DR. RAM MANOHAR LOHIA AVADH UNIVERSITY, AYODHYA

Proposed Structure of Syllabus for the

PROGRAM: B.A. / B.Sc.
SUBJECT: MATHEMATICS

Syllabus Developed/Proposed by				
S.No.	**Name of Expert/BoS Member**	**Designation**	**Department**	**College/ University**
1.	**Dr Shiv Kumar Tiwari**	Associate Professor & Convener	Mathematics	K.S. Saket P.G. College, Ayodhya
2.	**Prof. Arvind Kumar Misra**	Professor & Expert	Mathematics	Institute of Science, B.H.U., Varanasi
3.	**Dr Sanjay Kumar Pandey**	Associate Professor & Member	Mathematics	Shri L. B. S. Degree College, Gonda
4.	**Dr Jayash Nath Mishra**	Principal & Member	Mathematics	G. S. P.G. College, Sultanpur

Semester wise Title of the Papers in UG MATHEMATICS Course					
Year	**Semester**	**Course Code**	**Paper Title**	**Theory/Practical**	**Credits**
CERTIFICATE IN APPLIED MATHEMATICS					
FIRST	**SEM-I**	B030101T	DIFFERENTIAL CALCULUS & INTEGRAL CALCULUS	THEORY	**4**
		B030102P	PRACTICAL	PRACTICAL	**2**
	SEM-II	B030201T	MATRICES AND DIFFERENTIAL EQUATIONS & GEOMETRY	THEORY	**4**
		B030202P	PRACTICAL	PRACTICAL	**2**
DIPLOMA IN MATHEMATICS					
SECOND	**SEM-III**	B030301T	ALGEBRA & MATHEMATICAL METHODS	THEORY	**4**
		B030302P	PRACTICAL	PRACTICAL	**2**
	SEM-IV	B030401T	DIFFERENTIAL EQUATION & MECHANICS	THEORY	**4**
		B030402P	PRACTICAL	PRACTICAL	**2**
DEGREE IN MATHEMATICS					
THIRD	**SEM-V**	B030501T	GROUP AND RING THEORY & LINEAR ALGEBRA	THEORY	**4**

		B030502T	Opt Any one of the following (Elective/ Optional): NUMBER THEORY & GAME THEORY	THEORY	**4**
		B030503T	GRAPH THEORY & DISCRETE MATHEMATICS	THEORY	**4**
		B030504T	DIFFERENTIAL GEOMETRY & TENSOR ANALYSIS	THEORY	**4**
		B030505P	PRACTICAL	PRACTICAL	**2**
		B030506R	PROJECT-I	PROJECT & VIVA-VOCE	**3**
	SEM-VI	B030601T	METRIC SPACE & COMPLEX ANALYSIS	THEORY	**4**
		B030602T	NUMERICAL ANALYSIS & OPERATIONS RESEARCH	THEORY	**4**
		B030603P	PRACTICAL	PRACTICAL	**2**
		B030604R	PROJECT-II	PROJECT & VIVA-VOCE	**3**

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 basics of mathematics including applied aspects for the same.

PO2: It is to develop enhanced quantitative skills and 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 exposer to many aspects of mathematical sciences.
Third Year	Degree in Mathematics	Student is equipped with mathematical modelling ability, critical mathematical thinking, problem solving skill, etc and apply his/her skill and knowledge in various field of studies including Science, Engineering, Commerce and Management etc.

