Syllabus for B.Sc.

SUBJECT: MATHEMATICS

Modified on July 24, 2023, Board of Studies

	Semester wise Title of the Papers in UG MATHEMATICS Course				
Year	**Course Code**	**Paper Title**	**Theory/ Practical**	**Max. Marks**	**Credits**
FIRST		**SEMESTER-I**			
	B030101T	DIFFERENTIAL CALCULUS & INTEGRAL CALCULUS	THEORY	**50**	**4**
	B030102P	PRACTICAL	PRACTICAL	**25**	**2**
		SEMESTER-II			
	B030201T	MATRICES AND DIFFERENTIAL EQUATIONS & ANALYTICAL GEOMETRY	THEORY	**50**	**4**
	B030202P	PRACTICAL	PRACTICAL	**25**	**2**
SECOND		**SEMESTER-III**			
	B030301T	ALGEBRA & MATHEMATICAL METHODS	THEORY	**50**	**4**
	B030302P	PRACTICAL	PRACTICAL	**25**	**2**
		SEMESTER-IV			
	B030401T	DIFFERENTIAL EQUATION & MECHANICS	THEORY	**50**	**4**
	B030402P	PRACTICAL	PRACTICAL	**25**	**2**
THIRD		**SEMESTER-V**			
		(Opt any one of the following (Elective/ Optional)			
	B030501T	NUMBER THEORY & GAME THEORY	THEORY	**75**	**6**
	B030502T	GRAPH THEORY & DISCRETE MATHEMATICS		**75**	
	B030503T	DIFFERENTIAL GEOMETRY & TENSOR ANALYSIS		**75**	
	B030504T	GROUP, RING THEORY & LINEAR ALGEBRA	THEORY	**50**	**4**
	B030505P	PRACTICAL	PRACTICAL	**25**	**2**

		SEMESTER-VI			
	B030601T	METRIC SPACES & COMPLEX ANALYSIS	THEORY	**75**	**6**
	B030602T	NUMERICAL ANALYSIS & OPERATIONS RESEARCH	THEORY	**50**	**4**
	B030603P	PRACTICAL	PRACTICAL	**25**	**2**
				Total Credits	**48**

Marks Distribution out of 100:

Papers without Practical: 25 Marks for Assessment, Attendance & Mid Semester Test + 75 Marks for Theory Paper

Papers with Practical: 25 Marks for Assessment, Attendance & Mid Semester Test + 25 Marks for External Practical examination + 50 Marks for Theory Paper

Subject Prerequisites:
Mathematics in 12th/Certificate course in Applied Mathematics/Diploma in Mathematics.

Program Outcomes (POs)

PO1: It is to give foundation knowledge for the students to understand the basics of mathematics includingapplied aspects.

PO2: It is to develop enhanced quantitative skills in pursuing higher mathematics and research as well.

PO3: Students will be able to develop solution-oriented approach towards various issues related to their environment.

PO4: Students will become employable in various government and private sectors.

PO5: Scientific temper in general and mathematical temper, in particular, will be developed in students.

Program Specific Outcomes (PSOs)

First Year	Certificate in Applied Mathematics	Student should be able to possess recall basic idea about mathematics which can be displayed by them.
Second Year	Diploma in Mathematics	Student should have adequate exposure to many aspects of mathematical sciences.
Third Year	Degree in Mathematics	Student is equipped with mathematical modelling ability, critical mathematical thinking, problem solving skills, etc. and apply his/her skill and knowledge in various field of studies including Science, Engineering, Commerce and Management etc.

B.Sc. I (SEMESTER-I) PAPER-I

DIFFERENTIAL CALCULUS & INTEGRAL CALCULUS

Programme: B.Sc.	**Year: FIRST**	**Semester: FIRST**
Subject: MATHEMATICS		
Course Code: B030101T	**Course Title: DIFFERENTIAL CALCULUS & INTEGRAL CALCULUS**	

Course outcomes:

CO1: The program outcome is to give foundation knowledge for the students to understand basics of mathematics including applied aspect for developing enhanced quantitative skills and pursuing higher mathematics and research as well.

CO2: By the time students complete the course, they will have wide ranging application of the subject and have the knowledge of real valued functions along with sequence and series. They will also be able to know about convergence of sequence and series. Also, they have knowledge about curvature, envelope and evolutes and trace curve in polar curves, Cartesian curves as well as parametric curves.

CO3: The main objective of the course is to equip the student with necessary analytic and technical skills. By applying the principles of integral he/she learns to solve a variety of practical problems in science and engineering.

CO4: The student is equipped with standard concepts and tools at an intermediate to advance level that will serve him/her well towards taking more advance level course in mathematics.

Credits: 4	**Core Compulsory / Elective**
Max. Marks: 25+50	**Min. Passing Marks:** As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	**Topics**	**No. of Lectures**
	Introduction to **"Indian Ancient Mathematics and Mathematicians"** should be included under **Continuous Internal Evaluation (CIE).**	
	Part I **DIFFERENTIAL CALCULUS**	
I	Definition of a sequence, theorems on limits of sequences, bounded and monotonic sequences, Cauchy's convergence criterion, Cauchy sequence, limit superior and limit inferior of a sequence, subsequence, Series of non-negative terms, convergence and divergence, Comparison tests, Cauchy's integral test, Ratio tests, Root test, Raabe's test, logarithmic test, de Morgan and Bertrand's tests, alternating series, Leibnitz's theorem, absolute and conditional convergence.	9
II	Limit, continuity and differentiability of function of single variable, Cauchy's and Heine's definition of continuity, equivalence of definitions of Cauchy and Heine, Uniform continuity, Borel's theorem, boundedness theorem, Bolzano's theorem, Intermediate value theorem, extreme value theorem, Darboux's intermediate value theorem for derivatives, Chain rule, indeterminate forms.	7
III	Rolle's theorem, Lagrange and Cauchy Mean value theorems, mean value theorems of higher order, Taylor's theorem with various forms of remainders, Successive differentiation, Leibnitz theorem, Maclaurin's and Taylor's series expansion, Partial differentiation, Euler's theorem on homogeneous function.	7

IV	Tangent and normal, Asymptotes, Curvature, Envelops and evolutes, Tests for concavity and convexity, Points of inflexion, Multiple points, Parametric representation of curves and tracing of parametric curves, Tracing of curves in Cartesian and Polar forms.	7
	Part II **INTEGRAL CALCULUS**	
V	Definite integrals as limit of the sum, Riemann integral, Integrability of continuous and monotonic functions, Fundamental theorem of integral calculus, Mean value theorems of integral calculus, Differentiation under the sign ofIntegration.	**9**
VI	Improper integrals, their classification and convergence, Comparison test, μ-test, Abel's test, Dirichlet's test, quotient test, Beta and Gamma functions.	**7**
VII	Rectification, Volumes and Surfaces of Solid of revolution, Pappus theorem, Multiple integrals, change of order of double integration, Dirichlet's theorem, Liouville's theorem for multiple integrals.	**7**
VIII	Vector Differentiation, Gradient, Divergence and Curl, Normal on a surface, Directional Derivative, Vector Integration, Theorems of Gauss, Green, Stokes and related problems.	**7**

Suggested Readings (Part- I Differential Calculus):

1. R.G. Bartle & D.R. Sherbert, Introduction to Real Analysis, John Wiley & Sons
2. T.M. Apostal, Calculus Vol. I, John Wiley & Sons Inc.
3. Gorakh Prasad, A text book on Differential Calculus, Pothishala Private Ltd., Prayagraj
4. S. Balachandra Rao & C. K. Shantha, Differential Calculus, New Age Publication.
5. H. Anton, I. Birens and S. Davis, Calculus, John Wiley and Sons, Inc., 2002.
6. G.B. Thomas and R.L. Finney, Calculus, Pearson Education, 2007.
7. Course Books published in Hindi may be prescribed by the Universities.

Suggested Readings (Part-II Integral Calculus):

1. T.M. Apostal, Calculus Vol. II, John Wiley Publication
2. Gorakh Prasad, A text book on Integral Calculus, Pothishala Private Ltd., Prayagraj
3. Shanti Narayan & Dr. P.K. Mittal, Integral Calculus, S.Chand
4. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons.
5. Course Books published in Hindi may be prescribed by the Universities.

Suggestive Digital Platforms/ Web Links:

- National Programme on Technology Enhanced Learning (NPTEL)
- SWAYAM
- Massachusetts Institute of Technology (MIT) Open Learning
- Uttar Pradesh Higher Education Digital Library (UPHEDL)
- National Digital Library of India (NDLI)

This course can be opted as an elective by the students of following subjects: Open to all

Suggested Continuous Evaluation Methods (Max. Marks: 25)

S.No.	Assessment Type	Max. Marks
1	Class Tests	10
2	Online Quizzes/ Objective Tests	5
3	Presentation	5
4	Assignment on "Indian Ancient Mathematics and Mathematicians"	5

Course prerequisites:

To study this course, a student must have the subject Mathematics in class12th.

