets, uncountable sets and uncountability of R. Bounded above sets, Bounded below sets, Bounded Sets, Unbounded sets, Suprema and Infima. The Completeness Property of R, the Archimedean Property. Density of Rational (and Irrational) numbers in R Intervals.

Unit II Limit point of a set, Isolated points. Sequences, Bounded sequence, Convergent sequence, Limit of a sequence. Limit Theorems, Monotone Sequences, Monotone Convergence Theorem.

Unit III Subsequences, Divergence Criteria, Monotone Subsequence Theorem (statement only), Bolzano Weierstrass Theorem for Sequences. Cauchy sequence, Cauchy's Convergence Criterion.

Unit IV Infinite series, convergence and divergence of infinite series, Cauchy Criterion for series, Tests for convergence: Comparison test, Limit Comparison test, Ratio Test, Cauchy's n^{th} root test, Integral test, Alternating series, Leibniz test, Absolute and Conditional convergence.

Recommended Books and References:

1. R.G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. Gerald G. Bilodeau, Paul R. Thie, G.E. Keough, *An Introduction to Analysis*, 2nd Ed., Jones & Bartlett, 2010.
3. Terence Tao, *Analysis-I & II*, 3rd Ed., Hindustan Book Agency, Springer, 2016.
4. Brian S. Thomson, Andrew. M. Bruckner and Judith B. Bruckner, *Elementary Real Analysis*, Prentice Hall, 2001.
5. S.K. Berberian, *A First Course in Real Analysis*, Springer Verlag, New York, 1994.

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PDE and Systems of ODE (MJ-5)
Credit: 3(Theory) +1(Practical)

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Unit I Partial Differential Equations–Basic concepts and Definitions; First Order PDE: Classification; Construction and geometrical interpretation. Method of characteristics for obtaining general solution of quasi linear equations. Canonical forms of First-order linear equations. Method of Separation of Variables for solving first order partial differential equations.

Unit II Derivation of Heat equation; Wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of Second order Linear Equations to canonical forms.

The Cauchy problem; Cauchy problem of an infinite string; Initial Boundary Value Problems. Semi-infinite string with fixed and free end. Non-homogeneous wave equation. Solving heat conduction problem.

Unit III Systems of linear ordinary differential equations–types of linear systems; differential operators; an operator method for linear systems with constant coefficients; Basic Theory of linear systems in normal form; homogeneous linear systems with constant coefficients: Two Equations in two unknown functions.

List of Practicals (using any software)
1. Solution of Cauchy problem for first order PDE.
2. Finding the characteristics for the first order PDE.
3. Plot the integral surfaces of a given first order PDE with initial data.
4. Solution of wave equation $u_{tt} - c^2 u_{xx} = 0$ for the following associated conditions:

(a) $u(x,\ 0) = \phi(x), u_t(x,\ 0) = \psi(x), x \in R, t > 0$

(b) $u(x,0) = \phi(x), u_t(x,0) = \psi(x), u(0,t) = 0, x \in (0,\infty), t > 0$

(c) $u(x,0) = \phi(x), u_t(x,0) = \psi(x), u_x(0,t) = 0, x \in (0,\infty), t > 0$

(d) $u(x,0) = \phi(x), u_t(x,0) = \psi(x), u(0,t) = 0, u(l,\ 0) = 0, x \in (0,\infty), t > 0$

5. Solution of $u_t - k^2 u_{xx} = 0$ for the following associated conditions:

(a) $u(x,0) = \phi(x), u(0,t) = a, u(l,t) = b,\ 0 < x < l, t > 0$

(b) $u(x,0) = \phi(x), x \in R,\ 0 < t < T$

(c) $u(x,\ 0) = \phi(x), u(0,t) = a, x \in (0,\ \infty), t \geq 0$

Recommended Books and References:

1. Tyn Myint U and Lokenath Debnath, *Linear Partial Differential Equations for Scientists and Engineers,* 4th Ed., Springer, Indian reprint, 2006.
2. S.L. Ross, *Differential equations,* 3rd Ed., John Wiley and Sons, India, 2004.
3. Martha L Abell, James P Braselton, *Differential equations with MATHEMATICA,* 3rd Ed., Elsevier Academic Press, 2004.
4. Martha L Abell, James P Braselton, *Maple by Example,* 3rd Ed., Elsevier Academic Press.

Group Theory-I (MJ-6)
Credit: 4

Unit I Definition and examples of groups including permutation groups and quaternion groups (illustration through matrices), Symmetries of a square, Dihedral groups, Elementary properties of groups.

Unit II Subgroups and examples of subgroups, Centralizer, Normalizer, Center of a group, Product of two subgroups. Properties of cyclic groups, classification of subgroups of cyclic groups.

Unit III Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, Properties of Cosets, Lagrange's theorem and consequences including Fermat's Little theorem, Normal subgroups, Quotient Groups.

Unit IV Cauchy's theorem for finite abelian groups, Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms, First, Second and Third isomorphism theorems.

Recommended Books and References:

1. John B. Fraleigh, *A First Course in Abstract Algebra*, 7th Ed., Pearson, 2002.
2. M. Artin, *Abstract Algebra*, 2nd Ed., Pearson, 2011.
3. Joseph A. Gallian, *Contemporary Abstract Algebra,* 4th Ed., Narosa Publishing House, New Delhi, 1999.
4. David S. Dummit and Richard M. Foote, *Abstract Algebra*, 3rd Ed., John Wiley and Sons

(Asia) Pvt. Ltd., Singapore, 2004.

5. Joseph J. Rotman, *An Introduction to the Theory of Groups,* 4th Ed., Springer Verlag, 1995.
6. I.N. Herstein, *Topics in Algebra*, Wiley Eastern Limited, India, 1975.

Elementary Number Theory (MJ-7)
Credit: 4

Unit I   Divisibility Theory in the integers: The division algorithm, the greatest common divisor, The Euclidean algorithm, The Diophantine equation $ax+by=c$. Primes and their distribution: The fundamental theorem of arithmetic, the sieve of Eratosthenes, the Goldbach Conjecture.

Theory of congruences: Basic property of congruence, linear congruence and Chinese remainder theorem, Fermat's little theorem, Wilson's theorem.

Unit II   Number theoretic functions: the sum and number of divisors, multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function, Euler's phi function, Euler's theorem, some properties of the phi function.

Unit III   Order of an integer modulo n, Primitive roots for primes, composite numbers having primitive roots, Euler's criterion, the Legendre's symbol and its properties, quadratic reciprocity, quadratic congruences with composite moduli.

Unit IV   Introduction to Cryptography: from Caesar cipher to public key cryptography, the knapsack cryptosystem, application of primitive roots to cryptography.

Recommended Books and References:
1. David M. Burton, *Elementary Number Theory,* 6th Ed., Tata McGraw-Hill, Indian reprint, 2007.
2. Neville Robinns, *Beginning Number Theory,* 2nd Ed., Narosa Publishing House Pvt. Ltd., Delhi, 2007.
3. Ivan Niven, Herbert S. Zuckerman, and Hugh L. Montgomery, *An Introduction to the Theory of Numbers*, 5th Ed., John Wiley & Sons, 1991, ISBN-9788126518111
4. G. H. Hardy, Edward M. Wright, and Roger Heath-Brown, *An Introduction to the Theory of Numbers*, 6th Ed., Oxford University Press, 2008, ISBN-9780199219865.

Real Analysis-II (MJ-8)
Credit: 4

Unit I   Limits of functions (ϵ-δ approach)*,* sequential criterion for limits, divergence criteria*.* Limit theorems, one-sided limits. Infinite limits and limits at infinity. Continuous functions, continuous functions on an interval. Sequential criterion for continuity and discontinuity. Algebra of continuous functions.

Unit II   Intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorem. Differentiability of a function at a point and in an interval, Caratheodory's theorem. Algebra of differentiable functions.

Unit III   Relative extrema, interior extremum theorem. Rolle's theorem, Mean value theorem. Cauchy's mean value theorem. Intermediate value property of derivatives, Darboux's theorem. Applications of mean value theorem to inequalities and approximation of polynomials. Taylor's theorem to inequalities.

Unit IV Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, application of Taylor's theorem to convex functions, relative extrema. Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions.

Recommended Books and References:

1. R. Bartle and D.R. Sherbert, *Introduction to Real Analysis*, John Wiley and Sons, 2003.
2. S.R. Ghorpade and B.V. Limaye, *A Course in Calculus and Real Analysis*, Springer, 2006.
3. Terence Tao, *Analysis – I & II*, 3rd Ed., Hindustan Book Agency, Springer, 2016
4. K.A. Ross, *Elementary Analysis: The Theory of Calculus*, Springer, 2004.
5. A. Mattuck, *Introduction to Analysis*, Prentice Hall, 1999.

Numerical Analysis (MJ-9)
Credit: 3(Theory) +1(Practical)

Unit I Relative Error, Absolute Error, Round off Error, Truncation Error. Transcendental and Polynomial equations: Bisection method, Secant method, Method of False Position, Newton-Raphson method, Order and rate of convergence of these methods. System of linear equations: Direct Method: Gauss Elimination methods, triangularization method. Iterative methods: Gauss Jacobi method, Gauss Seidel method.

Unit II Lagrange interpolation, Newton's divided difference interpolation, finite difference operators, relation between differences and derivatives, Gregory-Newton forward and backward difference interpolations, Stirling and Bessel interpolations, Hermite interpolation, piecewise interpolation, Error analysis in each method.

Unit III Differentiation: Numerical differentiation, methods based on interpolation, methods based on finite differences. Integration: Numerical integration, methods based on interpolation, Newton-Cotes methods. Initial value problems: Euler method, Taylor series method, Runge-Kutta methods of order 2 and 4.