Semester wise Paper Titles with Details					
Year	**Semester**	**Paper**	**Paper Title**	**Prerequisite for Paper**	**Elective for Major Subjects**
CERTIFICATE IN APPLIED MATHEMATICS					
First	**SEM-I**	Theory Paper - I	DIFFERENTIAL CALCULUS AND INTEGRAL CALCULUS	Mathematics in 12th	Open to ALL
		Practical Paper - II	PRACTICAL (Practicals to be done using SageMath/Mathematica/ MATLAB /Maple /Scilab/ etc.)	Mathematics in 12th	Open to ALL
	SEM-II	Theory Paper - I	MATRICES AND DIFFERENTIAL EQUATIONS & GEOMETRY	Mathematics in 12th	Open to ALL
		Practical Paper- II	PRACTICAL (Practicals to be done using SageMath/Mathematica/ MATLAB /Maple /Scilab/ etc.)	Mathematics in 12th	Open to ALL
DIPLOMA IN MATHEMATICS					
Second	**SEM-III**	Theory Paper - I	ALGEBRA & MATHEMATICAL METHODS	Certificate course in Applied Mathematics	Open to ALL
		Practical Paper- II	PRACTICAL (Practicals to be done using SageMath/Mathematica/ MATLAB /Maple /Scilab/ etc.)	Certificate course in Applied Mathematics	Open to ALL
	SEM-IV	Theory Paper - I	DIFFERENTIAL EQUATION & MECHANICS	Certificate course in Applied Mathematics	Open to ALL
		Practical Paper- II	PRACTICAL (Practicals to be done using SageMath/Mathematica/ MATLAB /Maple /Scilab/ etc.)	Certificate course in Applied Mathematics	Open to ALL
DEGREE IN MATHEMATICS					
Third	**SEM-V**	Theory Paper - I	GROUP AND RING THEORY & LINEAR ALGEBRA	Diploma in Mathematics	Statistics , Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence & Strategic Studies , BCA,BBA B.Tech(Engg / Tech)
		Theory Paper - II	Opt Any One Of The Following (Elective/ Optional): I. NUMBER THEORY AND GAME THEORY	Diploma in Mathematics	Statistics , Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence

			II. GRAPH THEORY AND DISCRETE MATHEMATICS III. DIFFERENTIAL GEOMETRY AND TENSOR ANALYSIS		& Strategic Studies , BCA,BBA B.Tech(Engg / Tech)
		Practical Paper- III	PRACTICAL (Practicals to be done using SageMath/Mathematica/ MATLAB /Maple /Scilab/ etc.)	Diploma in Mathematics	Statistics , Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence & Strategic Studies , BCA,BBA B.Tech(Engg / Tech)
		Project Paper-IV	PROJECT-I	Diploma in Mathematics	Statistics , Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence & Strategic Studies , BCA,BBA B.Tech(Engg / Tech)
	SEM-VI	Theory Paper - I	METRIC SPACE & COMPLEX ANALYSIS	Diploma in Mathematics	Statistics , Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence & Strategic Studies , BCA,BBA B.Tech(Engg / Tech)
		Theory Paper - II	NUMERICAL ANALYSIS & OPERATIONS RESEARCH	Diploma in Mathematics	Statistics , Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence & Strategic Studies , BCA,BBA B.Tech(Engg / Tech)
		Practical Paper- III	PRACTICAL (Practicals to be done using SageMath/Mathematica/ MATLAB /Maple /Scilab/ etc.)	Diploma in Mathematics	Statistics , Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence & Strategic Studies , BCA,BBA B.Tech(Engg / Tech)
		Project Paper-IV	PROJECT-II	Diploma in Mathematics	Statistics , Physics, Computer Sc. / App Chem., Bio-Chem, Geography, Economics, Defence & Strategic Studies , BCA,BBA B.Tech(Engg / Tech)

B.A./B.Sc. I (SEMESTER-I) PAPER-I
DIFFERENTIAL CALCULUS & INTEGRAL CALCULUS

Programme : CERTIFICATE **Class: B.A. /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 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 well towards taking more advance level course in mathematics.

Credits: 4	**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: 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 normals, 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 of Integration.	**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. S. Balachandra Rao & C. K. Shantha, Differential Calculus, New Age Publication.
4. H. Anton, I. Birens and S. Davis, Calculus, John Wiley and Sons, Inc., 2002.
5. G.B. Thomas and R.L. Finney, Calculus, Pearson Education, 2007.
6. 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. Shanti Narayan & Dr. P.K. Mittal, Integral Calculus, S.Chand
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 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.A./B.Sc. I (SEMESTER-I) PAPER-II
PRACTICAL

Programme : CERTIFICATE Class: B.A. / 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 graph and solve the different types of equations by plotting the graph using different computer software such as SageMath/Mathematica/MATLAB /Maple /Scilab/ 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+75	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/ 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) $\frac{\lvert x\rvert}{x}; \sin(\frac{1}{x}); x\sin(\frac{1}{x})$; 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**

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 / 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.A./B.Sc. I (SEMESTER-II) PAPER-I
MATRICES AND DIFFERENTIAL EQUATIONS & GEOMETRY