Suggested equivalent online courses:

1. Swayam - https://www.swayam.gov.in/explorer?category=Math_and_Sciences
2. National Programme on Technology Enhanced Learning (NPTEL), https://nptel.ac.in/course.html
3. MIT Open Course Ware - Massachusetts Institute of Technology, https://ocw.mit.edu/courses/mathematics/
4. Coursera, https://www.coursera.org/courses?query=mathematics
5. edX, https://www.edx.org/course/subject/math

Further Suggestions:

Students and Faculty should be updated themselves by current knowledge of subjects and related course through digital resources, Journals and textbooks.

Any remarks/ suggestions:

The course content can be modified by BOS successively catering to local need of University and Students.

B.Sc. I (SEMESTER-I) PAPER-II
PRACTICAL

Programme: B.Sc.	Year: FIRST	Semester: FIRST
Subject: MATHEMATICS		
Course Code: B030102P	Course Title: PRACTICAL	

Course outcomes:

CO1: The main objective of the course is to equip the student to plot the different graphs and solve the different types of equations by plotting the graphs using different computer software such as SageMath/Mathematica/MATLAB / /Maple /Scilab/ R Programming/C programming etc.

CO2. After completion of this course student would be able to know the convergence of sequences through plotting.

CO3. Student would be able to verify Bolzano-Weierstrass theorem through plotting the sequence.

CO4. Student would be able to verify Cauchy's root test by plotting n^{th} roots and Ratio test by plotting the ratio of n^{th} and $(n+1)^{th}$ term.

Credits: 2	Core Compulsory / Elective
Max. Marks: 25	Min. Passing Marks: As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 0-0-4

Unit	Topics	No. of Lectures
	• **Practical / Lab work to be performed in Computer Lab.** • **List of the practicals to be done using SageMath/Mathematica/ MATLAB/Maple /Scilab/ R programming/ C programming etc.**	**60**
I.	Plotting the graphs of the following functions: (i) ax (ii) $[x]$ (greatest integer function) (iii) $x^{2n}; n\epsilon\ N$ (iv) $x^{2n-1}; n\epsilon\ N$ (v) $\frac{1}{x^{2n}}; n\epsilon\ N$ (vi) $\frac{1}{x^{2n-1}}; n\epsilon\ N$ (vii) $\sqrt{ax+b}$; $\lvert ax+b\rvert$; $c \pm \lvert ax+b\rvert$ (viii) $\lvert x\rvert$; $\sin(\frac{1}{x})$; $x\sin(\frac{1}{x})$; e^{x}; e^{-x} $for\ x \neq 0$ (ix) e^{ax+b}; $\log(ax+b)$; $\frac{1}{ax+b}$; $\sin(ax+b)$; $\cos(ax+b)$; $\lvert\sin(ax+b)\rvert$; $\lvert\cos(ax+b)\rvert$ Observe and discuss the effect of changes in the real constants a and b on the graphs.	9
II.	By plotting the graph find the solution of the equation:	7

	$x = e^x$, $x^2 + 1 = e^x$, $1 - x^2 = e^x$, $x = \log_{10}(x)$, $\cos(x) = x$, $\sin(x) = x$, $\cos(y) = \cos(x)$, $\sin(y) = \sin(x)$ etc.	
III.	Sketching parametric curves, e.g., Trochoid, Cycloid, Epicycloid and Hypocycloid etc.	7
IV.	Obtaining surface of revolution of curves.	7
V.	i. Study the convergence of sequences through plotting. ii. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot.	**9**
VI.	Study the convergence/divergence of infinite series by plotting their sequences of partial sum.	**7**
VII.	Find numbers between two real numbers and plotting of finite and infinite subset of R.	**7**
VIII	i. Cauchy's root test by plotting n^{th} roots. ii. Ratio test by plotting the ratio of n^{th} and $(n+1)^{th}$ term.	**7**

This course can be opted as an elective by the students of following subjects: Open to all

Suggested Continuous Evaluation Methods (Max. Marks: 25)

S.No.	Assessment Type	Max. Marks
1	Class Tests	10
2	Online Quizzes/ Objective Tests	5
3	Presentation	5
4	Assignment / Lab Record	5

Course prerequisites:

To study this course, a student must have the subject Mathematics in class12th.

Suggested equivalent online courses:

1. Swayam - https://www.swayam.gov.in/explorer?category=Math_and_Sciences
2. National Programme on Technology Enhanced Learning (NPTEL), https://nptel.ac.in/course.html

Further Suggestions:

The faculty members in colleges/universities should be trained in the following training programs: **SageMath/Mathematica/MATLAB /Python/ /Scilab/** etc. Experts from IIT's, NITTTR, or equivalent should be invited for the programs to ensure quality.

Any remarks/ suggestions:

- There should be a Computer Lab with minimum of 25 computer systems for 50 students with licensed and Free Open Source softwares related to this course.
- At least one **Computer Programmer / Computer Operator** must be assigned in computer lab.

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B.Sc. I (SEMESTER-II) PAPER-I
MATRICES, DIFFERENTIAL EQUATIONS & ANALYTICAL GEOMETRY

Programme: B.Sc.	Year: FIRST	Semester: SECOND
Subject: MATHEMATICS		
Course Code: B030201T	Course Title: MATRICES, DIFFERENTIAL EQUATIONS & ANALYTICAL GEOMETRY	

Course outcomes:

CO1: The topics of the course are included in such a way that they focus on developing mathematical skills in matrices, differential equations and geometry from basic level to depth of knowledge.

CO2: Thestudent will be ableto find the rank, eigen values of matrices and study the linear homogeneous and non-homogeneous equations. The course in differential equation intends to develop problem solving skills for solving various types of differential equations.

CO3: The students will be capable of learn and visualize the fundamental ideas about coordinate geometry and learn to describe some of the surfaces by using analytical geometry.

CO4: On successful completion of the course students have gained knowledge about regular geometrical figures and their properties. They have the foundation for higher course in Geometry.

Credits: 4	Core Compulsory / Elective
Max. Marks: 25+50	Min. Passing Marks: As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
	Part I **MATRICES AND DIFFERENTIAL EQUATIONS**	
I	Elementary operations on Matrices, Rank of a Matrix, Echelon form of a Matrix, Normal form of a Matrix, Inverse of a Matrix by elementary operations.	7
II	System of linear homogeneous and non-homogeneous equations, Theorems on consistency of a system of linear equations (without proof), Eigen values, Eigen vectors and characteristic equation of a matrix, Cayley-Hamilton theorem and its use in finding inverse of a matrix.	5
III	Formation of differential equations, Geometrical meaning of a differential equation, Equation of first order and first degree, Equation in which the variables are separable, Homogeneous differential equations, Exact differential equations and equations reducible to the exact form, Linear differential equations.	11
IV	First order higher degree differential equations solvable for p, y, x. Clairaut's differential equation and singular solutions, Orthogonal trajectories, Linear differential equation with constant coefficients,	7
	Part II	

ANALYTICAL GEOMETRY		
V	General equation of second degree, System of conics, Confocal conics, Polar equation of conics and its properties.	**9**
VI	Three-Dimensional Coordinates, Projection and Direction Cosines, Plane, Straight line in three dimensions.	**7**
VII	Sphere, Cone and Cylinder.	**7**
VIII	Central conicoids, Paraboloids	**7**

Suggested Readings (PART-I Matrices and Differential Equations):

1. Stephen H. Friedberg, A.J. Insel & L.E. Spence, Linear Algebra, Pearson
2. B. Rai, D.P. Choudhary & H. J. Freedman, A Course in Differential Equations, Narosa.
3. D.A. Murray, Introductory Course in Differential Equations, Orient Longman
4. Course Books published in Hindi may be prescribed by the Universities.

Suggested Readings (Part-II Analytical Geometry):

1. Robert J.T Bell, Elementary Treatise on Coordinate Geometry of three dimensions, Macmillan India Ltd.
2. P.R. Vittal, Analytical Geometry 2d & 3D, Pearson.
3. S.L. Loney, The Elements of Coordinate Geometry, McMillan and Company, London.
4. Course Books published in Hindi may be prescribed by the Universities.

Suggestive Digital Platforms/ Web Links:

- National Programme on Technology Enhanced Learning (NPTEL)
- SWAYAM
- Massachusetts Institute of Technology (MIT) Open Learning
- Uttar Pradesh Higher Education Digital Library (UPHEDL)
- National Digital Library of India (NDLI)

This course can be opted as an elective by the students of following subjects: Open to all

Suggested Continuous Evaluation Methods (Max. Marks: 25)

S.No.	Assessment Type	Max. Marks
1	Class Tests	10
2	Online Quizzes/ Objective Tests	5
3	Presentation	5
4	Assignment	5

Course prerequisites:

To study this course, a student must have the subject Mathematics in class12th.

Further Suggestions:

Students and Faculty should be updated themselves by current knowledge of subjects and related course through digital resources, Journals and textbooks.

Any remarks/ suggestions:

The course content can be modified by BOS successively catering to local need of University and Students.