List of Practicals (By using C programming)

1. Bisection method
2. Secant method
3. Regula−Falsi method
4. Newton-Raphson method
5. Gauss Elimination method
6. Gauss Jordan methods
7. Gauss−Jacobi method
8. Gauss−Seidel method
9. Lagrange interpolation
10. Newton interpolation
11. Trapezoidal rule
12. Simpson's rule
13. Euler's method
14. Runge-Kutta methods (Second and Fourth)

Recommended Books and References:

1. Brian Bradie, *A Friendly Introduction to Numerical Analysis,* Pearson Education, India, 2007.
2. M.K. Jain, S.R.K. Iyengar and R.K.Jain, *Numerical Methods for Scientific and Engineering Computation,* 6th Ed., New Age International Publisher, India, 2007.
3. Uri M. Ascher and Chen Greif, *A First Course in Numerical Methods,* 7th Ed., PHI Learning Private Limited, 2013.
4. John H. Mathews and Kurtis D. Fink, *Numerical Methods using Matlab,* 4th Ed., PHI Learning

Private Limited, 2012.
5. E. Balagurusamy, *Computer Programming and Data Structures* by, Tata McGraw Hill.
6. Brian Kernighan and Dennis Ritchie, *The C Programming Language,* 2nd Ed.

Group Theory-II (MJ-10/MJ-11)
Credit: 4

Unit I   Automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups, Characteristic subgroups, Commutator subgroup and its properties.

Unit II   External direct product and its properties, the group of units modulo n as an external direct product, internal direct products, Fundamental Theorem of finite abelian groups(without proof).

Unit III   Group actions, stabilizers and kernels, permutation representation associated with a given group action, Applications of group actions: Generalized Cayley's theorem, Index theorem, Groups acting on them by conjugation.

Unit IV   Class equation and consequences, Conjugacy in S_n, p-groups, Sylow's theorems and consequences, Cauchy's theorem, Simplicity of A_n for $n \geq 5$, Non-simplicity test.

Recommended Books and References:
1. John B. Fraleigh, *A First Course in Abstract Algebra*, 7th Ed., Pearson, 2002.
2. M. Artin, *Abstract Algebra*, 2nd Ed., Pearson, 2011.
3. Joseph A. Gallian, *Contemporary Abstract Algebra,* 4th Ed., Narosa Publishing House, 1999.
4. David S. Dummit and Richard M. Foote, *Abstract Algebra*, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2004.
5. J.R. Durbin, *Modern Algebra*, John Wiley & Sons, New York Inc., 2000.
6. D. A. R. Wallace, *Groups, Rings and Fields*, Springer Verlag London Ltd., 1998.

Multivariate Calculus (MJ-10/MJ-11)
Credit: 4

Unit I   Introduction to functions of several variables, limit and Continuity of functions of two variables, partial derivatives, geometric interpretation, differentiability and differentials, chain rule for one and two independent parameters.

Unit II   Directional derivatives and gradient, properties of gradient, tangent planes and linear approximations, maxima and minima of function of two variables, finding absolute on closed and bounded set, extremum problems with one and two constraints (Lagrange multipliers).

Unit III   Double integrals over rectangular and non-rectangular region, area calculated as a double integral, double integral in polar co-ordinates, surface area, parametric surfaces. Triple integrals, volume calculated as a triple integral, triple integral in cylindrical coordinates, triple integral in spherical coordinates.

Unit IV   Definition of vector field, divergence and curl. Line integrals, work as line integral, independence of path, fundamental theorem of line integral, conservative field, Green's theorem. Surface integrals, flux, Stokes' theorem, Divergence theorem.

Recommended Books and References:
1. James Stewart, *Multivariate Calculus, Concepts and Contexts*, 2nd Ed., Brooks/Cole, Thomson Learning, USA, 2001.

2. G.B. Thomas and R.L. Finney, *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
3. M.J. Strauss, G.L. Bradley & K.J. Smith, *Calculus*, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
4. Howard Anton, IRL Bivens & Stephen Davis, *Calculus – Early Transcendentals*, 10th Ed.

Portfolio Optimization (MJ-10/MJ-11)
Credit: 4

Unit I   Financial markets. Investment objectives. Measures of return and risk. Types of risks. Risk free assets.

Unit II   Mutual funds. Portfolio of assets. Expected risk and return of portfolio. Diversification.

Unit III   Mean-variance portfolio optimization- the Markowitz model and the two-fund theorem, risk-free assets and one fund theorem, efficient frontier. Portfolios with short sales. Capital market theory.

Unit IV   Capital assets pricing model- the capital market line, beta of an asset, beta of a portfolio, security market line. Index tracking optimization models. Portfolio performance evaluation measures.

Recommended Books and References:
1. F. K. Reilly, Keith C. Brown, *Investment Analysis and Portfolio Management*, 10th Ed., South-Western Publishers, 2011.
2. H.M. Markowitz, *Mean-Variance Analysis in Portfolio Choice and Capital Markets*, Blackwell, New York, 1987.
3. M.J. Best, *Portfolio Optimization*, Chapman and Hall, CRC Press, 2010.
4. D.G. Luenberger, *Investment Science*, 2nd Ed., Oxford University Press, 2013.

Industrial Mathematics (MJ-10/MJ-11)
Credit: 4

Unit I   Medical Imaging and Inverse Problems (The content is based on Mathematics of X-ray and CT scan based on the knowledge of calculus), elementary differential equations, complex numbers and matrices.

Unit II   Introduction to Inverse problems: Why should we teach Inverse Problems? Illustration of Inverse problems through problems taught in Pre-Calculus, Calculus, Matrices and differential equations. Geological anomalies in Earth's interior from measurements at its surface (Inverse problems for Natural disaster) and Tomography.

Unit III   X-ray: Introduction, X-ray behavior and Beers Law (The fundamental question of image construction), Lines in the plane.

Unit IV   Radon Transform: Definition and Examples, Linearity, Phantom (Shepp - Logan Phantom - Mathematical phantoms). Back Projection: Definition, properties and examples.

Recommended Books and References:
1. Timothy G. Feeman, *The Mathematics of Medical Imaging: A Beginners Guide*, Springer Under graduate Text in Mathematics and Technology, Springer, 2010.
2. C.W. Groetsch, *Inverse Problems*, *Activities for Undergraduates*, The Mathematical Association of America, 1999.
3. Andreas Kirsch, *An Introduction to the Mathematical Theory of Inverse Problems*, 2nd Ed., Springer, 2011.

Probability and Statistics (MJ-10/MJ-11)
Credit: 4

Unit I   Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function.

Unit II   Discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential. Joint cumulative distribution function and its properties, joint probability density functions, marginal and conditional distributions.

Unit III   Expectation of function of two random variables, conditional expectations, independent random variables. Bivariate normal distribution, correlation coefficient, joint moment generating function (*jmgf*) and calculation of covariance (from *jmgf*), linear regression for two variables.

Unit IV   Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers, Central Limit theorem for independent and identically distributed random variables with finite variance.

Recommended Books and References:

1. Robert V. Hogg, Joseph W. McKean and Allen T. Craig, *Introduction to Mathematical Statistics*, Pearson Education, Asia, 2007.
2. Irwin Miller, Marylees Miller and John E. Freund, *Mathematical Statistics with Applications*, 7th Ed., Pearson Education, Asia, 2006.
3. Sheldon Ross, *Introduction to Probability Models*, 9th Ed., Academic Press, 2007.
4. Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, *Introduction to the Theory of Statistics*, 3rd Ed., Tata McGraw- Hill, Reprint 2007.

Theory of Computation (MJ-10/MJ-11)
Credit: 4

Unit I   Introduction: Alphabets, strings, and languages. Deterministic and non-deterministic finite automata, regular expressions, regular languages and their relationship with finite automata, pumping lemma and closure properties of regular languages.

Unit II   Context free grammars (CFG), Regular CFG, Linear and nonlinear CFG, leftmost and rightmost derivation, parse trees, ambiguities in grammars and languages, Properties of CFL, Normal form.

Unit III   Pushdown automaton (PDA) and the language accepted by PDA, deterministic PDA, Non- deterministic PDA, pumping lemma, closure properties, decision properties.

Unit IV   Turing machine as a model of computation, programming with a Turing machine, variants of Turing machine and their equivalence. Recursively enumerable and recursive languages, undecidable problems: halting problem, Post Correspondence Problem, and undecidability problems about CFGs.

Recommended Books and References:

1. J. E. Hopcroft, R. Motwani and J. D. Ullman, *Introduction to Automata Theory, Languages and Computation,* 2nd Ed., Addison-Wesley, 2001.
2. H.R. Lewis, C.H. Papadimitriou, C. Papadimitriou, *Elements of the Theory of Computation*, 2nd Ed., Prentice-Hall, NJ, 1997.
3. J.A. Anderson, *Automata Theory with Modern Applications*, Cambridge University Press,

2006.

Econometrics (MJ-10/MJ-11)
Credit: 4

Unit I   Statistical Concepts Normal distribution; chi-square, t and F-distributions; estimation of parameters; properties of estimators; testing of hypotheses: defining statistical hypotheses; distributions of test statistics; testing hypotheses related to population parameters; Type I and TypeII errors; power of a test; tests for comparing parameters from two samples.

Unit II   Simple Linear Regression Model: Two Variable Case Estimation of model by method of ordinaryleast squares; properties of estimators; goodness of fit; tests of hypotheses; scaling and units of measurement; confidence intervals; Gauss-Markov theorem; forecasting.

Unit III   Multiple Linear Regression Model Estimation of parameters; properties of OLS estimators; goodness of fit-R2 and adjusted R2 ; partial regression coefficients; testing hypotheses-individualand joint; functional forms of regression models; qualitative (dummy) independent variables.