Programme : CERTIFICATE **Class: B.A. /B.Sc.**	**Year: FIRST**	**Semester: SECOND**
Subject: MATHEMATICS		
Course Code: B030201T	**Course Title: MATRICES AND DIFFERENTIAL EQUATIONS & GEOMETRY**	

Course outcomes:

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

CO2: The student will be able to 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+75	**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, System of linear homogeneous and non-homogeneous equations, Theorems on consistency of a system of linear equations (without proof).	9
II	Eigen values, Eigen vectors and characteristic equation of a matrix, Cayley-Hamilton theorem and its use in finding inverse of a matrix. Complex functions and separation into real and imaginary parts, Inverse Trigonometric and Hyperbolic Functions.	7
III	Formation of differential equations, Equation of first order and first degree, Equation in which the variables are separable, Homogeneous differential equations, Exact differential equations, Linear differential equations.	7
IV	First order higher degree differential equations solvable for p, y ,x. Clairaut's differential equation and singular solutions, Linear differential equation with constant coefficients, Cauchy- Euler form.	7

Part II 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, Plane section of conicoids, Confocal conicoids.	**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 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. R.J.T. Bill, Elementary Treatise on Coordinate Geometry of Three Dimensions, McMillan India Ltd., 1994
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 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.A./B.Sc. I (SEMESTER-II)
PAPER-II PRACTICAL

Programme : CERTIFICATE Class: B.A. / 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/ 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+75	**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/ etc.**	**60**
I.	i. Complex numbers and their representations, Operations like addition, Multiplication, Division, Modulus. Graphical representation of polar form. ii. Graph of Circular trigonometric function, Inverse trigonometric function and Hyperbolic function.	**9**
II.	Matrix Operations: Addition, Multiplication, Inverse, Transpose, Determinant, Rank.	**7**
III.	i. For square matrices finding characteristic equation, Eigen-values, Eigen-vectors. ii. Verification of the Cayley-Hamilton theorem and solving the systems of linear equations.	**7**
IV.	Tracing of Circle, Ellipse, Hyperbola and Parabola in Cartesian coordinates/ polar coordinates.	**7**
V.	Tracing of Sphere, Cone, Cylinder, Ellipsoid, Hyperboloid of one and two sheets, Elliptic cone, Elliptic paraboloid, and Hyperbolic paraboloid using Cartesian coordinates.	**9**
VI.	Plotting of family of curves which are solutions of first order differential equation.	**7**
VII.	Plotting of family of curves which are solutions of second order differential equation.	**7**
VIII.	Plotting of family of curves which are solutions of third order differential equation.	**7**

Suggestive Digital Platforms/ Web Links:

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- 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 / 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.

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

Programme : DIPLOMA **Class: B.A. / 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: A student 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 in going for higher studies and research.

Credits: 4	**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: 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	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, Coset decomposition, Lagrange's theorem and its consequences, Fermat and Euler theorems.	7
III	Normal subgroups, Quotient groups, Homomorphism and isomorphism, Cayley's theorem, Fundamental theorem of homomorphism.	7
IV	Rings, Subrings, Integral domains and fields, subfield, Characteristic of a ring, Ideal and quotient rings.	7
	Part II **MATHEMATICAL METHODS**	
V	Limit and Continuity of functions of two variables, Differentiation of function of two variables, Taylor's theorem for functions of two variables with examples, Maxima and minima for functions of two variables, Lagrange	**9**

	multiplier method, Jacobians.	
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.	**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, Addison-weley
2. Gallian, Joseph. A. , 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, Person
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.A./B.Sc. II (SEMESTER-III) PAPER-II
PRACTICAL

Programme : DIPLOMA Class: B.A. / 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/ etc.

CO2: After completion of course students would be able to visualize important 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+75	**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/ etc.**	**60**
I.	i. Calculation of Addition modulo n and Multiplication modulo n. ii. Finding elements of group U(n) and Inverse of each element in U(n).	**9**
II.	Cyclic subgroups of group U(n) generated by each k in U(n) for given n (e.g. n = 12, 15, and 30).	**7**
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. $z = x^2 + y^2$).	**9**
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**

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 / Lab Record	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

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.