B.Sc. I (SEMESTER-II)
PAPER-II PRACTICAL

Programme: B.Sc.	Year: FIRST	Semester: SECOND
Subject: MATHEMATICS		
Course Code: B030202P	Course Title: PRACTICAL	

Course outcomes:
CO1: The objective of the course is to familiarize the students to use mathematical softwares such as SageMath/ Mathematica / MATLAB /Maple /Scilab/ R Programming/C programming etc.
CO2: After completion of course, students would be able to perform various operation related to matrices such as addition, multiplication, finding inverse, and finding Eigen-values, Eigen-vectors.
CO3: Students would be able to trace complex number, trigonometric function, conics and coinicoids.
CO4: Students would be able to visualize the solution of ordinary differential equation.

Credits: 2	Core Compulsory / Elective
Max. Marks: 25	Min. Passing Marks: As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 0-0-4

Unit	Topics	No. of Lectures
	• **Practical / Lab work to be performed in Computer Lab.** • **List of the practicals to be done using SageMath/Mathematica/ MATLAB /Maple /Scilab/ R Programming/C programming etc.**	**60**
I.	Graph of Circular trigonometric function, Inverse trigonometric function	6
II.	Matrix Operations: Addition, Multiplication, Inverse, Transpose, Adjoint (Adjugate), Determinant, Rank.	9
III.	For square matrices finding characteristic equation, Eigen-values, Eigen-vectors.	**7**
IV.	Verification of the Cayley-Hamilton theorem and solving the systems of linear equations.	**7**
V.	Tracing of Circle, Ellipse, Hyperbola and Parabola in Cartesian coordinates/ polar coordinates.	**7**
VI.	Tracing of Sphere, Cone, Cylinder, Ellipsoid, Hyperboloid of one and two sheets, Elliptic cone, Elliptic paraboloid, and Hyperbolic paraboloid using Cartesian coordinates.	10
VII.	Plotting of family of curves which are solutions of first order differential equation.	**7**
VIII.	Plotting of family of curves which are solutions of second order differential equation.	**7**

This course can be opted as an elective by the students of following subjects: Open to all

Suggestions: The faculty members in colleges/universities should be trained in the following training programs: **SageMath/Mathematica/MATLAB /Python/ /Scilab/** etc. Experts from IIT's, NITTTR, or equivalent should be invited for the programs to ensure quality.

Any remarks/ suggestions:
- There should be a Computer Lab with minimum of 25 computer systems for 50 students with licensed and Free Open Source softwares related to this course.
- At least one **Computer Programmer / Computer Operator** must be assigned in computer lab.

B.Sc. II (SEMESTER-III) PAPER-I
ALGEBRA & MATHEMATICAL METHODS

Programme: B.Sc.	Year: SECOND	Semester: THIRD
Subject: MATHEMATICS		
Course Code: B030301T	Course Title: ALGEBRA & MATHEMATICAL METHODS	

Course outcomes:

CO1: Group theory is one of the building blocks of modern algebra. Objective of this course is to introduce students to basic concepts of Group theory, Ring theory and their properties.

CO2: Astudent learning this course gets a concept of Group, Ring, Integral Domain and their properties. This course will lead the student to basic course in advanced mathematics particularly in Algebra.

CO3: The course gives emphasis to enhance students' knowledge of functions of two variables, Laplace Transforms, Fourier Transforms and series.

CO4: On successful completion of the course students would have acquire knowledge about higher different mathematical methods and will help him/her in going for higher studies and research.

Credits: 4	Core Compulsory / Elective
Max. Marks: 25+50	Min. Passing Marks: As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
	Introduction to **"Indian Ancient Mathematics and Mathematicians"** should be included under **Continuous Internal Evaluation (CIE).**	
	Part I **ALGEBRA**	
I	Equivalence relations and partitions, Congruence modulo n, Definition of a group with examples and simple properties, Subgroups, Generators of a group, Cyclic groups.	9
II	Permutation groups, Even and odd permutations, The alternating group, Cayley's theorem, Coset decomposition, Lagrange's theorem and its consequences, Fermat and Euler theorems.	7
III	Normal subgroups, Quotient groups, Homomorphism and isomorphism, Fundamental theorem of homomorphism.	7
IV	Rings, Subrings, Integral domains and fields, subfield, Characteristic of a ring, Ideal and quotient rings. Ring homomorphism.	7
	Part II	

MATHEMATICAL METHODS		
V	Limit and Continuity of functions of two variables, Differentiation of function of two variables, Necessary and sufficient condition for differentiability of functions of two variables, Taylor's theorem for functions of two variables with examples, Maxima and minima for functions of two variables, Lagrange multiplier method, Jacobians.	**9**
VI	Laplace transform, Existence theorem for Laplace Transform, Linearity of Laplace transform and their properties, Laplace transform of the derivatives and integrals of a function, Inverse Laplace transforms and their properties, Convolution theorem. Solution of Ordinary Differential Equations using Laplace Transform".	**7**
VII	Fourier series, Fourier expansion of piecewise monotonic functions, Half and full range expansions, Fourier transforms (finite and infinite).	**7**
VIII	Calculus of variations-Variational problems with fixed boundaries- Euler's equation for functionals containing first order derivative and one independent variable, Extremals, Functionals dependent on higher order derivatives.	**7**

Suggested Readings (Part-I Algebra):

1. J.B. Fraleigh, A first course in Abstract Algebra, Narosa Publishing House
2. Joseph. A. Gallian, Contemporary Abstract Algebra, Cengage Learning India Private Limited, Delhi., Fourth impression, 2015.
3. I. N. Herstein, Topics in Algebra, John Wiley & Sons
4. Course Books published in Hindi may be prescribed by the Universities.

Suggested Readings (Part-II Mathematical Methods):

1. T.M. Apostal, Mathematical Analysis, Pearson
2. G. F. Simmons, Differential Equations with Application and Historical Notes, Tata - McGrawHill
3. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons.
4. Course Books published in Hindi may be prescribed by the Universities.

Suggestive Digital Platforms/ Web Links:

- National Programme on Technology Enhanced Learning (NPTEL)
- SWAYAM
- Massachusetts Institute of Technology (MIT) Open Learning
- Uttar Pradesh Higher Education Digital Library (UPHEDL)
- National Digital Library of India (NDLI)

This course can be opted as an elective by the students of following subjects: Open to all

Suggested Continuous Evaluation Methods (Max. Marks: 25)

S.No.	Assessment Type	Max. Marks
1	Class Tests	10
2	Online Quizzes/ Objective Tests	5
3	Presentation	5
4	Assignment on "Indian Ancient Mathematics and Mathematicians"	5

Course prerequisites:

To study this course, a student must have Certificate in Applied Mathematics.

Suggested equivalent online courses:

1. Swayam - https://www.swayam.gov.in/explorer?category=Math_and_Sciences

2. National Programme on Technology Enhanced Learning (NPTEL), https://nptel.ac.in/course.html
3. MIT Open Course Ware - Massachusetts Institute of Technology, https://ocw.mit.edu/courses/mathematics/
4. Coursera, https://www.coursera.org/courses?query=mathematics
5. edX, https://www.edx.org/course/subject/math

Further Suggestions:

Students and Faculty should be updated themselves by current knowledge of subjects and related course through digital resources, Journals and textbooks.

Any remarks/ suggestions:

The course content can be modified by BOS successively catering to local need of University and Students.

B.Sc. II (SEMESTER-III) PAPER-II
PRACTICAL

Programme: B.Sc.	Year: SECOND	Semester: THIRD
Subject: MATHEMATICS		
Course Code: B030302P	Course Title: PRACTICAL	

Course outcomes:

CO1: The objective of the course is to familiarize the students to use mathematical softwares such as SageMath/ Mathematica / MATLAB /Maple /Scilab/ R Programming/C programming etc.

CO2: After completion of course, students would beable to visualizeimportant properties related to Group and Cyclic group.

CO3: The course will enable the students to solve problems of continuity and differentiability of function of two variables, Maxima and Minima, Laplace transforms and inverse Laplace transforms.

CO4: Students would be able to approximate the expansion of the function of two variables by Taylor's Theorem and plot the outputs.