Unit IV   Violations of Classical Assumptions: Consequences, Detection and Remedies Multi-collinearity; heteroscedasticity; serial correlation. Specification Analysis Omission of a relevant variable; inclusion of irrelevant variable; tests of specification errors.

Recommended Books and References:
1. Jay L. Devore, *Probability and Statistics for Engineers,* Cengage Learning, 2010.
2. John E. Freund, *Mathematical Statistics,* Prentice Hall, 1992.
3. Richard J. Larsen and Morris L. Marx, *An Introduction to Mathematical Statistics and its Applications,* Prentice Hall, 2011.
4. D. N. Gujarati and D.C. Porter, *Essentials of Econometrics,* McGraw Hill, 4th Ed., International Edition, 2009.
5. Christopher Dougherty, *Introduction to Econometrics,* Oxford University Press, 3rd Ed., Indian edition, 2007.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

Three Dimensional Geometry (MJ-10/MJ-11)
Credit: 4

Unit I: The Plane: General equation, normal form, planes parallel to coordinate axes, planes parallel to coordinate planes. Intercept form, plane passing through three given points, plane passing through the intersection of three given planes, angle between two planes, distance of a point from a plane, equation of bisectors of angles between planes.

Unit II: The Straight Line: Equations of a line in two plane forms, symmetrical form, line joining two points, coplanar lines, shortest distance, distance of a point from a line, orthogonal projection of a plane, intersection of three planes, point of intersection, common line of intersection, necessary and sufficient condition for three planes to pass through one line, line intersecting two and three given lines

Unit III: The Sphere: equation of the sphere, center and radius of a sphere, condition for general equation of the second degree to represent the sphere, section of a sphere by a plane, intersection of two sphere, equation of a sphere by joining two points as diameter, sphere passing through a circle, sphere of the form $S + \lambda S'$, tangent line and tangent plane, equation of the tangent plane to the sphere given by the general equation, condition for the plane to be a tangent plane to the sphere.

Unit IV: The Cone: equation of a cone with its vertex at origin, equation of the cone with a given vertex and a given guiding curve, condition for general equation to represent cone, right circular cone, tangent plane, reciprocal cone, three mutually perpendicular generators.

The Cylinder: Equation of cylinder generated by lines parallel to a fixed lines, equation of the cylinder with a given generator and a given guiding curve, Right Circular Cylinder, equation of the right circular cylinder whose axis is the line.

Recommended Books and References:

1. B. Das, *Analytical Geometry and Vector Analysis*, Oriental Book Company, 1998.
2. R. J.T. Bell, *An elementary treatise on coordinate geometry of three dimensions*, Macmillan and co., limited, 1912.
3. R.M. Khan, *Analytical Geometry of two and three dimension and vector analysis*, New Central Book Agency (P) Ltd, 2019.

Research Methodology (MJ-10/MJ-11)
Credit: 4

Unit I **Research Methodology**
Introduction to Research, importance of research, research methods and research methodology, types of research, selection of research problem, formulation of research problem.

Unit II **Manuscript Preparation**
Literature survey, knowledge of web search, importance and typology, Elements of an article: Title, Abstract, keyword, introduction, formulation, result and discussion, references, research ethics.

Unit III **Scientific Writing**
Importance of science writing, meaning and nature of scientific style, writing effective scientific prose, effective word selection in science writing, common Mathematical functions and their abbreviation, symbols, operators commonly used in Mathematics.

Unit IV **Typesetting Mathematical Text with LATEX**
Simple document, type style, environments, lists, centering, tables, verbatim, vertical and horizontal spacing, equation environments, fonts, underlying, arrays and matrices, customised commands, document classes and overall structure, title for documents, sectioning commands, inputting files, making a bibliography, making an index.

Recommended Books and References:

1. C. R. Kothari & G Garg, *Research Methodology: Methods and Techniques*, 4th Ed., 2018, New Age international, ISBN: 9789386649225.
2. Harold Rabinowitz and Suzanne Vogel, *The Manual of Scientific Style: A Guide for Authors, Editors, and Researchers*, 2009, Academic Press, 1st Ed., ISBN: 9780123739803.
3. Leslie Lamport, *LATEX: A Document Preparation System*, 1994, 2nd Ed., Pearson, ISBN: 9788177584141.

Linear Algebra-I (MJ-12)
Credit: 3(Theory) +1(Practical)

Unit I Systems of linear equations, row reduction and echelon forms, Solutions of a system of linear equations, condition of consistency and nature of the general solution of a system of linear non-homogeneous equations.

Unit II Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination

of vectors, linear span, linear independence, basis and dimension, dimension of subspaces.

Unit III Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. Isomorphisms, Isomorphism theorems, invertibility and isomorphisms, dual spaces, dual basis, double dual, transpose of a linear transformation and its matrix in the dual basis.

Linear Algebra-I (List of Practical)

1. Matrix operations (Addition, subtraction, product, transpose, inverse).
2. Determinant of a square matrix.
3. Rank of a matrix.
4. Row reduced echelon form and reduced echelon form of a matrix.
5. Solving a system of linear equations.
6. Null space, row space, column space.
7. Linear span, linear independence, basis, dimension, linear transformation.

Recommended Books and References:

1. David C. Lay, *Linear Algebra and its Applications,* 3rd Ed., Pearson Education Asia, Indian, Reprint, 2007.
2. Kenneth Hoffman, Ray Alden Kunze, *Linear Algebra,* 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.
3. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra,* 4th Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
4. S. Lang, *Introduction to Linear Algebra,* 2nd Ed., Springer, 2005.
5. Gilbert Strang, *Linear Algebra and its Applications*, Thomson, 2007.
6. S. Kumaresan, *Linear Algebra- A Geometric Approach*, Prentice Hall of India, 1999.
7. Axler, *Linear Algebra Done Right*, 3rd Ed., Springer.
8. P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, *First Course in Linear Algebra*, Wiley Eastern Ltd.
9. P. K. Saikia, *Linear Algebra*, Pearson.

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Real Analysis-III (MJ-13)
Credit: 4
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Unit I Riemann integration; inequalities of upper and lower sums; Riemann conditions of integrability. Riemann sum and definition of Riemann integral through Riemann sums; equivalence of two definitions. Riemann integrability of monotone and continuous functions, Properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Intermediate Value Theorem for Integrals; Fundamental theorems of Calculus.

Unit II Improper integrals; Types of improper integrals, Comparison test, Limit comparison test; Convergence of Beta and Gamma functions; Problems based on Beta and Gamma functions. Pointwise and uniform convergence of a sequence of functions, Theorems on continuity, derivability and integrability of the limit function of a sequence of functions.

Unit III Series of functions; Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test. Limit superior and Limit inferior, Power series, radius of convergence,

Cauchy Hadamard Theorem, Differentiation and integration of power series; Abel's Theorem; Weierstrass Approximation Theorem (statement only).

Unit IV   Metric spaces: definition and examples. Sequences in metric spaces, Cauchy sequences. Complete Metric Spaces, Open and closed balls, neighbourhood, open set, interior of a set, Limit point of a set, closed set, diameter of a set, Cantor's theorem. Subspaces, dense sets, separable spaces, Continuous mappings, sequential criteria and other characterizations of continuity, Uniform continuity.

Recommended Books and References:
 1. K.A. Ross, *Elementary Analysis, The Theory of Calculus*, *Undergraduate Texts in Mathematics*, Springer (SIE), Indian reprint, 2004.
 2. R.G. Bartle D.R. Sherbert, *Introduction to Real Analysis*, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
 3. Terence Tao, *Analysis -I & II*, 3rd Ed., Hindustan Book Agency, Springer, 2016.
 4. Charles G. Denlinger, *Elements of Real Analysis*, Jones & Bartlett (Student Edition), 2011.

Ring Theory (MJ-14)
Credit-4

Unit I   Definition and examples of rings, properties of rings, Subrings, integral domains and fields, characteristic of a ring. Ideals, ideal generated by a subset of a ring, operations on ideals

Unit II   Factor rings, prime and maximal ideals. Ring homomorphisms, properties of ring homomorphisms, Isomorphism theorems I, II and III, Field of quotients.

Unit III   Polynomial rings over commutative rings, division algorithm and consequences, principal ideal domains, factorization of polynomials, reducibility tests, irreducibility tests, Gauss' Lemma, Eisenstein criterion.

Unit IV   Unique factorization in Z[x]. Divisibility in integral domains, irreducibles and prime elements, unique factorization domains, Euclidean domains.

Recommended Books and References:
1. C. Musili, *Introduction to Rings and Modules*, 2nd Revised Edition, Narosa Publishing House, 2015, ISBN 978-81-7319-037-2.
2. I.N. Herstein, *Topics in Algebra*, Wiley Eastern Limited, India, 1975.
3. M. Artin, *Abstract Algebra*, 2nd Ed., Pearson, 2011.
4. Joseph A. Gallian, *Contemporary Abstract Algebra*, 4th Ed., Narosa Publishing House, New Delhi, 1999.
5. D.A.R. Wallace, *Groups, Rings and Fields*, Springer Verlag London Ltd., 1998.

Complex Analysis-I (MJ-15)
Credit: 4

Unit I   Complex numbers: sum and products, algebraic properties, vectors and moduli, triangle inequality, complex conjugate, exponential form, products and powers in exponential form, arguments of product and quotients, roots of complex numbers, regions in the complex plane, stereographic projection.

Unit II   Analytic functions: functions and mappings, limits, limits involving the point at infinity, continuity, derivatives, rules for differentiation, Cauchy-Riemann equations, sufficient conditions for differentiability, analytic functions, harmonic

functions.

Unit III Elementary functions: the exponential function, the logarithmic function, branches and derivatives of logarithmic functions, identities involving logarithms, the power function, trigonometric functions, zeros and singularities of trigonometric functions, hyperbolic functions, inverse trigonometric and inverse hyperbolic functions.