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

Programme : DIPLOMA Class: B.A. / 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+75	**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	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, Monge's method of solution.	7

Part II MECHANICS		
V	Forces in three dimensions, Poinsot's central axis, Wrenches, Null lines and Null planes.	**9**
VI	Virtual work, Stable and Unstable equilibrium, Catenary.	**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 three dimensions.	**7**

Suggested Readings(Part-I Differential Equations):

1. G.F. Simmons, Differential Equations with Application and Historical Notes, Tata–McGrawHill
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, Prentics Hall Publishers
2. R.C. Hibbeler, Engineering Mechanics-Dynamics, Prentics Hall Publishers
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.A./B.Sc. II (SEMESTER-IV) PAPER-II
PRACTICAL

Programme : DIPLOMA Class: B.A. / 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/ 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+75	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/ 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 Pn (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**

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 / Lab Record	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

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.

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

Programme : DEGREE Class: B.A. / B.Sc.	Year: THIRD	Semester: FIFTH
Subject: MATHEMATICS		
Course Code: **B030501T**	Course Title: GROUP AND RING THEORY & LINEAR ALGEBRA	

Course outcomes:

CO1: Objective of this course is to sustain the students in Abtract 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+75	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. Normalizer and center of Group.	**8**
II	Conjugacy classes, The class equation, *p*-groups, The Sylow theorems and consequences, Applications of Sylow theorems; Finite simple groups, Nonsimplicity tests.	**8**
III	Polynomial rings over commutative rings, Division algorithm, Principal ideal domains, Factorization of polynomials, Reducibility tests, Unique factorization in Z[x].	**7**
IV	Divisibility in integral domains, Irreducibles, Primes, Unique factorization domains.	**7**
	Part II **LINEAR ALGEBRA**	
V	Vector spaces, Subspaces, Linear independence and dependence of vectors, Basis and Dimension, Quotient space.	**8**

VI	Linear transformations, The Algebra of linear transformations, Rank Nullity theorem, their representation as matrices.	**8**
VII	Linear functionals, Dual space, Dual Basis and Dimension, Annihilators.	**7**
VIII	Inner product spaces and norms, Cauchy-Schwarz inequality, Orthogonal vectors, Orthonormal sets and bases, Bessel's inequality for finite dimensional spaces, Bilinear and Quadratic forms.	**7**

Suggested Readings (Part I: Group And Ring Theory)

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

Suggested Readings (Part II: Linear Algebra)

1. Linear Algebra by K. Hoffman and R. Kunze.
2. Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
3. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2003). Linear Algebra (4th ed.). Prentice-Hall of India Pvt. Ltd. New Delhi
4. Lang, Serge (1987). Linear Algebra (3rd ed.). 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.

B.A./B.Sc. III (SEMESTER-V) PAPER-II (i)
NUMBER THEORY & GAME THEORY

Programme : DEGREE Class: B.A. / 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 problems in 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 enable to use concept of Game Theory in Real-World problems and Case-Studies.

Credits: 4	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: 4-0-0	

Unit	Topics	No. of Lectures
	Part I **NUMBER THEORY**	
I	**Theory of Numbers** Divisibility; Euclidean algorithm; primes; congruences; Fermat's theorem, Euler's theorem and Wilson's theorem; Fermat's quotients and their elementary consequences; solutions of congruences; Chinese remainder theorem; Euler's phi-function.	8
II	**Congruences** Congruence modulo powers of prime; primitive roots and their existence; quadratic residues; Legendre symbol, Gauss' lemma about Legendre symbol; quadratic reciprocity law.	8
III	**Diophantine Equations** Solutions of ax + by = c, $x^n + y^n = z^n$; properties of Pythagorean triples; sums of two, four and five squares; assorted examples of diophantine equations.	7
IV	**Generating Functions and Recurrence Relations** Generating Function Models, Calculating coefficient of generating functions, Partitions, Exponential Generating Functions, A Summation Method. Recurrence Relations: Recurrence Relation Models, Solution of Linear, Recurrence Relations, Solutions with Generating Functions.	7
	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, Solving rectangular game by Simplex method, reduction of m x n game and solution of 2x2, 2 x s, and r x 2 cases by graphical method.	**7**

Suggested Readings (Part-I Number Theory):

1. Niven, I., Zuckerman, H. S. and Montegomery, H. L. (2003) An Int. to the Theory of Numbers (6th edition) John Wiley and sons, Inc., New York.
2. Burton, D. M. (2002) Elementary Number Theory (4th edition) Universal Book Stall, New Delhi.
3. Balakrishnan, V. K. (1994) Schaum's Outline of Theory and Problems of Combinatorics Including Concepts of Graph Theory, Schaum's Outline.
4. Balakrishnan,V. K. (1996) Introductory Discrete Mathematics, Dover Publications.
5. Course Books published in Hindi may be prescribed by the Universities.