Credits: 2	Core Compulsory / Elective
Max. Marks: 25	Min. Passing Marks: As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 0-0-4

Unit	Topics	No. of Lectures
	• **Practical / Lab work to be performed in Computer Lab.** • **List of the practicals to be done using SageMath/Mathematica/ MATLAB /Maple /Scilab/ R programming/ C programming etc.**	**60**
I.	i. Calculation of Addition modulo n and Multiplication modulo n. ii. Finding elements of ring of integers Z(n), Inverse of each element in Z(n) and order of elements in Z(n). iii. Construction of Cayley tables for Z(n) w.r.to addition modulo n and multiplication modulo n.	**9**
II.	i. Finding the elements of symmetric group S(n), construction of Cayley table for S(n), for given n (e.g., n = 12, 15, and 30) ii. Cyclic subgroups of S(n), generated by each element in S(n), Subgroups and normal subgroups of S(n) with generators.	9
III.	Draw the given surfaces and find level curves at the given heights (e.g. $f(x, y) = x^2 + y^2$; $z = 1$, $z = 6$, $z = 9$).	**7**
IV.	Draw the given surface and discuss whether limit exits or not as (x, y) approaches to the given points. Find the limit, if it exists.	**7**
V.	i. Draw the tangent plane to the given surfaces at the given point (e.g., $f(x, y) = 10 - x^2 - y^2$ at (2,2,2)). ii. Find critical points and identify relative maxima, relative minima or saddle points to the given surfaces, if it exists (e.g. $z = x^2 + y^2$).	7
VI.	Visualization by creating graphs: Taylor's polynomials – approximated up to certain degrees.	**7**
VII.	Finding the Laplace transform of the given functions. Expand the given function into partial fractions.	**7**

VIII.	Finding the inverse Laplace transform of the given functions.	**7**

Suggestions:

The faculty members in colleges/universities should be trained in the following training programs : **SageMath/Mathematica/MATLAB /Python/ /Scilab/** etc. Experts from IIT's, NITTTR, or equivalent should be invited for the programs to ensure quality.

Any remarks/ suggestions:

- There should be a Computer Lab with minimum of 25 computer systems for 50 students with licensed and Free Open Source softwares related to this course.
- At least one **Computer Programmer / Computer Operator** must be assigned in computer lab.

B.Sc. II (SEMESTER-IV) PAPER-I
DIFFERENTIAL EQUATIONS & MECHANICS

Programme: B.Sc.	Year: SECOND	Semester: FOURTH
Subject: MATHEMATICS		
Course Code: B030401T	Course Title: DIFFERENTIAL EQUATIONS & MECHANICS	

Course outcomes:

CO1: The objective of this course is to familiarize the students with various methods of solving differential equations, partial differential equations of first order and second order and to have qualitative applications.

CO2: A student doing this course is able to solve differential equations and is able to model problems in nature using ordinary differential equations. After completing this course, a student will be able to take more courses on wave equation, heat equation, diffusion equation, gas dynamics, non-linear evolution equation etc. These entire courses are important in engineering and industrial applications for solving boundary value problems.

CO3: The object of the course is to give students knowledge of basic mechanics such as simple harmonic motion, motion under other laws and forces.

CO4: The student, after completing the course can go for higher quality problems in mechanics such as hydrodynamics. This will be helpful in getting employment in industry.

Credits: 4	Core Compulsory / Elective
Max. Marks: 25+50	Min. Passing Marks: As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
	Part I **DIFFERENTIAL EQUATIONS**	
I	Second order linear differential equations with variable coefficients: Use of a known solution to find another, normal form, method of variation of parameters. Series solutions of differential equations.	9
II	Bessel and Legendre Functions with their properties, Recurrence and Generating Relations.	7
III	Origin of partial differential equations. Partial differential equations of the first order and degree one, Lagrange's solution, Partial differential equation of first order and degree greater than one, Charpit's method of solution.	7
IV	Origin of second order PDE, Solution of partial differential equations of the second and higher order with constant coefficients, Classification of linear partial differential equations of second order, Solution of second order partial differential equations with variable coefficients.	7
	Part II	

MECHANICS		
V	Frame of reference, Forces in three dimensions, Poinsot's central axis, Wrenches, Null lines and Null planes.	**9**
VI	Virtual work, Stable and Unstable equilibrium, Catenary of uniform strength	**7**
VII	Velocities and accelerations along radial and transverse directions, and along tangential and normal directions, Simple Harmonic motion, Elastic strings, Motion in resisting medium.	**7**
VIII	Motion of particle of varying mass, Rocket motion, Central orbit, Kepler's laws of motion, Motion of particle in threedimensions.	**7**

Suggested Readings (Part-I Differential Equations):

1. G.F. Simmons, Differential Equations with Application and Historical Notes, Tata–McGraw-Hill
2. B. Rai, D.P. Choudhary & H. J. Freedman, A Course of Ordinary Differential Equations, Narosa
3. Ian N. Snedden, Elements of Partial Differential Equations, Dover Publication
4. L.E. Elsgolts, Differential Equation and Calculus of variations, University Press of the Pacific.
5. Course Books published in Hindi may be prescribed by the Universities.

Suggested Readings (Part-II Mechanics):

1. R.C. Hibbeler, Engineering Mechanics-Statics, Pearson.
2. R.C. Hibbeler, Engineering Mechanics-Dynamics, Prentice Hall Publication
3. A. Nelson, Engineering Mechanics Statics and Dynamics, Tata McGraw Hill
4. J.L. Synge & B.A. Griffith, Principles of Mechanics, Tata McGraw Hill
5. Course Books published in Hindi may be prescribed by the Universities.

Suggestive Digital Platforms/ Web Links:

- National Programme on Technology Enhanced Learning (NPTEL)
- SWAYAM
- Massachusetts Institute of Technology (MIT) Open Learning
- Uttar Pradesh Higher Education Digital Library (UPHEDL)
- National Digital Library of India (NDLI)

This course can be opted as an elective by the students of following subjects: Open to all

Suggested Continuous Evaluation Methods (Max. Marks: 25)

S.No.	Assessment Type	Max. Marks
1	Class Tests	10
2	Online Quizzes/ Objective Tests	5
3	Presentation	5
4	Assignment	5

Course prerequisites:

To study this course, a student must have Certificate in Applied Mathematics.

Suggested equivalent online courses:

1. Swayam - https://www.swayam.gov.in/explorer?category=Math_and_Sciences
2. National Programme on Technology Enhanced Learning (NPTEL), https://nptel.ac.in/course.html
3. MIT Open Course Ware - Massachusetts Institute of Technology, https://ocw.mit.edu/courses/mathematics/
4. Coursera, https://www.coursera.org/courses?query=mathematics
5. edX, https://www.edx.org/course/subject/math

Further Suggestions:

Students and Faculty should be updated themselves by current knowledge of subjects and related course through digital resources, Journals and textbooks.

Any remarks/ suggestions:

The course content can be modified by BOS successively catering to local need of University and Students.

B.Sc. II (SEMESTER-IV) PAPER-II
PRACTICAL

Programme: B.Sc.	Year: SECOND	Semester: FOURTH
Subject: MATHEMATICS		
Course Code: B030402P	Course Title: PRACTICAL	

Course outcomes:

CO1: The objective of the course is to familiarize the students to use mathematical softwares such as SageMath/ Mathematica / MATLAB /Maple /Scilab/ R programming/C programming etc.

CO2: This course will enable the students to visualize the solution of first order partial differential equation.

CO3: After completion of course, students will be capable of solving second order ordinary differential equation such as Legendre and Bessel differential equation.

CO4: This course will enable the students to visualize the solution related to the problems of Kinematics, SHM, Resisting medium and Central orbit.

Credits: 2	Core Compulsory / Elective
Max. Marks: 25	Min. Passing Marks: As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 0-0-4

Unit	Topics	No. of Lectures
	• **Practical / Lab work to be performed in Computer Lab.** • **List of the practicals to be done using SageMath/Mathematica/ MATLAB /Maple /Scilab/ R programming/ C programming etc.**	**60**
I.	i. Solution of Cauchy problem for first order PDE. ii. Plotting the characteristics for the first order PDE.	**9**
II.	Plot the integral surfaces of a given first order PDE with initial data	**7**
III.	Plotting of Legendre polynomial for n = 1 to 5 in the interval [0, 1]. Verifying graphically that all the roots of $P_n(x)$ lie in the interval [0, 1].	**7**
IV.	Plotting of the Bessel's function of first kind of order 0 to 3.	**7**
V.	(i) Automatic computation of coefficients in the series solution near ordinary points (ii) Automating the Frobenius Series Method.	**9**
VI.	Find the Solution of SHM and plot the solution.	**7**
VII.	Find the orbit of a particle under the influence of different central forces.	**7**
VIII	Find the trajectory of a particle moving in a resistance media when its resistance varies with different power of velocity of particle.	**7**

This course can be opted as an elective by the students of following subjects: Open to all
Suggestions: The faculty members in colleges/universities should be trained in the following training programs: **SageMath/Mathematica/MATLAB /Python/ /Scilab/** etc. Experts from IIT's, NITTTR, or equivalent should be invited for the programs to ensure quality.
Any remarks/ suggestions: • There should be a Computer Lab with minimum of 25 computer systems for 50 students with licensed and Free Open Source softwares related to this course. • At least one **Computer Programmer / Computer Operator** must be assigned in computer lab.

B.Sc. III (SEMESTER-V) PAPER-I
GROUP, RING THEORY & LINEAR ALGEBRA

Programme: B.Sc.	Year: THIRD	Semester: FIFTH
Subject: MATHEMATICS		
Course Code: B030501T	Course Title: GROUP, RING THEORY & LINEAR ALGEBRA	

Course outcomes:
CO1: Objective of this course is to sustain the students in Abstract Algebra of almost Advanced Level.
CO2: Liner algebra is a basic course in almost all branches of science. The objective of this course is to introduce a student to the basics of linear algebra and some of its applications.
CO3: After successful completion of course, students will enable themselves to knowledge of Orthogonal set, Orthonormal set and Bilinear and Quadratic forms.
CO4: Student will use this knowledge in computer science, finance mathematics, industrial mathematics and Bio mathematics. After completion of this course students will appreciate its interdisciplinary nature.