Unit IV Integrals: Derivatives, definite integrals, contours, contour integrals, upper bounds for moduli of contour integrals, Cauchy-Goursat theorem, Cauchy-integral formula, Louville's theorem and the fundamental theorem of algebra, maximum modulus principle.

Recommended Books and References:

1. Titu Andreescu and Dorin Andrica, *Complex Numbers from A to Z*, Birkhauser, 2006.
2. James Ward Brown and Ruel V. Churchill, *Complex Variables and Applications,* 8th Ed., McGraw – Hill International Edition, 2009.
3. D Sarason, Complex Function Theory, 2nd Ed., American Mathematical Society, 2021.
4. Joseph Bak and Donald J. Newman, *Complex Analysis,* 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., New York, 1997.
5. J. H. Mathews, and R. W. Howell, *Complex Analysis for Mathematics and Engineering*, 5th Ed., Narosa, 2010, ISBN-10: 817319761X ISBN-13: 978-8173197611
6. J. B. Conway, *Functions of One Complex Variable*, 2nd Ed., Narosa Publishing House, India, 1994, ISBN 978-81-85015-37-8
7. L. V. Ahlfors, *Complex Analysis*, 3rd Ed., McGraw-Hill Education, 1979, ISBN-13: 978-1-25-906482-1, ISBN-10: 1-25-906482-4
8. H.A. Priestly , *Introduction to Complex Analysis*, 2nd Ed., 2003, Oxford University Press.

Ordinary Differential Equations (MJ-16)
Credit: 3(Theory) +1(Practical)

Unit I Linear equations with variable coefficients; initial value problems for the homogeneous equations; existence theorem; uniqueness theorem; solutions of homogeneous equations; the theorem on *n* linearly independent solutions; the Wronskian and linear independence; a formula for the Wronskian; The non-homogeneous equations.

Unit II Homogeneous equations with analytic coefficients; Legendre equation and polynomials, Rodrigues formulae and applications, Linear equations with regular singular points; the Euler equation, the Bessel equation, regular singular points at infinity.

Unit III Existence and uniqueness of solutions to first order equations; separable and exact differential equations; The method of successive approximation; Lipschitz condition; non-local existence of solutions; uniqueness of solutions; existence and uniqueness theorem for first order equations.

Ordinary Differential Equations (Practical)
Problems from ODE may be solved with the help of any software.

Recommended Books and References:

1. E. A. Coddington, *An Introduction to Ordinary Differential Equations*, Prentice-Hall of India Private Ltd., New Delhi, 2001, ISBN-10:0486659429
2. Dennis G. Zill and Michael R. Cullen, *Differential Equations with Boundary-value Problems*,

Thomson Brooks/Cole, 2005.

3. W.T. Martain and E. Relssner, *Elementary Differential Equations*,3rd Ed., Addison Wesley Publishing Company, Inc, 1995, ISBN-9780201045031

4. E. A. Codington and N. Levinson, *Theory of Ordinary Differential Equations*, Tata McGraw hill Publishing Co. Ltd. New Delhi, 1999, ISBN-9780070992566

5. G. F. Simmons, *Differential equation with applications and historical Notes*, 2nd Ed., McGraw Hill Education, 2017, ISBN-9780070530713.

Complex Analysis- II (MJ-17)
Credit: 4

Unit I   Series: Convergence of sequences, Taylor series, Laurent series, absolute and uniform convergence of power series, Continuity of sums of power series, integration and differentiation of power series, uniqueness of series representation, multiplication and division of power series.

Unit II   Residues and Poles: Isolated singular points, residues, Cauchy residue theorem, residue at infinity, types of isolated singular points, zeros of analytic functions, zeros and poles, behavior of functions near isolated singular points.

Unit III   Applications of residues: Evaluation of improper integrals, improper integrals from Fourier analysis, Jordan's lemma, an indented path, integration through a branch cut, definite integrals involving sines and cosines, argument principle, Rouche's theorem.

Unit IV   Mapping by elementary functions: Linear fractional transformations, cross ratios, mappings of the half planes and circles, conformal mapping.

Recommended Books and References:

1. J.W. Brown and Ruel V. Churchill, *Complex Variables and Applications,* 8th Ed., McGraw Hill International Edition, 2009.

2. Joseph Bak and Donald J. Newman, *Complex Analysis,* 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., New York, 1997.

3. D. Sarason, *Complex Function Theory*, 2nd Ed., American Mathematical Society, 2021.

4. J.H. Mathews, and Howell, R. W., *Complex Analysis for Mathematics and Engineering*, 5th Ed., Narosa, 2010, ISBN-10: 817319761X ISBN-13: 978-8173197611.

5. J. B. Conway, , *Functions of One Complex Variable*, 2nd Ed., Narosa Publishing House, India, 1994, ISBN 978-81-85015-37-8.

6. L. V. Ahlfors, *Complex Analysis*, 3rd Ed., McGraw-Hill Education, 1979, ISBN-13: 978-1-25-906482-1, ISBN-10: 1-25-906482-4.

7. H.A. Priestly, *Introduction to Complex Analysis*, 2nd Ed., Oxford University Press, 2003, ISBN-10: 0198525613, ISBN-13: 978-0198525615.

Linear Algebra-II (MJ-18)
Credit: 4

Unit I   Similarity of matrices and linear transformations, trace of matrices and linear transformations, characteristic roots and characteristic vectors, characteristic polynomials, relation between characteristic polynomial and minimal polynomial; Cayley-Hamilton theorem (statement and illustrations only); diagonalizability, necessary and sufficient condition for diagonalizability.

Unit II   Projections and their relation with direct sum decomposition of vector spaces; invariant subspaces; primary decomposition theorem, cyclic subspaces; companion matrices; a proof of Cayley-Hamilton theorem; triangulability; canonical forms of nilpotent transformations; Jordan canonical forms; rational canonical forms.

Unit III   Inner product spaces, properties of inner products and norms, Cauchy-Schwarz

inequality; orthogonality and orthogonal complements, orthonormal basis, Gram-Schmidt process, Bessel's inequality, adjoint of a linear transformation; Hermitian, unitary and normal transformations and their diagonalizations.

Unit IV   Forms on inner product spaces and their matrix representations; bilinear forms; Hermitian forms; symmetric bilinear forms; orthogonal diagonalization of real quadratic forms.

Recommended Books and References:
1. David C. Lay, *Linear Algebra and its Applications,* 3rd Ed., Pearson Education Asia, Indian, Reprint, 2007.
2. Kenneth Hoffman, Ray Alden Kunze, *Linear Algebra,* 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.
3. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra,* 4th Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
4. S. Lang, *Introduction to Linear Algebra,* 2nd Ed., Springer, 2005.
5. Gilbert Strang, *Linear Algebra and its Applications*, Thomson, 2007.
6. S. Kumaresan, *Linear Algebra- A Geometric Approach*, Prentice Hall of India, 1999.
7. Axler, *Linear Algebra Done Right*, 3rd Ed., Springer.
8. P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, *First Course in Linear Algebra*, Wiley Eastern Ltd, 1983.
9. P. K. Saikia, *Linear Algebra*, Pearson, 2014.

Topology (MJ-19)
Credit: 4

Unit I   Topological spaces: Open sets, closed sets, neighbourhoods, limit points, interiors, closures, boundary points, bases, and sub-bases. Finer and coarser topology, subspace topology, order topology, product topology, metric topology. Continuous functions, continuity at a point, Sequential continuity at a point, open functions, closed functions.

Unit II   Homeomorphisms, Composition of continuous functions, Pasting lemma. Quotient topology, Quotient spaces, Connected spaces; Connected subspaces of the real line, Intermediate value theorem, Path-connected space, Components and path components, Local connectedness.

Unit III   Covers, Compact sets, Subsets of a compact space. Finite intersection properties. Compactness and Hausdorff spaces, Compact sets in the real line, Limit point compactness, Sequential compactness, Local compactness, One-point compactification, Tychonoff Theorem.

Unit IV   First countable spaces, Second countable spaces, Lindelöf space, Separable spaces. Hereditary properties, T1 spaces, Hausdorff spaces, Regular spaces, Normal spaces, The Urysohn lemma, Tietze extension theorem.

Recommended Books and References:
1. James R. Munkres, *Topology*, Pearson Education India, 2004.
2. K.D. Joshi, *Introduction to General Topology*, New Age International Pvt. Ltd, 2017.
3. George F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw Hill pub, 1983.
4. Stephen Willard, *General Topology*, Dover publication, 2004.

Partial Differential Equations (MJ-20)
Credit: 3(Theory) +1(Practical)

Unit I   First order non-linear equations– Cauchy method of characteristics; Compatible systems of first order equations; Charpit's method; Special types of first order equations; Adjoint operators; Riemann's method.

Linear second order PDE with constant coefficients–General method for finding complementary functions of (i) reducible non- homogeneous linear PDE (ii) irreducible non-homogeneous linear PDE; Methods for finding particular integrals.

Unit II   Homogeneous linear second order PDE with constant coefficients – methods for finding complementary functions and particular integrals; Linear second order PDE with variable coefficients; Monge's method of solution of non- linear PDE of second order.

Unit III Occurrence of diffusion equation; Boundary conditions; Elementary solutions of diffusion equation; Separation of variables; Solution of diffusion equation in cylindrical and spherical coordinates; Non-linear equations–semi-linear, quasi-linear and Burger's equations; Initial value problem for Burger's equation.