Suggested Readings (Part-II Game Theory):

1. Martin Osborne, An Introduction to Game Theory, Oxford University Press, 2003
2. Vijay Krishna, Game Theory, Academic Press.
3. Prajit Dutta, Strategies and Games, MIT Press, http://www.ece.stevens-tech.edu/~ccomanic/ee800c.html
4. Allan MacKenzie, Game Theory for Wireless Engineers, Synthesis lectures on Communications, 2006
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.A./B.Sc. III (SEMESTER-V) PAPER-II (ii)
GRAPH THEORY & DISCRETE MATHEMATICS

Programme : DEGREE Class: B.A. / 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 isomorphism and 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: 4	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: 4-0-0

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, Bipartite, regular, planar and connected graphs, connected components in a graph, Euler graphs, Directed graph, Undirected graph.	8
II	Walk and unilateral components, unicursal graph, Hamiltonian path and circuits, Graph colouring, chromatics number, isomorphism and homomorphism of graphs.	8
III	Operation of graph circuit, Path and circuits, Eulerian circuits, Hamiltonian path and cycles, Adjacency matrix, Weighted graph, Shortest path, Dijkstra's algorithm.	7
IV	Tree, Binary and Spanning trees, Coloring, Color problems, Vertex coloring and important properties.	7

	Part II DISCRETE MATHEMATICS	
V	**Propositional Logic-** Proposition logic, logical connectives, truth tables, tautologies, contradiction, normal forms (conjunctive and disjunctive), modus ponens and modus tollens, validity, universal and existential quantification, proof by implication, converse, inverse contrapositive, contradiction, direct proof by using truth table.	**8**
VI	**Relation**- Definition, types of relation, domain and range of a relation, pictorial representation of relation, properties of relation, partial ordering relation. **Boolean Algebra-** Basic definitions, Sum of products and products of sums, Logic gates and Karnaugh maps.	**8**
VII	**Combinatories-** Recurrence relations (nth order recurrence relation with constant coefficients, Homogeneous recurrence relations, Inhomogeneous recurrence relations), Generating function (closed form expression, properties of G.F., solution of recurrence relations using G.F. solution of combinatorial problem using G.F.)	**7**
VIII	**Finite Automata-** Basic concepts of automation theory, Deterministic Finite Automation (DFA), transition function, transition table, Non Deterministic Finite Automata (NDFA), Mealy and Moore machine.	**7**

Suggested Readings (Part-I Graph Theory):

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

Suggested Readings (Part-II Discrete Mathematics):

1. Discrete Mathematics by C. L.Liu.
2. Discrete Mathematics with computer application by Trembley and Manohar.
3. Discrete Mathematics and its Application by Kenneth H. Rosen.
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:

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.A./B.Sc. III (SEMESTER-V) PAPER-II (iii)
DIFFERENTIAL GEOMETRY & TENSOR ANALYSIS

Programme : DEGREE **Class: B.A. / 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, Einstein space and Einstein tensor etc.

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

Credits: 4	**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: 4-0-0	

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, fundamental existence theorem for space curves.	**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, lines of 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.	**8**
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, scalar curvature, Einstein space and Einstein tensor.	**7**

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. An Introduction to Differential Geometry (with the use of tensor Calculus), L. P. Eisenhart, Princeton University Press, 1940.
8. Tensor Analysis, Theory and Applications to Geometry and Mechanics of Continua, 2nd Edition, I. S. Sokolnikoff, 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.A./B.Sc. III (SEMESTER-V) PAPER-III
PRACTICAL

Programme : DEGREE Class: B.A. / 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+75	**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/ etc.**	**60**
I.	Write a program to do the following- i) Enter a vector u as a n-list. ii) Enter another vector v as a n-list. iii) Find the vector au +bv for different values of a and b. iv) Find the dot product of u and v.	**8**
II.	Write a program to do the following- i. Enter an r by c matrix M(r and c being positive integers). ii. Display M in matrix format. iii. Display the row and columns of the matrix M. iv. Find the scalar multiplication of M for a given scalar. v. Find the transpose of the matrix M	**8**
III.	Write a program to do the following- i. Find the vector-matrix multiplication of a r by c matrix M with an c- vector u. ii. Find the matrix- matrix product of M with a c by p matrix N.	**7**
IV.	Write a program to do the following- i. Enter a vector b and find the projection of b orthogonal to a given vector u. ii. Find the projection of b orthogonal to a set of given vectors.	**7**
V.	i. Write a program to enter a matrix and check if it is invertible. If the inverse exists, find the inverse. ii. Write a program to convert a matrix into its row echelon form.	**8**
VI.	i. Write a program to print all primes (Sieve_of_Eratosthenes) smaller than or equal to a specified number.	**8**