Credits: 4	Core Compulsory / Elective
Max. Marks: 25+50	Min. Passing Marks: As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
	Assignment on "Indian Ancient Mathematics and Mathematicians" should be included under Continuous Internal Evaluation (CIE).	
	Part I **GROUP AND RING THEORY**	
I	Automorphism, inner automorphism, Automorphism groups, Automorphism groups of finite and infinite cyclic groups, Commutator subgroup and its properties.	6
II	Conjugacy classes, The class equation, Normalizer and center of Group.	6
III	Polynomial rings over commutative rings, Division algorithm, Principal ideal domains, Factorization of polynomials, Reducibility tests, Eisenstein criterion, Unique factorization in Z[x].	9
IV	Divisibility in integral domains, Irreducible, Primes, Unique factorization domains, Euclidean domains.	9
	Part II	

LINEAR ALGEBRA		
V	Vector spaces, Subspaces, Linear independence and dependence of vectors, Basis and Dimension, Linear sum and Direct sum of two subspaces, Quotient space.	**9**
VI	Linear transformations, The Algebra of linear transformations, Rank Nullity theorem, their representation as matrices.	**9**
VII	Linear functionals, Dual space, Dual Basis and Dimension.	**7**
VIII	Bilinear andQuadratic forms.	**5**

Suggested Readings (Part I: Group and Ring Theory)

1. I. N. Herstein, Topics in Algebra, Wiley
2. Joseph. A. Gallian, Contemporary Abstract Algebra, Cengage Learning India Private Limited, Delhi., Fourth impression, 2015.
3. David S. Dummit, & Richard M. Foote, Abstract Algebra (3rd ed.) (2016), Student Edition. Wiley India.
4. Course Books published in Hindi may be prescribed by the Universities.

Suggested Readings (Part II: Linear Algebra)

1. K. Hoffman and R. Kunze, Linear Algebra (2nd ed.), Prentice-Hall of India.
2. Gilbert Strang, Linear Algebra and its Applications, Cengage Learning, 2018.
3. Stephen H. Friedberg, Arnold J. Insel, & Lawrence E. Spence (2003). Linear Algebra (4th ed.). Pearson.
4. Serge Lang, Linear Algebra (3rd ed.) (1987), Springer
5. S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999
6. Course Books published in Hindi may be prescribed by the Universities.

Suggestive Digital Platforms/ Web Links:

- National Programme on Technology Enhanced Learning (NPTEL)
- SWAYAM
- Massachusetts Institute of Technology (MIT) Open Learning
- Uttar Pradesh Higher Education Digital Library (UPHEDL)
- National Digital Library of India (NDLI)

This course can be opted as an elective by the students of following subjects:

Statistics, Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence & Strategic Studies, BCA, BBA, B. Tech (Engg / Tech).

Suggested Continuous Evaluation Methods (Max. Marks: 25)

S.No.	Assessment Type	Max. Marks
1	Class Tests	10
2	Online Quizzes/ Objective Tests	5
3	Presentation	5
4	Assignment	5

Course prerequisites:

To study this course, a student must have Diploma in Mathematics.
Suggested equivalent online courses: 1. Swayam - https://www.swayam.gov.in/explorer?category=Math_and_Sciences 2. National Programme on Technology Enhanced Learning (NPTEL), https://nptel.ac.in/course.html 3. MIT Open Course Ware - Massachusetts Institute of Technology, https://ocw.mit.edu/courses/mathematics/ 4. Coursera, https://www.coursera.org/courses?query=mathematics 5. edX, https://www.edx.org/course/subject/math
Further Suggestions: Students and Faculty should be updated themselves by current knowledge of subjects and related course through digital resources, Journals and textbooks.
Any remarks/ suggestions: The course content can be modified by BOS successively catering to local need of University and Students.

NUMBER THEORY & GAME THEORY

Programme: B.Sc.	Year: THIRD	Semester: FIFTH
Subject: MATHEMATICS		
Course Code: B030502T	Course Title: NUMBER THEORY & GAME THEORY	

Course outcomes:

CO1: Upon successful completion, students will have the knowledge and skills to solve problemsin elementary number theory and also apply elementary number theory to cryptography.

CO2: This course provides an introduction to Game Theory. Game Theory is a mathematical framework which makes possible the analysis of the decision-making process of interdependent subjects. It is aimed at explaining and predicting how individuals behave in a specific strategic situation, and therefore help improve decision making.

CO3: A situation is strategic if the outcome of a decision problem depends on the choices of more than one person. Most decision problems in real life are strategic.

CO4: Students are able to use concepts of Game Theory in Real-World problems and Case-Studies.

Credits: 6	Core Compulsory / Elective
Max. Marks: 25+75	Min. Passing Marks: As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 6-0-0

Unit	Topics	No. of Lectures
	Part I **NUMBER THEORY**	
I	**Theory of Numbers** Divisibility, gcd, lcm, primes, Euclidean algorithm, Fundamental theorem of arithmetic, Congruences and their properties, Residue systems, solutions of linear congruences, Chinese remainder theorem, Fermat's Little theorem, Wilson's theorem, Fermat's quotients and their elementary consequences.	8
II	Arithmetic functions $\phi(n)$, μ(n), r(n), $\sigma(n)$, their multiplicative property and evaluation, Mobius inversion formula and applications, Euler's theorem, Euler's phi-function and their properties	7
III	Congruence modulo powers of prime, primitive roots and their existence, quadratic residues, Legendre symbols, Gauss's lemma about Legendre symbol, Law of quadratic reciprocity.	7
IV	**Diophantine Equations** Solutions of ax + by = c, $x^n + y^n = z^n$; properties of Pythagorean triples; sums of two and four squares; assorted examples of Diophantine equations.	8
	Part II **GAME THEORY**	

V	Introduction, uses of game theory, some applications and examples, payoffs, mixed strategies, pure strategy, Nash equilibrium, Characteristic of game theory	**8**
VI	Two- person zero-sum game, Pure and Mixed strategies, Saddle point and its existence.	**8**
VII	Fundamental Theorem of Rectangular games, Concept of Dominance, Dominance and Graphical method of solving rectangular games.	**7**
VIII	Relationship between rectangular game and Linear Programming Problem, Method of oddments for the solution of 2× 2 game and solution of 3×3 game without saddle point, reduction of mx n gameand solution of 2x2, 2 x s, and r x 2cases by graphical method.	**7**

Suggested Readings (Part-I Number Theory):

1. I. Niven, H. S. Zuckerman, and H. L. Montgomery, (2003) An Introduction to the Theory of Numbers (6th edition) John Wiley and sons, Inc., NewYork.
2. D. M. Burton, Elementary Number Theory (4th edition) (2002), McGraw-Hill.
3. Course Books published in Hindi may be prescribed by the Universities.

Suggested Readings (Part-II Discrete Mathematics):

4. Martin Osborne, An Introduction to Game Theory, Oxford University Press, 2003
5. Vijay Krishna, Game Theory, Academic Press.
6. Prajit Dutta, Strategies and Games, MIT Press,
   http://www.ece.stevens-tech.edu/~ccomanic/ee800c.html
7. Allan MacKenzie, Game Theory for Wireless Engineers, Synthesis lectures on Communications, 2006
8. Course Books published in Hindi may be prescribed by the Universities.

Suggestive Digital Platforms/ Web Links:

9. National Programme on Technology Enhanced Learning (NPTEL)
10. SWAYAM
11. Massachusetts Institute of Technology (MIT) Open Learning
12. Uttar Pradesh Higher Education Digital Library (UPHEDL)
13. National Digital Library of India (NDLI)

This course can be opted as an elective by the students of following subjects:

Statistics, Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence & Strategic Studies, BCA, BBA, B. Tech (Engg / Tech).

Suggested Continuous Evaluation Methods (Max. Marks: 25)

S.No.	Assessment Type	Max. Marks

1	Class Tests	10
2	Online Quizzes/ Objective Tests	5
3	Presentation	5
4	Assignment	5

Course prerequisites: To study this course, a student must have Diploma in Mathematics.

Suggested equivalent online courses:

1. Swayam - https://www.swayam.gov.in/explorer?category=Math_and_Sciences
2. National Programme on Technology Enhanced Learning (NPTEL), https://nptel.ac.in/course.html
3. MIT Open Course Ware - Massachusetts Institute of Technology, https://ocw.mit.edu/courses/mathematics/
4. Coursera, https://www.coursera.org/courses?query=mathematics
5. edX, https://www.edx.org/course/subject/math

Further Suggestions:

Students and Faculty should be updated themselves by current knowledge of subjects and related course through digital resources, Journals and textbooks.

Any remarks/ suggestions:

The course content can be modified by BOS successively catering to local need of University and Students.