Partial Differential Equations (Practical)
Solutions of the problems of PDEs by the following numerical methods:
1. Finite difference method for solving elliptic equations
2. Finite difference method for solving parabolic equations
3. Finite difference method for solving hyperbolic equations
4. Finite volume method

Recommended Books and References:

1. I. N. Sneddon, *Elements of Partial Differential Equations*, 3rd Ed., McGraw Hill Book Company, 1998.
2. E. C. Zachmanoglou and Dale W. Thoe, *Introduction to Partial Differential Equations with Applications*, Dover Publications, Inc., New York, 1986
3. K. Sankara Rao, *Introduction to Partial Differential Equations*, Prentice Hall of India, 2017
4. Martin J. Gander and Felix Kwok, *Numerical Analysis of Partial Differential Equations Using Maple and MATLAB*, Siam publications, 2018.
5. E. T. Copson, *Partial Differential Equations*, 2nd Ed., Cambridge University Press, 1995.
6. Tyn Myint-U & Lokenath Debnath, *Linear Partial Differential Equations for Scientists and Engineers*, Birkhauser, 2007.

Number Theory (MJ-21/MJ-22/MJ-23)
Credit: 4

Unit I   Number of special forms: Marin Mersenne, perfect numbers, Mersenne primes and amicable numbers, Fermat's numbers. The equation $x^2 + y^2 = z^2$, Fermat's Last theorem.

Unit II   Sum of two squares, Sum of more than two squares. Fibonacci numbers: the Fibonacci sequence, certain identities involving Fibonacci numbers.

Unit III Continued fractions: Finite continued fractions, infinite continued fractions, Farey fractions, Pell's equation.

Unit IV   Primality testing and factorization, remote coin flipping, the prime number theorem and zeta function.

Recommended Books and References:

1. David M. Burton, *Elementary Number Theory,* 6th Ed., Tata McGraw-Hill, Indian reprint, 2007.
2. Neville Robinns, *Beginning Number Theory,* 2nd Ed., Narosa Publishing House Pvt. Ltd., Delhi, 2007.
3. Ivan Niven, Herbert S. Zuckerman, and Hugh L. Montgomery, *An Introduction to the Theory of Numbers*, 5th Ed., John Wiley & Sons, 1991, ISBN-9788126518111.
4. G. H. Hardy, Edward M. Wright, and Roger Heath-Brown, *An Introduction to the Theory of Numbers*, 6th Ed., Oxford University Press, 2008, ISBN-9780199219865.

Operations Research-I (MJ-21/MJ-22/MJ-23)
Credit: 4

Unit I   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.

Unit II   Duality, formulation of the dual problem, primal-dual relationships, economic interpretation of the dual. Sensitivity analysis.

Unit III   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.

Unit IV   Assignment problem and its mathematical formulation, Hungarian method for solving assignment problem. Travelling Salesman Problem.

Recommended Books and References:

1. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, *Linear Programming and Network Flows*, 2nd Ed., John Wiley and Sons, India, 2004.
2. F.S. Hillier and G.J. Lieberman, *Introduction to Operations Research*, 9th Ed., Tata McGraw Hill, Singapore, 2009.
3. Hamdy A. Taha, *Operations Research, An Introduction*, 8th Ed., Prentice-Hall India, 2006.
4. G. Hadley, *Linear Programming*, Narosa Publishing House, New Delhi, 2002.
5. J.K Sharma, *Operations Research Theory and Applications*, Trinity Press, 6th Ed., 2009.

Graph Theory (MJ-21/MJ-22/MJ-23)
Credit: 4

Unit I   Trees, Properties of Trees, rooted and binary tree, Spanning Trees, BFS and DFS algorithm, Minimum Spanning Tree, Kruskal's algorithm, Prim's algorithm, the labeling algorithm, distance and diameter, cut set, cut vertex, bridge, Blocks and their Characterization, Connectivity and edge-connectivity.

Unit II   Planar Graphs, Kuratowski's graphs, Homeomorphic graphs, maximal planar graphs, Bipartite graph, complete bipartite graph, Euler's formula, Kuratowski theorem.

Unit III   Graph coloring, chromatic number, chromatic polynomial, decomposition theorem, colour problem, the four colour theorem, the five colour theorem, Matching theory, Hall's marriage theorem.

Unit IV   Coverings, independence, vertex covering, edge covering, critical points and lines,

line-core and point core, 1-factorization, 2-factorization, Digraphs, types of digraphs, connected digraph, Euler digraphs, directed walk, directed path, directed circuit. Matrix representation of digraphs, Tournaments.

Recommended Books and 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) P. Ltd., Indian Reprint 2003.
3. Rudolf Lidl and Gunter Pilz, *Applied Abstract Algebra*, 2nd Ed., *Undergraduate Texts in Mathematics*, Springer (SIE), Indian reprint, 2004.
4. J. A. Bondy, and U.S.R. Murty, *Graph Theory*, Springer-Verlag, 2008.
5. F. Harary, *Graph Theory*, Addison-Wesley, 1969.
6. Edgar G. Goodaire and Michael M. Parmenter, *Discrete Mathematics with Graph Theory*, 3rd Ed., Pearson Education Pvt. Ltd. Indian Reprint, 2006.
7. Gary Chartrand and P. Zhang, *A First Course in Graph Theory*. Dover Publications, 2012.
8. R. Diestel, *Graph Theory* (Graduate Texts in Mathematics). Springer Verlag, 1997.
9. Douglas B. West, *Introduction to graph theory*, 2nd Ed., Pearson India, 2001.

Mechanics (MJ-21/MJ-22/MJ-23)
Credit: 4

Unit I   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.

Unit II   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.

Unit III 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.

Unit IV   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.

Recommended Books and References:

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

Differential Geometry (MJ-21/MJ-22/MJ-23)
Credit: 4

Unit I   Theory of Space Curves: Space curves, Planer curves, Curvature, torsion and Serret-Frenet formulae. Osculating circles, Osculating circles and spheres. Existence of space curves. Evolutes and involutes of curves.

Unit II   Theory of Surfaces: Parametric curves on surfaces. Direction coefficients. First and secondFundamental forms. Principal and Gaussian curvatures. Lines of curvature, Euler's theorem. Rodrigue's formula, Conjugate and Asymptotic lines.

Unit III	Developables: Developable associated with space curves and curves on surfaces, Minimal surfaces.
Unit IV	Geodesics: Canonical geodesic equations. Nature of geodesics on a surface of revolution. Clairaut'stheorem. Normal property of geodesics. Torsion of a geodesic. Geodesic curvature. Gauss-Bonnet theorem. Surfaces of constant curvature. Conformal mapping. Geodesic mapping. Tissot's theorem.

Recommended Books and References:

1. T.J. Willmore, *An Introduction to Differential Geometry,* Dover Publications, 2012.
2. B. O'Neill, *Elementary Differential Geometry,* 2nd Ed., Academic Press, 2006.
3. C.E. Weatherburn, *Differential Geometry of Three Dimensions,* Cambridge University Press, 2003.
4. D.J. Struik*, Lectures on Classical Differential Geometry,* Dover Publications, 1988.
5. S. Lang, *Fundamentals of Differential Geometry,* Springer, 1999.
6. B. Spain, *Tensor Calculus: A Concise Course,* Dover Publications, 2003.

Finite Element Methods (MJ-21/MJ-22/MJ-23)
Credit: 4

Unit I	Introduction to finite element methods, comparison with finite difference methods, Methods of weighted residuals, collocations, least squares and Galerkin's method. Variational formulation of boundary value problems equivalence of Galerkin and Ritz methods. Applications to solve simple problems of ordinary differential equations.
Unit II	Linear, quadratic and higher order elements in one dimensional and assembly, solution of assembled system.
Unit III	Simplex elements in two and three dimensions, quadratic triangular elements, rectangular elements, serendipity elements and isoperimetric elements and their assembly, discretization with curved boundaries
Unit IV	Interpolation functions, numerical integration, and modeling considerations. Solution of two dimensional partial differential equations under different Geometric conditions.

Recommended Books and References:

1. J.N. Reddy, *Introduction to the Finite Element Methods,* Tata McGraw-Hill, 2003.
2. K.J. Bathe, *Finite Element Procedures,* Prentice-Hall, 2001**.**
3. R.D. Cook, D.S. Malkus and M.E. Plesha, *Concepts and Applications of Finite ElementAnalysis,* John Wiley and Sons, 2002.
4. Thomas J.R. Hughes, *The Finite Element Method: Linear Static and Dynamic Finite Element Analysis*, Dover Publication, 2000.
5. George R. Buchanan, *Finite Element Analysis,* McGraw Hill, 1994.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

Advanced LaTeX (MJ-21/MJ-22/MJ-23)
Credit: 3(Theory) +1(Practical)

Unit I	Getting Started with LaTeX: Introduction to TeX and LaTeX, Typesetting a simple document, Adding basic information to a document, Environments, Footnotes, Sectioning and displayed material.
Unit II	Mathematical Typesetting with LaTeX: Accents and symbols, Mathematical Typesetting (Elementary and Advanced): Subscript/ Superscript, Fractions, Roots, Ellipsis, Mathematical Symbols, Arrays, Delimiters, Multiline formulas, Spacing and changing style in math mode.

Unit III   Graphics and Beamer Presentation in LaTeX: Graphics in LaTeX, Simple pictures using PS Tricks, Plotting of functions, Beamer presentation.

List of (LaTeX) Practical / Lab work to be performed
1. Starting LaTeX, Preparing an input file, Sequences and paragraphs, Quotation marks, Dashes, Space after a period, Special symbols, Simple text- generating commands, Emphasizing text, Preventing line breaks, Footnotes, ignorable input.
2. The document, The document class, The title page, Sectioning, Displayed material, Quotations, Lists, Displayed formulas, Declarations.
3. Running LaTeX, Changing the type style, Accents, Symbols, Subscripts and superscripts, Fractions, Roots, Ellipsis.
4. Mathematical Symbols, Greek letters, Calligraphic letters, Log-like functions, Arrays, The array environment, Vertical alignment, Delimiters, Multiline formulas.
5. Putting one thing above another, over and underlining, Accents, Stacking symbols, Spacing in math mode, changing style in math mode, Type style, Math style.
6. Defining commands, Defining environments, Theorems.
7. Figure and tables, Marginal notes, The tabbing environment, The tabular environment.
8. The Table and contents, Cross-references, Bibliography and citation.
9. Beamer: Templates, Frames, Title page frame, Blocks, Simple overlays, Themes.