	ii. Write a program to implement Euclidean Algorithm to compute the greatest common divisor (gcd)	
VII.	i. Write a program to create a new plot in which the points of S are translated, scaled and rotated. ii. Write a program to print a complex number and its real and imaginary parts	**7**
VIII.	i. Write a program to find all the roots of a quadratic equation. ii. Write a program to get the length and the angle of a complex number.	**7**

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 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

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.

B.A./B.Sc. III (SEMESTER-V) PAPER-IV
PROJECT-I

Programme : DEGREE Class: B.A. / B.Sc.	Year: THIRD	Semester: FIFTH
Subject: MATHEMATICS		
Course Code: B030506R	**Course Title: PROJECT -I**	
Course outcomes: After successful completion of project work, the student will gain basic platform for independent and critical thinking and confidence for completing any assignment.		
Credits: 3	**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: 0-0-6		

Unit	Topics	Expected Hours by student
	In this course, students are encouraged to choose the topic of their interest and do an in-depth study of the same and with some illuminating real time applications under supervision of a faculty member.	90

Guidelines for Under Graduate (B.A./B.Sc.) Mathematics Project

1. Any student registering for doing project is required to inform the In-charge , Mathematics the name of his/her project supervisor(s) at the time of pre-registration.
2. The student must submit the "Project Registration Form'' to the In-charge, Mathematics. Sample of Project Registration Form is given below:

Project Registration Form

Name of the college:	
Department	
Name of the student:	
Roll No. :	
e-mail :	
Name of the supervisor(s):	
Title of the Project:	
Signature of the Student:	
Signature of supervisor(s):	
Signature of HOD, Mathematics	

3. A student may have at the most two Project Supervisors and the topic of the project should be relevant to Mathematical Sciences. If a student desires to have two Supervisors, at least one of these should be from the Department of Mathematics.
4. The student will be required to submit hard copy and an electronic version of the final Project Report / Dissertation to the Department of Mathematics. The final Project Report / Dissertation should not be longer than 50 A4 size pages in 1.5 line spacing. The following sequence for the thesis organization should be followed:
   (i) **Preliminaries** (Title Page; Certificate; Abstract/Synopsis; Acknowledgement and/ or Dedication; Table of Contents; List of Figures ,Tables, Illustrations, Symbols, etc (wherever applicable))
   (ii) **Text of Thesis** (Introduction; The body of the thesis, summary and conclusions)
   (iii) **Reference Material** (List of References /Bibliography)
   (iv) **Appendices** (if any)

5. The student will be required to make an oral presentation in front of a Project committee of the following members:
   i. Internal Examiner or / and Supervisor (s) or / and In-charge (Mathematics)
   ii. External Examiner (appointed by University / BOS Mathematics)

   In addition, the project is evaluated by the Project committee as per prescribed marks distribution.

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	Project Report /Dissertation	10
2	Presentation & Viva-Voce	10
3	Significance of Project work at Local /National / International level.	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

Further Suggestions:

The students should be encouraged to visit different institute. During such visits a learner has access to knowledge by attending academic activities such as seminars, colloquia, library consultation and discussion with faculty members. These activities provide guidance and direction for further study.

Any remarks/ suggestions:

Industrial / Institution visits offer an opportunity to observe real time applications of mathematical concepts. During these visits the students may be accompanied by faculty members also. These visits give an opportunity to realize the power of mathematical ideas and their translation in problem solving.