B.Sc. III (SEMESTER-V) PAPER-II (ii)

GRAPH THEORY & DISCRETE MATHEMATICS

Programme: B.Sc.	**Year: THIRD**	**Semester: FIFTH**
Subject: MATHEMATICS		
Course Code: B030503T	**Course Title: GRAPH THEORY & DISCRETE MATHEMATICS**	

Course outcomes:

CO1: Upon successful completion, students will have the knowledge of various types of graphs, their terminology and applications.

CO2: After Successful completion of this course students will be able to understand the isomorphismand homomorphism of graphs. This course covers the basic concepts of graphs used in computer science and other disciplines. The topics include path, circuits, adjacency matrix, tree, coloring. After successful completion of this course the student will have the knowledge of graph coloring, color problem, vertex coloring.

CO3: After successful completion, students will have the knowledge of Logic gates, Karnaugh maps and skills to proof by using truth tables. After Successful completion of this course students will be able to apply the basics of the automation theory, transition function and table.

CO4: This course covers the basic concepts of discrete mathematics used in computer science and other disciplines that involve formal reasoning. The topics include logic, counting, relations, Hasse diagram and Boolean algebra. After successful completion of this course the student will have the knowledge in Mathematical reasoning, combinatorial analysis, discrete structures and Applications.

Credits: 6	**Core Compulsory / Elective**
Max. Marks: 25+75	**Min. Passing Marks:** As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 6-0-0

Unit	Topics	No. of Lectures
	Part I **GRAPH THEORY**	
I	Introduction to graphs, basic properties of graphs, Simple graph, multi graph, graph terminology, representation of graphs, Walk, Path and circuit, Bipartite, regular, planar and connected graphs, unicursal graph, Directed graph, unilateral connected graphs.	**8**
II	Isomorphism of graphs, Components in a graph, Eulerian paths and circuits, Hamiltonian path and circuits.	**8**
III	Operation of graphs, Adjacency matrix, Weighted graph, shortest path, Dijkstra's algorithm.	**7**
IV	Tree, Binary and Spanning trees, Graph (Vertex) colouring, chromatic number, Color problems, and important properties.	**7**

Part II DISCRETE MATHEMATICS		
V	**Propositional Logic-** Proposition, logical connectives, truth tables, tautologies, contradiction, normal forms (conjunctive and disjunctive), modus ponens and modus tollens, validity, proof by implication, converse, inverse contrapositive, contradiction, direct proof by using truth table, predicate logic, universal and existential quantification.	**8**
VI	**Relation**- Definition, types of relation, domain and range of a relation, pictorial representation of relation, properties of relation, partial ordering relation. **Lattices**: Lattices as partially ordered sets, Lattices as algebraic systems, Properties of lattices, Sublattice, Direct product, complete lattice, bounded lattice, complemented lattice, distributive lattice. **Boolean Algebra-** Basic definitions, Sum of products and products of sums, Logic gates and Karnaugh maps.	**8**
VII	**Combinatorics-** Recurrence relations (nth order recurrence relation with constant coefficients, Homogeneous recurrence relations, Inhomogeneousrecurrence relations), Generating function (closed form expression,properties of G.F., solution of recurrence relations using G.F. solution ofcombinatorial problem using G.F.).	**7**
VIII	**Finite Automata-** Basic concepts of automata theory, Deterministic Finite Automation (DFA), transition function, transition table, Non-Deterministic Finite Automata (NDFA), Minimization of finite automata.	**7**

Suggested Readings (Part-I Graph Theory):

1. Narsingh Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice Hall of India.
2. Douglas B. West, Introduction to Graph Theory, Prentice Hall.
3. Santanu Saha Ray, Graph Theory with Algorithms and Its Applications: In Applied Science and Technology, Springer.
4. Course Books published in Hindi may be prescribed by the Universities.

Suggested Readings (Part-II Discrete Mathematics):

5. C. L. Liu, Elements of Discrete Mathematics (2nd Edition), McGraw-Hill.
6. J. P. Tremblay and R. Manohar, Discrete Mathematical Structures with applications to Computer Science, Tata McGraw-Hill
7. Kenneth H. Rosen, Discrete Mathematics and its Applications, McGraw-Hill.
8. Alan Tucker, Applied Combinatorics (5th Edition), Wiley
9. Course Books published in Hindi may be prescribed by the Universities.

Suggestive Digital Platforms/ Web Links:

10. National Programme on Technology Enhanced Learning (NPTEL)
11. SWAYAM
12. Massachusetts Institute of Technology (MIT) Open Learning
13. Uttar Pradesh Higher Education Digital Library (UPHEDL)
14. National Digital Library of India (NDLI)

This course can be opted as an elective by the students of following subjects:

Statistics, Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence & Strategic Studies, BCA, BBA, B. Tech (Engg / Tech).

Suggested Continuous Evaluation Methods (Max. Marks: 25)

S.No.	Assessment Type	Max. Marks
1	Class Tests	10
2	Online Quizzes/ Objective Tests	5
3	Presentation	5
4	Assignment	5

Course prerequisites: To study this course, a student must have Diploma in Mathematics.

Suggested equivalent online courses:

6. Swayam - https://www.swayam.gov.in/explorer?category=Math_and_Sciences
7. National Programme on Technology Enhanced Learning (NPTEL), https://nptel.ac.in/course.html
8. MIT Open Course Ware - Massachusetts Institute of Technology, https://ocw.mit.edu/courses/mathematics/
9. Coursera, https://www.coursera.org/courses?query=mathematics
10. edX, https://www.edx.org/course/subject/math

Further Suggestions:

Students and Faculty should be updated themselves by current knowledge of subjects and related course through digital resources, Journals and textbooks.

Any remarks/ suggestions:

The course content can be modified by BOS successively catering to local need of University and Students.

B.Sc. III (SEMESTER-V) PAPER-II (iii)

DIFFERENTIAL GEOMETRY & TENSOR ANALYSIS

Programme: B.Sc..	**Year: THIRD**	**Semester: FIFTH**
Subject: MATHEMATICS		
Course Code: B030504T	**Course Title: DIFFERENTIAL GEOMETRY & TENSOR ANALYSIS**	

Course outcomes:

CO1: After Successful completion of this course, students should be able to determine and calculate curvature of curves in different titles of Space.

CO2: This course covers the Local theory of Curves, Local theory of surfaces, Geodesics, Geodesics curvature, Geodesic polars, Curvature of curves on surfaces, Gaussian curvature, Normal curvature etc.

CO3: After Successful completion of this course, students should have the knowledge of tensor algebra, different types of tensors, Riemannian space, Ricci tensor etc.

CO4: This course enables students to make basic platform for higher studies and research in Geometry of different type.

Credits: 6	**Core Compulsory / Elective**
Max. Marks: 25+75	**Min. Passing Marks:** As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 6-0-0

Unit	**Topics**	**No. of Lectures**
	Part- I **DIFFERENTIAL GEOMETRY**	
I	Local theory of curves-Space curves, Examples, Plane Curves, tangent and normal and binormal, Osculating Plane, normal plane and rectifying plane, osculating circle, osculating sphere Helices, Serret-Frenet apparatus, contact between curve and surfaces, tangent surfaces.	**8**
II	Local Theory of Surfaces- Family of surfaces (one parameter), ruled surfaces, skew ruled surfaces and developable surfaces, surfaces of revolution, Helicoids.	**8**
III	Metric-first fundamental form and arc length, families of curves, geodesics, canonical geodesic equations, normal properties of geodesics, geodesics curvature.	**7**
IV	Gauss-Bonnet theorem, curvature of curves on surfaces, Gaussian curvature, normal curvature, Meusneir's theorem, mean curvature, umbilic points, linesof curvature, Rodrigue's formula, Euler's theorem.	**7**

Part-II TENSOR ANALYSIS		
V	Tensor algebra: Vector spaces, the dual spaces, tensor product of vector spaces, transformation formulae, Symmetric and skew-symmetric tensors, associated tensor with examples.	**8**
VI	Tensor Analysis: Contravariant and covariant vectors and tensors, Mixed tensors, Kronecker delta and its properties, Algebra of tensors, Contraction and inner product, Quotient theorem, Reciprocal tensors, Christoffel's symbols, Law of transformation of Christoffel's symbols, Covariant differentiation.	**7**
VII	Gradient of scalars, Divergence of a contravariant vector, covariant vector and conservative vectors, Laplacian of an invariant, curl of a covariant vector, irrotational vector.	**7**
VIII	Riemannian space, Riemannian curvatures and their properties, Ricci tensor.	**8**

Suggested Readings (Part-I Differential Geometry):

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.
7. L. P. Eisenhart,An Introduction to Differential Geometry (with the use of tensor Calculus), Princeton University Press, 1940.
8. I. S. Sokolnikoff, Tensor Analysis, Theory and Applications to Geometry and Mechanics of Continua, 2nd Edition, John Wiley and Sons.,1964.
9. Q. Khan, Tensor Calculus & Differential Geometry and their Applications, Misha Books, Delhi
10. Course Books published in Hindi may be prescribed by the Universities.