Recommended Books and References:
1. Donald Bindner and Martin Erickson, *A Student's Guide to the Study, Practice, and Tools of Modern Mathematics*. CRC Press, Taylor & Francis Group, LLC, 2011.
2. Leslie Lamport, *LaTeX: A Document Preparation System, User's Guide and Reference Manual,* 2nd Ed., Pearson Education. Indian Reprint, 1994.

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Bio Mathematics (MJ-21/MJ-22/MJ-23)
Credit: 4
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Unit I   Mathematical Biology and the modeling process: an overview. Continuous models: Malthus model, logistic growth, Allee effect, Gompertz growth, Michaelis-Menten Kinetics, Holling type growth, Bacterial growth in a Chemostat.

Unit II   Harvesting a single natural population, Prey predator systems and Lotka Volterra equations, Populations in competitions, Epidemic Models (SI, SIR, SIRS, SIC), Activator-Inhibitor system, Insect Outbreak Model: Spruce Budworm, Numerical solution of the models and its graphical representation.

Unit III   Qualitative analysis of continuous models: Steady state solutions, stability and linearization, multiple species communities and Routh-Hurwitz Criteria, Phase plane methods and qualitative solutions, bifurcations and limit cycles with examples in the context of biological scenario.

Unit IV   Spatial Models: One species model with diffusion, Two species model with diffusion, Conditions for diffusive instability, Spreading colonies of microorganisms, Blood flow in circulatory system, Travelling wave solutions, Spread of genes in a population.

Recommended Books and References:
1. L.E. Keshet, *Mathematical Models in Biology*, SIAM, 1988.
2. J. D. Murray, *Mathematical Biology*, Springer, 1993.
3. Y.C. Fung, *Biomechanics*, Springer-Verlag, 1990.
4. F. Brauer, P.V.D. Driessche and J. Wu, *Mathematical Epidemiology*, Springer, 2008.
5. M. Kot, *Elements of Mathematical Ecology*, Cambridge University Press, 2001.

Discrete Mathematics (MJ-21/MJ-22/MJ-23)
Credit: 4

Unit I   **Lattice:** Introduction: Lattices as partially ordered sets; Definition and examples, Properties of lattices, Lattices as algebraic systems; sub-lattices, direct product and homomorphism, Special lattices.

Unit II   **Boolean algebra:** Introduction; Definition and examples, sub-algebra, direct product and homomorphism, Boolean functions: Boolean forms and free Boolean algebras, values of Boolean expressions and Boolean functions, representation of Boolean functions, minimization of Boolean functions, design examples using Boolean algebra.

Unit III   **Graph Theory:** Basic definitions, Paths, reachability and connectedness, Matrix representation of graphs, trees: their representation and operations, list structures and graphs.

Unit IV   **Combinatorics:** Principles of addition multiplication, Permutation, combinations, Pigeonhole principle, binomial theorem, multinomial coefficient, Recurrence relation, solution of recurrence relation, homogeneous and non-homogeneous recurrence relation, generating function, solution of recurrence relation by method of generating functions

Recommended Books and References:

1. J. P. Tremblay and R. Manohar, *Discrete mathematical structures with applications to computer science*, Tata McGraw-Hill India, 2008.
2. B.A. Davey and H.A. Priestley, *Introduction to Lattices and Order*, Cambridge University Press, Cambridge, 1990.
3. Edgar G. Goodaire and Michael M. Parmenter, *Discrete Mathematics with Graph Theory*, 2nd Ed, Pearson Education (Singapore) P. Ltd., Indian Reprint, 2003.
4. C L Liu, *Elements of Discrete Mathematics*, Tata McGraw Hill, 2005, 4th Ed, ISBN-978-1259006395
5. V K Balakrishnan, *Introductory Discrete Mathematics*, ISBN-978-0486691152
6. Rudolf Lid and Gunter Pilz, *Applied Abstract Algebra*, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
7. J. A. Bondy and U.S.R. Murty, *Graph Theory*, Springer-Verlag, 2008
8. F. Harary, *Graph Theory*, Addison-Wesley, 1969.
9. S. Lipschutz and M. L. Lipson, *Schaum's Outline of Theory and Problems of Discrete Mathematics*, 2nd Ed., Tata McGraw-Hill, 1999, ISBN-978-0071615877.

MINOR PAPERS
Algebra (MN-1)
Credit: 3(Theory) +1(Practical)

Unit I   Polynomial functions: Division algorithm, Synthetic division, Remainder Theorem, Factor Theorem. Polynomial equations, Relation between roots and Coefficients of a polynomial equation, Symmetric function of the roots of an equation, sum of powers of the roots, Solution of cubic and bi-quadratic equations.

Unit II   Matrix introduction, matrix operations, types of matrices (symmetric, skew-symmetric, Hermitian and skew-Hermitian matrices, idempotent, nilpotent, involuntary, orthogonal and unitary matrices, singular and non-singular matrices),

elementary operations on matrices, adjoint, inverse of a matrix.

Unit III   Trace of a matrix, rank of a matrix, invariance of rank through elementary transformations, normal form of a matrix, elementary matrices and inverse of a non-singular matrix through elementary row transformations.

Recommended Books and References:
1. M.K. Singal, Asha Rani Singal, *Algebra,* 31st Ed., R Chand & Co, New Delhi. 2020.
2. Chandrika Prasad, *Text Book on Algebra and Theory of Equations,* Pothishala Pvt. Ltd, 1963.
Algebra (Practical)
Problems from Algebra (Theory) may be solved with the help of any software.

Calculus (MN-2)
Credit: 3(Theory) +1(Practical)

Unit I   L'Hospital's rule. Higher order derivatives, Leibniz rule and its applications to problems of type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n\sin x$, $(ax+b)^n\cos x$. Concavity and inflection points; applications of derivatives in business, economics and life sciences.

Curve tracing in Cartesian coordinates, introduction to polar coordinates and curve tracing in polar coordinates of standard curves (cycloid, cardioid, other simple curves).

Unit II   Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin^n x\, dx$, $\int \cos^n x\, dx$, $\int \sin^n x \cos^n x\, dx$, $\int \tan^n x\, dx$, $\int \sec^n x\, dx$, $\int x^m (\log x)^n dx$.

Volumes by slicing; disks and washers' methods, volumes by cylindrical shells, volumes by parametric equations, arc length, arc length of parametric curves, area of surface of revolution.

Unit III   Hyperbolic functions, Introduction to vector-valued functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions, tangent and normal components of acceleration.

List of Practicals (using any software)
1. Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and studying the nature of the curve.
2. Obtaining the volume and surface of revolution of curves.
3. Plotting of parametric curves (E.g. Trochoid, cycloid, epicycloids, hypocycloid)
4. Plotting of graphs of function e^{ax+b}, $\log(ax+b)$, $\frac{1}{ax+b}$, $\sin(ax+b)$, $\cos(ax+b)$, $|ax+b|$ and to illustrate the effects of a and b on the graph.

Recommended Books and References:
1. G.B. Thomas and R.L. Finney, *Calculus,* 9th Ed., Pearson Education, Delhi, 2005.
2. M.J. Strauss, G.L. Bradley and K.J. Smith, *Calculus,* 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
3. H. Anton, I. Bivens and S. Davis, *Calculus,* 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
4. James Stewart, *Calculus: Early Transcendentals*, 7th Ed, Cengage India Private Limited, 2017

5. R. Courant and F. John, *Introduction to Calculus and Analysis* (*Vol. I & II*), Springer Verlag, New York, Inc., 1989.

Group Theory (MN-3)
Credit: 4

Unit I   Definition and examples of groups including permutation groups and quaternion groups (illustration through matrices), Elementary properties of groups.

Unit II   Subgroups and examples of subgroups, Centralizer, Normalizer, Center of a group, Cyclic groups, Properties of cyclic groups, classification of subgroups of cyclic groups.

Unit III   Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, Cosets, Properties of Cosets, Lagrange's theorem for finite groups, Normal subgroups, Quotient Groups.

Unit IV   Group homomorphisms, properties of homomorphisms, Cayley's theorem, First, Second and Third isomorphism theorems.

Recommended Books and References:

1. John B. Fraleigh, *A First Course in Abstract Algebra*, 7th Ed., Pearson, 2002.
2. M. Artin, *Abstract Algebra*, 2nd Ed., Pearson, 2011.
3. Joseph A. Gallian, *Contemporary Abstract Algebra,* 4th Ed., Narosa Publishing House, New Delhi, 1999.
4. David S. Dummit and Richard M. Foote, *Abstract Algebra*, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2004.
5. Joseph J. Rotman, *An Introduction to the Theory of Groups,* 4th Ed., Springer Verlag, 1995.
6. I.N. Herstein, *Topics in Algebra*, Wiley Eastern Limited, India, 1975.

Differential Equations (MN-4)
Credit: 3(Theory) +1(Practical)

Unit I   General, particular, singular, explicit and implicit solution of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors.

Unit II   Introduction to compartmental model, exponential decay model, lake pollution model (case study of Lake Burley Griffin), exponential growth of population, limited growth of population, limited growth with harvesting.

Unit III   General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications. Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Method of undetermined coefficients, method of variation of parameters.
Equilibrium points, Interpretation of the phase plane. Predatory-prey model and its analysis, epidemic model of influenza and its analysis.