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

Programme : DEGREE Class: B.A. / 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: 4	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: 4-0-0	

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

Suggested Readings (Part-II Complex Analysis):

1. Function of Complex Variable by Shanti Narain.
2. Complex variable and applications by Brown & Churchill.
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.A./B.Sc. III (SEMESTER-VI) PAPER-II
NUMERICAL ANALYSIS & OPERATION RESEARCH

Programme : DEGREE **Class: B.A. / B.Sc.**	**Year: THIRD**	**Semester: SIXTH**
Subject: MATHEMATICS		
Course Code: B030602T	**Course Title: NUMERICAL ANALYSIS & OPERATION 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 concept 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 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+75	**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, Regular 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, Givens 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	7

	polynomial approximation. **Numerical solution of Difference Equations:** Shooting method and Difference equation method for solving elementary Linear second order differential equation.	
	Part II **OPERATION RESEARCH**	
V	Introduction, Linear programming problems, statement and formation of general linear programming problems, graphical method, slack and surplus variables, standard and 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. Numerical Methods for Engineering and scientific computation by M. K. Jain, S.R.K. Iyengar & R.K. Jain.
2. Introductory methods of Numerical Analysis by S. S. Sastry
3. Course Books published in Hindi may be prescribed by the Universities.

Suggested Readings (Part-II Operation Research):

1. Taha, Hamdy H, "Opearations 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(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.A./B.Sc. III (SEMESTER-VI) PAPER-III
PRACTICAL

Programme : DEGREE Class: B.A. / 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+75	**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/ 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-eight rule iv. Weddle's Rule	7
V.	Finding Eigenvalue by Power method/ Jacobi's method/ Givens method.	8
VI.	Solution of ordinary differential equations by i. Euler method	8

	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

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 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

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.

B.A./B.Sc. III (SEMESTER-VI) PAPER-IV
PROJECT-II

Programme : DEGREE Class: B.A. / B.Sc.	Year: THIRD	Semester: SIXTH
Subject: MATHEMATICS		
Course Code: B030604R	**Course Title: PROJECT-II**	
Course outcomes: After successful completion of project work, the student will gain basic platform for independent and critical thinking and confidence for completing any assignment.		
Credits: 3	**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: 0-0-6		

Unit	Topics	Expected Hours by student
	In this course, students are encouraged to choose the topic of their interest and do an in-depth study of the same and with some illuminating real time applications under supervision of a faculty member.	90

Guidelines for Under Graduate (B.A./B.Sc.) Mathematics Project

1. Any student registering for doing project is required to inform the In-charge , Mathematics the name of his/her project supervisor(s) at the time of pre-registration.
2. The student must submit the "Project Registration Form'' to the In-charge, Mathematics. Sample of Project Registration Form is given below:

Project Registration Form

Name of the college:	
Department	
Name of the student:	
Roll No. :	
e-mail :	
Name of the supervisor(s):	
Title of the Project:	
Signature of the Student:	
Signature of supervisor(s):	
Signature of HOD, Mathematics	

3. A student may have at the most two Project Supervisors and the topic of the project should be relevant to Mathematical Sciences. If a student desires to have two Supervisors, at least one of these should be from the Department of Mathematics.
4. The student will be required to submit hard copy and an electronic version of the final Project Report / Dissertation to the Department of Mathematics. The final Project Report / Dissertation should not be longer than 50 A4 size pages in 1.5 line spacing. The following sequence for the thesis organization should be followed:
   (i) **Preliminaries** (Title Page; Certificate; Abstract/Synopsis; Acknowledgement and/ or Dedication; Table of Contents; List of Figures ,Tables, Illustrations, Symbols, etc (wherever applicable))
   (ii) **Text of Thesis** (Introduction; The body of the thesis, summary and conclusions)
   (iii) **Reference Material** (List of References /Bibliography)
   (iv) **Appendices** (if any)

5. The student will be required to make an oral presentation in front of a Project committee of the following members:
   i. Internal Examiner or / and Supervisor (s) or / and In-charge (Mathematics)
   ii. External Examiner (appointed by University / BOS Mathematics)

   In addition, the project is evaluated by the Project committee as per prescribed marks distribution.

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	Project Report /Dissertation	10
2	Presentation & Viva-Voce	10
3	Significance of Project work at Local /National / International level.	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

Further Suggestions:

The students should be encouraged to visit different institute. During such visits a learner has access to knowledge by attending academic activities such as seminars, colloquia, library consultation and discussion with faculty members. These activities provide guidance and direction for further study.

Any remarks/ suggestions:

Industrial / Institution visits offer an opportunity to observe real time applications of mathematical concepts. During these visits the students may be accompanied by faculty members also. These visits give an opportunity to realize the power of mathematical ideas and their translation in problem solving.