Suggested Readings (Part-II Tensor Analysis):

1. Tensors- Mathematics of Differential Geometry by Z. Ahsan, PHI,2015
2. David C. Kay, Tensor Analysis, Schaum's Outline Series, McGraw Hill 1988.
3. R. S, Mishra, A Course in Tensors with Applications to Reimannian Geometry, Pothishala Pvt. Ltd, Allahabad.
4. Q. Khan, Tensor Calculus & Differential Geometry and their Applications, Misha Books, Delhi
5. Course Books published in Hindi may be prescribed by the Universities.

Suggestive Digital Platforms/ Web Links:

- National Programme on Technology Enhanced Learning (NPTEL)
- SWAYAM
- Massachusetts Institute of Technology (MIT) Open Learning
- Uttar Pradesh Higher Education Digital Library (UPHEDL)
- National Digital Library of India (NDLI)

This course can be opted as an elective by the students of following subjects:

Statistics, Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence &Strategic Studies, BCA, BBA, B.Tech(Engg / Tech).

Suggested Continuous Evaluation Methods (Max. Marks: 25)

S.No.	Assessment Type	Max. Marks
1	Class Tests	10
2	Online Quizzes/ Objective Tests	5
3	Presentation	5
4	Assignment	5

Course prerequisites: To study this course, a student must have Diploma in Mathematics.

Suggested equivalent online courses:

1. Swayam - https://www.swayam.gov.in/explorer?category=Math_and_Sciences
2. National Programme on Technology Enhanced Learning (NPTEL), https://nptel.ac.in/course.html
3. MIT Open Course Ware - Massachusetts Institute of Technology, https://ocw.mit.edu/courses/mathematics/
4. Coursera, https://www.coursera.org/courses?query=mathematics
5. edX, https://www.edx.org/course/subject/math

Further Suggestions:

Students and Faculty should be updated themselves by current knowledge of subjects and related course through digital resources, Journals and textbooks.

Any remarks/ suggestions:

The course content can be modified by BOS successively catering to local need of University and Students.

B.Sc. III (SEMESTER-V) PAPER-III
PRACTICAL

Programme: B.Sc.	Year: THIRD	Semester: FIFTH
Subject: MATHEMATICS		
Course Code: B030505P	Course Title: PRACTICAL	

Course outcomes: This course will enable the students to:

CO1: Visualize the basic concepts of vector spaces and their properties.

CO2: Employ the row echelon form in a number of applications to solve numerical problems.

CO3: Familiarize the students with suitable tools of mathematical software to handle issues and problems in Linear Algebra, Group and Rings.

CO4: Represent the outputs of programs visually in terms of well formatted text and plots.

Credits: 2	Core Compulsory / Elective
Max. Marks: 25	Min. Passing Marks: As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 0-0-4

Unit	Topics	No. of Lectures
	• **Practical / Lab work to be performed in Computer Lab.** • **List of the practicals to be done using SageMath/Mathematica/ MATLAB /Maple /Scilab/ R programming / C programming etc.**	**60**
I.	i. Check whether Z(n), Z[x], Z/Z(n) are integral domains. ii. Check whether Z(n), Z[x], Z/Z(n) are fields. iii. Check whether a subset of a ring is a subring of the ring.	**8**
II.	i. Finding zero element and unity element (if exists) of a ring. ii Finding the list of element of multiplicative group of Z(p)-{0}, . Also find multiplicative inverse of the elements in that list. iii Check whether multiplicative group of Z(p)-{0} is cyclic, if so, find multiplicative generator.	**10**
III.	Finding characteristic of rings Z(n), Q, Z.	**2**
IV.	i. Represent a vector as an n-tupe ii. Find vector addition and scalar multiplication of n tuples. iii. Find vector addition and scalar multiplication of matrices iv. Write linear combination of vectors v. Find linear span of a set of vectors	**7**
V.	Find basis and dimension of a vector space.	**8**
VI.	Check whether a given set of vectors is linearly independent or linearly dependent.	**3**

VII.	i. Find bases of kernel and range space of a linear transformation. ii. Verify Rank and Nullity Theorem for a linear transformation on a finite dimensional vector space. iii. Check whether a linear transformation is injective/surjective and hence check whether the linear transformation is an isomorphism. iv. Find the inverse of a bijective linear transformation. v. Find the pre-image of an element of range space of a linear transformation	**12**
VIII.	i. Find matrix representation of a linear transformation and check whether the linear transformation is invertible by using its matrix representation. ii. Find matrix representations of addition and composition of two linear operators on the same vector space.	**10**

This course can be opted as an elective by the students of following subjects: Open to all

Suggestions:

The faculty members in colleges/universities should be trained in the following training programs: **SageMath/Mathematica/MATLAB /Python/ /Scilab/** etc. Experts from IIT's, NITTTR, or equivalent should be invited for the programs to ensure quality.

Any remarks/ suggestions:

- There should be a Computer Lab with minimum of 25 computer systems for 50 students with licensed and Free Open Source softwares related to this course.
- At least one **Computer Programmer / Computer Operator** must be assigned in computer lab.

B.Sc. III (SEMESTER-VI) PAPER-I
METRIC SPACES & COMPLEX ANALYSIS

Programme: B.Sc.	Year: THIRD	Semester: SIXTH
Subject: MATHEMATICS		
Course Code: B030601T	Course Title: METRIC SPACES & COMPLEX ANALYSIS	

Course outcomes:

CO1: The course is aimed at exposing the students to foundations of analysis which will be useful in understanding various physical phenomena and gives the student the foundation in mathematics.

CO2: After completion of this course the student will have rigorous and deeper understanding of fundamental concepts in Mathematics. This will be helpful to the student in understanding pure mathematics and in research.

CO3: Students will be able to know the concepts of metric space, basic concepts and developments of complex analysis which will prepare the students to take up further applications in the relevant fields.

CO4: The course enables the students the basics of analytic function and contour integration for further application in higher studies.

Credits: 6	Core Compulsory / Elective
Max. Marks: 25+75	Min. Passing Marks: As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 6-0-0

Unit	Topics	No. of Lectures
	Part I **METRIC SPACES**	
I	**Basic Concepts** Metric spaces**:** Definition and examples, Sequences in metric spaces, Cauchy sequences, Complete metric space.	8
II	**Topology of Metric Spaces** Open and closed ball, Neighbourhood, Open set, Interior of a set, limit point of a set, derived set, closed set, closure of a set, diameter of a set, Cantor's theorem, Subspaces, Dense set.	8
III	**Continuity & Uniform Continuity in Metric Spaces** Continuous mappings, Sequential criterion and other characterizations of continuity, Uniform continuity, Homeomorphism, Contraction mapping, Banach fixed point theorem.	7
IV	**Connectedness and Compactness** Connectedness, Connectedness and continuous mappings, Compactness, Compactness and boundedness, Continuous functions on compact spaces.	7
	Part II	

COMPLEX ANALYSIS		
V	**Analytic Functions and Cauchy-Riemann Equations** Functions of complex variable, Mappings; Mappings by the exponential function, Limits, Theorems on limits, Limits involving the point at infinity, Continuity, Derivatives, Differentiation formulae, Analytic functions and their examples, Cauchy-Riemann equations, Sufficient conditions for Analyticity.	**8**
VI	**Elementary Functions and Integrals** Exponential function, Logarithmic function, Branches and derivatives of logarithms, Trigonometric function, Derivatives of functions, Definite integrals of functions, Contours, Contour integrals and its examples, Upper bounds for moduli of contour integrals.	**8**
VII	**Cauchy's Theorems and Fundamental Theorem of Algebra** Antiderivatives, Proof of antiderivative theorem, Cauchy-Goursat theorem, Cauchy integral formula; An extension of Cauchy integral formula, Consequences of Cauchy integral formula, Liouville's theorem and the fundamental theorem of algebra.	**7**
VIII	**Series and Residues** Convergence of sequences and series, Taylor series and its examples; Laurent series and its examples, Absolute and uniform convergence of power series, Uniqueness of series representations of power series, Isolated singular points, Types of isolated singular points, Residues, Residues at poles and its examples, Residue at infinity, Cauchy's residue theorem.	**7**

Suggested Readings (Part-I Metric Space):

1. Shanti Narayan, A Course of Mathematical Analysis, S. Chand Publication.
2. Satish Shirali and H. L Vasudeva. Metric Spaces, (2009), Springer, First Indian Print.
3. S. Kumaresan. Topology of Metric Spaces (2nd ed.), (2014). Narosa Publishing House. New Delhi.
4. G. F. Simmons, Introduction to Topology and Modern Analysis (2004), Tata McGraw Hill. New Delhi
5. Course Books published in Hindi may be prescribed by the Universities.

Suggested Readings (Part-II Complex Analysis):

1. Shanti Narayan, Theory of Functions of a Complex Variable, S. Chand Publications
2. J.W. Brown and R.V. Churchill Complex variables and Applications, McGraw-Hill Higher Education.
3. Course Books published in Hindi may be prescribed by the Universities.