List of Practical (using any software)

1. Finding solutions of separable equations, exact, and first order linear equations.
2. Finding solutions and plotting of second order solution family of differential equation.
3. Finding solutions and plotting of third order solution family of differential equation.
4. Growth model (exponential case only).
5. Decay model (exponential case only).

6. Lake pollution model.
7. Limited growth of population.
8. Predatory-prey model.
9. Epidemic model of influenza.

Recommended Books and References:
1. Belinda Barnes and Glenn R. Fulford, *Mathematical Modelling with Case Studies, Using Maple and MATLAB,* 3rd Ed., CRC Press, Taylor & Francis Group, 2015.
2. Shepley L. Ross, *Differential Equations,* 3rd Ed., John Wiley & Sons. India, 2004.

Complex Variable (MN-5)
Credit: 4

Unit I   Complex numbers: sum and products, algebraic properties, vectors and moduli, triangle inequality, complex conjugate, exponential form, products and powers in exponential form, arguments of product and quotients, roots of complex numbers, regions in the complex plane, stereographic projection.

Unit II   Analytic functions: functions and mappings, limits, limits involving the point at infinity, continuity, derivatives, rules for differentiation, Cauchy-Riemann equations, sufficient conditions for differentiability, analytic functions, harmonic functions.

Unit III   Elementary functions: the exponential function, the logarithmic function, branches and derivatives of logarithmic functions, identities involving logarithms, the power function, trigonometric functions, zeros and singularities of trigonometric functions, hyperbolic functions, inverse trigonometric and inverse hyperbolic functions.

Unit IV   Integrals: Derivatives, definite integrals, contours, contour integrals, upper bounds for moduli of contour integrals, Cauchy-Goursat theorem, Cauchy-integral formula, Louville's theorem and the fundamental theorem of algebra, maximum modulus principle.

Recommended Books and References:
1. Titu Andreescu and Dorin Andrica, *Complex Numbers from A to Z*, Birkhauser, 2006.
2. James Ward Brown and Ruel V. Churchill, *Complex Variables and Applications,* 8th Ed., McGraw – Hill International Edition, 2009.
3. D Sarason, *Complex Function Theory*, 2nd Ed., American Mathematical Society, 2021.
4. Joseph Bak and Donald J. Newman, *Complex Analysis,* 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., New York, 1997.
5. J. H. Mathews, and R. W. Howell, *Complex Analysis for Mathematics and Engineering*, 5th Ed., Narosa, 2010, ISBN-10: 817319761X ISBN-13: 978-8173197611
6. J. B. Conway, *Functions of One Complex Variable*, 2nd Ed., Narosa Publishing House, India, 1994, ISBN 978-81-85015-37-8
7. L. V. Ahlfors, *Complex Analysis*, 3rd Ed., McGraw-Hill Education, 1979, ISBN-13: 978-1-25-906482-1, ISBN-10: 1-25-906482-4
8. H.A. Priestly , *Introduction to Complex Analysis*, 2nd Ed., 2003, Oxford University Press, ISBN-10: 0198525613, ISBN-13: 978-0198525615.

Numerical Analysis (MN-6)
Credit: 3(Theory) +1(Practical)

Unit I   Relative Error, Absolute Error, Round off Error, Truncation Error. Transcendental and Polynomial equations: Bisection method, Secant method, Method of False Position, Newton-Raphson method, Order and rate of convergence of these methods. System of linear equations: Direct Method: Gauss Elimination methods, triangularization method. Iterative methods: Gauss Jacobi method, Gauss Seidel method.

Unit II   Lagrange interpolation, Newton's divided difference interpolation, finite difference operators, relation between differences and derivatives, Gregory-Newton forward and backward difference interpolations, Stirling and Bessel interpolations, Hermite interpolation, piecewise interpolation, Error analysis in each method.

Unit III   Differentiation: Numerical differentiation, methods based on interpolation, methods based on finite differences. Integration: Numerical integration, methods based on interpolation, Newton-Cotes methods. Initial value problems: Euler method, Taylor series method, Runge-Kutta methods of order 2 and 4.

List of Practicals (By using C programming)

1. Bisection method
2. Secant method
3. Regula-Falsi method
4. Newton-Raphson method
5. Gauss Elimination method
6. Gauss Jordan methods
7. Gauss−Jacobi method
8. Gauss−Seidel method
9. Lagrange interpolation
10. Newton interpolation
11. Trapezoidal rule
12. Simpson's rule
13. Euler's method
14. Runge-Kutta methods (Second and Fourth)

Recommended Books and References:

1. Brian Bradie, *A Friendly Introduction to Numerical Analysis,* Pearson Education, India, 2007.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation,* 6th Ed., NewAge International Publisher, India, 2007.
3. Uri M. Ascher and Chen Greif, *A First Course in Numerical Methods,* 7th Ed., PHI Learning Private Limited, 2013.
4. John H. Mathews and Kurtis D.Fink, *Numerical Methods using Matlab,* 4th Ed., PHI Learning Private Limited, 2012.
5. E. Balagurusamy, *Computer Programming and Data Structures* by, Tata McGraw Hill.
6. Brian Kernighan and Dennis Ritchie, *The C Programming Language,* 2nd Ed.

Linear Algebra (MN-7)
Credit: 3(Theory) +1(Practical)

Unit I   Systems of linear equations, row reduction and echelon forms, Solutions of a system of linear equations, condition of consistency and nature of the general solution of a system of linear non-homogeneous equations.

Unit II   Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces.

Unit III   Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. Isomorphisms, Isomorphism theorems, invertibility and isomorphisms, dual spaces, dual basis, double dual, transpose of a linear transformation and its matrix in the dual basis.

Linear Algebra-I (Practical)

1. Matrix operations (Addition, subtraction, product, transpose, inverse).
2. Determinant of a square matrix.
3. Rank of a matrix.
4. Row reduced echelon form and reduced echelon form of a matrix.
5. Solving a system of linear equations.
6. Null space, row space, column space.
7. Linear span, linear independence, basis, dimension, linear transformation.

Recommended Books and References:

1. David C. Lay, *Linear Algebra and its Applications,* 3rd Ed., Pearson Education Asia, Indian, Reprint, 2007.
2. Kenneth Hoffman and Ray Alden Kunze, *Linear Algebra,* 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.
3. Stephen H. Friedberg, Arnold J. Insel and Lawrence E. Spence, *Linear Algebra,* 4th Ed., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.
4. S. Lang, *Introduction to Linear Algebra,* 2nd Ed., Springer, 2005.
5. Gilbert Strang, *Linear Algebra and its Applications*, Thomson, 2007.
6. S. Kumaresan, *Linear Algebra- A Geometric Approach*, Prentice Hall of India, 1999.
7. Axler, *Linear Algebra Done Right*, 3rd Ed., Springer.
8. P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, *First Course in Linear Algebra*, Wiley Eastern Ltd.
9. P. K. Saikia, *Linear Algebra*, Pearson.

Ordinary Differential Equations (MN-8)
Credit: 3(Theory) +1(Practical)

Unit I   Linear equations with variable coefficients; initial value problems for the homogeneous equations; existence theorem; uniqueness theorem; solutions of homogeneous equations; the theorem on n linearly independent solutions; the Wronskian and linear independence; a formula for the Wronskian; The non-homogeneous equations.

Unit II   Homogeneous equations with analytic coefficients; Legendre equation and polynomials, Rodrigues formulae and applications, Linear equations with regular singular points; the Euler equation, the Bessel equation, regular singular points at infinity.

Unit III   Existence and uniqueness of solutions to first order equations; separable and exact differential equations; The method of successive approximation; Lipschitz condition; non-local existence of solutions; uniqueness of solutions; existence and uniqueness

theorem for first order equations.

Ordinary Differential Equations (Practical)
Problems from ODE may be solved with the help of any software.

Recommended Books and References:

1. E. A. Coddington, *An Introduction to Ordinary Differential Equations*, Prentice-Hall of India Private Ltd., New Delhi, 2001, ISBN-10:0486659429
2. Dennis G. Zill and Michael R. Cullen, *Differential Equations with Boundary-value Problems*, Thomson Brooks/Cole, 2005.
3. W.T. Martain and E. Relssner, *Elementary Differential Equations*, 3rd Ed., Addison Wesley Publishing Company, Inc, 1995, ISBN-9780201045031
4. E. A. Codington and N. Levinson, *Theory of Ordinary Differential Equations*, Tata McGraw Hill Publishing Co. Ltd. New Delhi, 1999, ISBN-9780070992566
5. G. F. Simmons, *Differential equation with applications and historical Notes*, 2nd Ed., McGraw Hill Education, 2017, ISBN-9780070530713.

MULTI-DISCIPLINARY COURSES
Introductory Mathematics (MD-I)
Credit-3

Unit I   **Trigonometry**
Simple identities, heights and distances, trigonometric equations, general solutions of trigonometric equations.

Unit II   **Algebra**
Set theory, factorization, expansions, partial fraction, simultaneous linear/quadratic equations, arithmetic, geometric and harmonic progressions, determinants and matrices.

Unit III   **Calculus**
Limits, continuity, differentiation, integration; Methods of integration (substitution, by parts, partial fraction). Rate of change, increasing and decreasing functions, definite integrals and properties.

Recommended Books and References:

Class 11 and Class 12 NCERT Mathematics Textbook

Quantitative Aptitude (MD-II)
Credit-3

Unit I   Numbers system and Basic Numeracy-H.C.F and L.C.M, Decimal and Fractions. Simplifications, power and roots, averages, percentage, Odd man out and Series completion, logarithms, surds and indices.

Unit II   Basic Arithmetic- Percentage, Profit and Loss, Ratio and Proportion, Mixtures and Alligations, Partnership.

Unit III   Chain Rule, Time and Work, Time and Wages, Pipes and Cisterns, Time and Distance, Problems on Trains and Boats, Clocks and Calendars.