Suggestive Digital Platforms/ Web Links:

- National Programme on Technology Enhanced Learning (NPTEL)
- SWAYAM
- Massachusetts Institute of Technology (MIT) Open Learning
- Uttar Pradesh Higher Education Digital Library (UPHEDL)
- National Digital Library of India (NDLI)

This course can be opted as an elective by the students of following subjects:

Statistics, Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence & Strategic Studies, BCA, BBA, B. Tech (Engg. / Tech).

Suggested Continuous Evaluation Methods (Max Marks: 25)

S.No.	Assessment Type	Max. Marks
1	Class Tests	10
2	Online Quizzes/ Objective Tests	5
3	Presentation	5
4	Assignment	5

Course prerequisites: To study this course, a student must have Diploma in Mathematics.

Suggested equivalent online courses:

1. Swayam - https://www.swayam.gov.in/explorer?category=Math_and_Sciences
2. National Programme on Technology Enhanced Learning (NPTEL), https://nptel.ac.in/course.html
3. MIT Open Course Ware - Massachusetts Institute of Technology, https://ocw.mit.edu/courses/mathematics/
4. Coursera, https://www.coursera.org/courses?query=mathematics
5. edX, https://www.edx.org/course/subject/math

Further Suggestions:

Students and Faculty should be updated themselves by current knowledge of subjects and related course through digital resources, Journals and textbooks.

Any remarks/ suggestions:

The course content can be modified by BOS successively catering to local need of University and Students.

B.Sc. III (SEMESTER-VI) PAPER-II
NUMERICAL ANALYSIS & OPERATIONS RESEARCH

Programme: B.Sc.	Year: THIRD	Semester: SIXTH
Subject: MATHEMATICS		
Course Code: **B030602T**	Course Title: NUMERICAL ANALYSIS & OPERATIONS RESEARCH	

Course outcomes:

CO1: The aim of this course is to teach the students the application of various numerical technique for variety of problems occurring in daily life. At the end of the course, the student will be able to understand the basic concepts of Numerical Analysis and to solve algebraic and differential equation.

CO2: The main outcome will be that students will be able to handle problems and finding approximated solution. Later (s)he can opt for advance course in Numerical Analysis in higher Mathematics.

CO3: The student will be able to solve various problems based on convex sets and linear programming. After successful completion of this paper will enable the students to apply the basic concepts of transportation problems and its related problems to apply in further concepts and application of operation research.

CO4: After successful completion of this course students have basic knowledge of Numerical Analysis and Operations Research for higher study and Research.

Credits: 4	Core Compulsory / Elective
Max. Marks: 25+50	Min. Passing Marks: As per UGC/ University CBCS norm.

Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 4-0-0

Unit	Topics	No. of Lectures
	Part I **NUMERICAL ANALYSIS**	
I	**Solution of equations:** Bisection, Regula-Falsi, Secant, Newton-Raphson's method, Newton's method for multiple roots, Interpolation, Lagrange interpolation, Difference schemes, Divided differences, Interpolation formula using differences.	8
II	**Numerical differentiation, Numerical Quadrature:** Newton-Cotes Formulas, Gaussian Quadrature Formulas, **System of Linear equations:** Direct method for solving systems of linear equations (Gauss elimination, LU Decomposition), Iterative methods (Jacobi, Gauss Seidel).	8
III	**The Algebraic Eigen value problem:** Power method, Jacobi's method, Given's method. **Numerical solution of Ordinary differential equations:** Single step methods: Euler method, Runge-Kutta method, multi-step method: Milne-Simpson method.	7
IV	**Types of approximation:** Least Square polynomial approximation, Chebyshev polynomial approximation. **Numerical solution of Difference Equations:** Shooting method and Difference equation method for solving elementary Linear second order differential equation.	7

Part II OPERATIONS RESEARCH		
V	Introduction, Linear programming problems, statement and formation of general linear programming problems, graphical method, slack and surplus variables, standardand matrix forms of linear programming problem, basic feasible solution.	**8**
VI	Convex sets, fundamental theorem of linear programming, basic solution, Simplex method, introduction to artificial variables, two phase method Big-M method and their comparison.	**8**
VII	Resolution of degeneracy, duality in linear programming problems, primal dual relationships, revised simplex method, sensitivity analysis.	**7**
VIII	Transportation problems, Assignment problems.	**7**

Suggested Readings (Part-I Numerical Analysis):

1. M. K. Jain, S.R.K. Iyengar & R.K. Jain, Numerical Methods for Engineering and scientific computation
2. S. S. Sastry, Introductory methods of Numerical Analysis
3. Course Books published in Hindi may be prescribed by the Universities.

Suggested Readings (Part-II Operation Research):

1. Taha, Hamdy H, Operations Research- An Introduction, Pearson Education.
2. Kanti Swarup , P. K. Gupta , Man Mohan Operations research, Sultan Chand & Sons
3. Hillier Frederick S and Lieberman Gerald J., Operations Research, McGraw Hill Publication.
4. Winston Wayne L., Operations Research: Applications and Algorithms, Cengage Learning, 4th Edition.
5. Hira D.S. and Gupta Prem Kumar, "Problems in Operations Research: Principles and Solutions", S Chand & Co Ltd.
6. Kalavathy S., Operations Research, S. Chand.
7. Course Books published in Hindi may be prescribed by the Universities.

Suggestive Digital Platforms/ Web Links:

- National Programme on Technology Enhanced Learning (NPTEL)
- SWAYAM
- Massachusetts Institute of Technology (MIT) Open Learning
- Uttar Pradesh Higher Education Digital Library (UPHEDL)
- National Digital Library of India (NDLI)

This course can be opted as an elective by the students of following subjects:

Statistics, Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence & Strategic Studies, BCA, BBA, B. Tech (Eng./ Tech).

Suggested Continuous Evaluation Methods (Max. Marks: 25)

S.No.	Assessment Type	Max. Marks
1	Class Tests	10
2	Online Quizzes/ Objective Tests	5
3	Power Point Presentation	5

4	Assignment	5

Course prerequisites: To study this course, a student must have Diploma in Mathematics.

Suggested equivalent online courses:

1. Swayam - https://www.swayam.gov.in/explorer?category=Math_and_Sciences
2. National Programme on Technology Enhanced Learning (NPTEL), https://nptel.ac.in/course.html
3. MIT Open Course Ware - Massachusetts Institute of Technology, https://ocw.mit.edu/courses/mathematics/
4. Coursera, https://www.coursera.org/courses?query=mathematics
5. edX, https://www.edx.org/course/subject/math

Further Suggestions:

Students and Faculty should be updated themselves by current knowledge of subjects and related course through digital resources, Journals and textbooks.

Any remarks/ suggestions:

The course content can be modified by BOS successively catering to local need of University and Students.

B.Sc. III (SEMESTER-VI) PAPER-III

PRACTICAL

Programme: B.Sc.	Year: THIRD	Semester: SIXTH
Subject: MATHEMATICS		
Course Code: B030603P	Course Title: PRACTICAL	
Course outcomes: The main objective of the course is to equip the student to solve the transcendental and algebraic equations, system of linear equations, Interpolation, Numerical Integration, method of finding Eigenvalue by Power method, ordinary differential equations, ordinary difference equations and Linear Programming Problem.		
Credits: 2	Core Compulsory / Elective	
Max. Marks: 25	Min. Passing Marks: As per UGC/ University CBCS norm.	
Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 0-0-4		

Unit	Topics	No. of Lectures
	• **Practical / Lab work to be performed in Computer Lab.** • **List of the practicals to be done using SageMath/Mathematica/ MATLAB /Maple /Scilab/ R programming / C programming etc.**	**60**
I.	Solution of transcendental and algebraic equations by i. Bisection method ii. Regula Falsi method iii. Secant method iv. Newton Raphson method	8
II.	Solution of system of linear equations by i. LU decomposition method ii. Gaussian elimination method iii. Gauss-Jacobi method iv. Gauss-Seidel method	8
III.	Interpolation by i. Lagrange Interpolation ii. Newton's forward Interpolation iii. Newton's backward Interpolation iv. Newton's divided difference interpolations	7
IV.	Numerical Integration by i. Trapezoidal Rule ii. Simpson's one third rule iii. Simpson's three-eighth rule iv. Weddle's Rule	7
V.	Complex numbers and their representations, Operations like addition, Multiplication, Division, Modulus, Graphical representation of polar formand Hyperbolic functions.	8
VI.	Solution of ordinary differential equations by	8

	i. Euler method ii. Runge- Kutta method (order 4)	
VII.	Solution of ordinary difference equations by Shooting method.	7
VIII.	Solution of Linear Programming Problem by Simplex method.	7

This course can be opted as an elective by the students of following subjects: Open to all

Suggestions:

The faculty members in colleges/universities should be trained in the following training programs: **SageMath/Mathematica/MATLAB /Python/ /Scilab/** etc. Experts from IIT's, NITTTR, or equivalent should be invited for the programs to ensure quality.

Any remarks/ suggestions:

- There should be a Computer Lab with minimum of 25 computer systems for 50 students with licensed and Free Open Source softwares related to this course.
- At least one **Computer Programmer / Computer Operator** must be assigned in computer lab.