Recommended Books and References:

1. R.S Aggarwal, *Quantitative Aptitude*, S. Chand and Company Ltd., New Delhi, 2007.
2. Abhijit Guha, *Quantitative Aptitude for Competitive Examinations*, McGraw Hill Education, 2011.

Vector Algebra (MD-III)
Credit-3

Unit I   Vectors: Definition, types of vectors, magnitude of vectors, vector algebra operations, applications. Scalar or dot product and its properties, projection of one vector onto the other, work.

Unit II   Vector Product: Vector or cross product, geometrical interpretation of vector product, properties of vector product, torque, angular velocity and moments. Scalar triple product, geometrical interpretation of scalar triple product, vector triple product.

Unit III   Geometry using vectors : Direction cosines and direction ratios, lines and plane. The equation of a line, the shortest distance between two straight lines, the equation of a plane, the shortest distance from a point to a plane.

Recommended Books and References:

1. Shanti Narayan and P.K. Mittal, *Vector Algebra*, S. Chand and Company Ltd., New Delhi, 2005.
2. G.B. Thomas and R.L. Finney, *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
3. *Class 12 NCERT Mathematics Textbook.*

SKILL ENHANCEMENT COURSES
Foundation Course in Mathematics (SEC-I)
Credit: 1(T) +2(P)

Unit I   Logic and Sets: Statements and negations, statements with quantifiers, compound statements, implications; Sets, operations on sets, family of sets, power sets, Cartesian product of sets; Proof techniques in Mathematics.

Relation: Types of relations, partitions, equivalence relations and various examples, partial and total orders, chains, bounds and maximal elements.

Functions: basic definitions, one-one, onto functions and bijections, composition of functions, inverse of a function, image and inverse image of subsets under functions.

List of Practical

1. Assigning variables and giving names.
2. List, arrays, sequences
3. Operations on sets (Union, Intersection, Complement, Symmetric difference, Cartesian products)
4. Logical operations (AND, NAND, OR, NOR, NOT, implies, truth table, etc.)
5. Defining functions
6. Graphs of elementary functions (ax+b, |ax+b|, log(ax+b), exp(ax+b), trigonometric functions)
7. Compositions of functions
8. Calculation of inverse functions
9. Algebra of real valued functions (Addition, Subtraction, multiplication, division).

Recommended Books and References:

1. Ajit Kumar, S. Kumaresan, Bhaba Kumar Sarma, *A Foundation Course in Mathematics*, Narosa Publishing House, New Delhi, 2018.
2. R.P. Grimaldi, *Discrete Mathematics and Combinatorial Mathematics*, Pearson Education, 1998.
3. P.R. Halmos, *Naive Set Theory*, Springer, 1974.
4. E. Kamke, *Theory of Sets*, Dover Publishers, 1950.

5. P. Adams, K.Smith and R. Vyborny, *Introduction to Mathematics with maple,* World Scientific Publishing, 2004.

Programming in C (SEC II)
Credit: 1(T) +2(P)

Unit I   Introduction to structured approach to programming, Flow chart Algorithms, Pseudocode (bubble sort, linear search - algorithms and pseudocode), Character set, Tokens, Identifiers in C, Variables and Data Types, Constants, Console IO Operations, *printf* and *scanf* Operators and Expressions: Expressions and Arithmetic Operators, Relational and Logical Operators, Conditional operator, size of operator, Assignment operators and Bitwise Operators. Operators Precedence Control Flow Statements: If Statement, Switch Statement, Unconditional Branching using goto statement, While Loop, Do While Loop, For Loop, Break and Continue statements. (Simple programs covering control flow).

Arrays and strings Arrays Declaration and Initialization, 1-Dimensional Array, 2-Dimensional Array String processing: In built String handling functions (*strlen*, *strcpy*, *strcat* and *strcmp*, puts, gets) Linear search program, bubble sort program, simple programs covering arrays and strings, Working with functions, Introduction to modular programming, Call by Value, Call by Reference, Functions returning value, Void function, simple programs using functions.

Programming in C (list of Practical).

1. Display "Hello World"
2. Read two numbers, add them and display their sum
3. Read the radius of a circle, calculate its area and display it
4. Evaluate the arithmetic expression ((a -b / c * d + e) * (f +g)) and display its solution. Read the values of the variables from the user through console.
5. Read 3 integer values and find the largest among them.
6. Read a Natural Number and check whether the number is prime or not
7. Read a Natural Number and check whether the number is Armstrong or not
8. Read a Natural number and find its factorial
9. Read two numbers and find the GCD/LCM
10. Read *n* integers, store them in an array and find their sum and average
11. Read *n* integers, store them in an array and search for an element in the array using Linear Search algorithm
12. Read *n* integers, store them in an array and sort the elements in the array using Bubble Sort algorithm
13. Read a string (word), store it in an array and check whether it is a palindrome word or not.
14. Generating Fibonacci sequence.
15. Calculation of Mean, Median, Mode, Standard Deviation, etc
16. Find the factorial of a given Natural Number n using recursive and non-recursive functions
17. Write program to perform
   (a) matrix addition
   (b) matrix multiplication
   (c) Finding the transpose
18. Write program using functions to (i) read a matrix, (ii) find the sum of two matrices, (iii) find the product of two matrices; (i) find the transpose of a matrix and (v) display a matrix.

Recommended Books and References:

1. E. Balguruswamy, *Programming in ANSI C*, Tata McGraw Hill India
2. Yaswant Kanitkar, *Let us C*, BPB Publication
3. B.S. Gottfried, *Programming with C*, Schaum Series, Tata McGraw Hill
4. Asok N. Kamthane, *Programming in C*, Pearson
5. Anita Goel and Ajay Mittal, *Computer fundamentals and Programming in C*, Pearson.
6. Brian W. Kernighan and Dennis M. Ritchie, *C Programming Language*, Pearson.
7. V. Rajaraman, *Computer Basics and Programming in C*, PHI Learning Private Limited
8. Xavier, *C Language and Numerical Methods*, New Age International Ltd. Pub.

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Introduction to LaTeX (SEC-III)
Credit: 1(T) +2(P)

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Unit I Introduction to LaTeX, Formatting words, lines and paragraphs: Understanding logical formatting, exploring the document structure, latex commands, writing special characters, formatting texts: font shapes and styles, common paragraph boxes, lines breaking, using environment for justification, quoting longer texts, spacing between paragraphs.

Designing pages: defining margin, two columns landscape document, creating a table of content, sectioning, customizing header and footer, creating tables and inserting pictures, adding captions to tables, generating multipage tables, coloring tables, scaling pictures, embedding picture with texts. Introduction to Beamer

List of Practical:

1. Centering a title
2. Writing special characters
3. Use of environment to adjust font size
4. Creating narrow text column
5. Breaking lines and paragraphs
6. Inserting new page
7. Spacing between paragraphs
8. Displaying quotes
9. Setting paper size and margin
10. Typing mathematical and chemical formulae
11. Inserting tables into document
12. Creating enumeration list
13. Creating itemized list
14. Inserting equations
15. Using header and footer
16. Inserting images behind texts
17. Adding caption to tables and images
18. make presentation with the BEAMER

Recommended Books and References:

1. Stefan Kottwitz, *Latex: beginner's guide,* Packt publishing, 2011.
2. Helmut Kopka, Patrick W. Daly, *Guide to LATEX, fourth edition*, Addison-Wesley, 2004
3. Leslie Lamport, *LaTeX: A Document Preparation System, User's Guide and Reference Manual* (2nd Ed.). Pearson Education, Indian Reprint, 1994.

COMMON VALUE ADDED COURSES
Mathematics for Competitive Examinations (VAC-II)
Credit: 3

Unit I   Fraction, Average, Time and Distance, Ratio and Proportion, Percentage, Profit and Loss, Interest (Simple and Compound) and Discount, Stock and Share, Banking.

Unit II   Chain Rule, Time and Work, Pipes and Cisterns, Time and Distance, Problems on Trains, Boats and Streams.

Unit III   Area, Perimeter, Volume and Surface Area of geometric shapes, Permutation and Combination.

Recommended Books and References:
1. R.S. Agarwal, *Quantitative Aptitude*, Sultan Chand and Company Ltd, New Delhi, 2012.
2. Abhijit Guha, *Quantitative Aptitude for Competitive Examinations*, McGraw Hill Education, 2011.

Vedic Mathematics (VAC-II)
Credit: 3

Unit I   History and Evolution of Vedic Mathematics, Introduction of Basic Vedic Mathematics Techniques in Multiplication (Special Case, Series of 9, Series of 1 etc), Tables etc., Comparison of Standard Methods with Vedic Methods. Various techniques to carry out basic operations covering Addition, Subtraction, Multiplication, Division, Complements and Bases, Vinculum number, General multiplication (Vertically Crosswise).

Unit II   Multiplications by numbers near base, Verifying answers by use of digital roots, Divisibility tests, Division of numbers near base, Comparison of fractions. Applications of Vinculum, Different methods of Squares (General method, Base method, Duplex method etc.).

Unit III   Cubes, Cube roots, Square roots, General division, Quadratic Equations, Simultaneous Equations, Use of various Vedic Techniques for answering numerical aptitude questions from Competitive Examinations.

Recommended Books and References:
1. Atul Gupta, *Power of Vedic Maths with Trigonometry*, Jaico Books, 2004.
2. Bhatiya Dhaval, *Vedic Mathematics Made Easy*, Jaico Publishing House, 2021.
3. V.G.Unkalkar, *Magical World of Mathematics (Vedic Mathematics)*, Vandana Publishers, Bangalore, 2008.
4. Rajesh Kumar Thakur, *Vedic Mathematics for students taking Competitive Examinations*, Unicorn Books 2015 or Later Edition.

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