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Category- I University Status awarded by UGC

No. 2026/June/AAMS/C-167/48223

Date:05th June, 2026

CIRCULAR:-

Attention of all the Principals of the Affiliated Colleges, all Academic Heads of University Departments, the Directors of the Recognized Institutions/Centres, Director, Centre for Distance & Online Education, Director, Dharmaveer Anand Dighe Thane Sub-Campus, Co-ordinator, School of Engineering and Applied Sciences, Kalyan Sub-Campus, Director, Chitrakar Padmabhushan Dr.Dhananjay Keer Ratnagiri Sub-Campus, Director, Sindhudurg Sub-Campus, Principal, Vishwabhusan Bharatratna Dr. B. A. Ambedkar College, Ambadave, Ratnagiri and Principal, V.V. Dalvie College, Talere, Sindhudurg is invited to this office Circular No.2026/May/AAMS-III/C-73/42964 dated 08th May, 2026 relating to the B.A / B.Sc. (Mathematics) (Sem V & VI) (Scheme - I).

They are hereby informed that the recommendations made by the Board of Studies in Mathematics at its meeting held on 15th April, 2026 and subsequently passed by the Board of Deans at its meeting held on 15th May, 2026 vide item No.1 have been accepted by the Academic Council at its meeting held on 18th May, 2026 vide item No.6.14 (N). In accordance therewith syllabus of B.A./B.Sc.(Hons.) in Mathematics (Sem VII & VIII) (NEP 2020) is introduced as per appendix with effect from the academic year 2026-27.

(The said circular is available on the University's website www.mu.ac.in).

MUMBAI – 400 032

05th June, 2026

To

(Dr. Prasad Karande)
REGISTRAR

All the Principals of the Affiliated Colleges, all Academic Heads of Departments, the Directors of the Recognized Institutions/Centres, Director, Centre for Distance & Online Education, Director, Dharmaveer Anand Dighe Thane Sub-Campus, Co-ordinator, School of Engineering and Applied Sciences, Kalyan Sub-Campus, Director, Chitrakar Padmabhushan Dr.Dhananjay Keer Ratnagiri Sub-Campus, Director, Sindhudurg Sub-Campus, Principal, Vishwabhusan Bharatratna Dr. B. A. Ambedkar College, Ambadave, Ratnagiri and Principal, V.V. Dalvie College, Talere, Sindhudurg

AC./6.14 (N)/18/5/2026

Copy forwarded with Compliments for information to:-

- 1) The Chairman, Board of Deans,
- 2) The Dean, Faculty of Science,
- 3) The Chairman, **Board of Studies in Mathematics**
- 4) The Director, Board of Examinations and Evaluation,
- 5) The Director, Department of Students Development,
- 6) The Director, Department of Information & Communication Technology,
- 7) The Director, Centre for Distance and Online Education (CDOE)Vidyanagari,
- 8) The Deputy Registrar, Admission, Enrolment, Eligibility & Migration Department (AEM),

Copy forwarded for information and necessary action to :-	
1	The Deputy Registrar, (Admissions, Enrolment, Eligibility and Migration Dept)(AEM), dr@eligi.mu.ac.in
2	The Deputy Registrar, Result unit, Vidyanagari drresults@exam.mu.ac.in
3	The Deputy Registrar, Marks and Certificate Unit,. Vidyanagari dr.verification@mu.ac.in
4	The Deputy Registrar, Appointment Unit, Vidyanagari dr.appointment@exam.mu.ac.in
5	The Deputy Registrar, CAP Unit, Vidyanagari cap.exam@mu.ac.in
6	The Deputy Registrar, College Affiliations & Development Department (CAD), deputyregistrar.uni@gmail.com
7	The Deputy Registrar, PRO, Fort, (Publication Section), Pro@mu.ac.in
8	The Deputy Registrar, Executive Authorities Section (EA) eau120@fort.mu.ac.in He is requested to treat this as action taken report on the concerned resolution adopted by the Academic Council referred to the above circular.
9	The Deputy Registrar, Research Administration & Promotion Cell (RAPC), rapc@mu.ac.in
10	The Deputy Registrar, Academic Appointments & Quality Assurance (AAQA) dy.registrar.tau.fort.mu.ac.in ar.tau@fort.mu.ac.in
11	The Deputy Registrar, College Teachers Approval Unit (CTA), concolsection@gmail.com
12	The Deputy Registrars, Finance & Accounts Section, fort draccounts@fort.mu.ac.in
13	The Deputy Registrar, Election Section, Fort drelection@election.mu.ac.in
14	The Assistant Registrar, Administrative Sub-Campus Thane, thanesubcampus@mu.ac.in
15	The Assistant Registrar, School of Engg. & Applied Sciences, Kalyan, ar.seask@mu.ac.in
16	The Assistant Registrar, Ratnagiri Sub-centre, Ratnagiri, ratnagirisubcentar@gmail.com
17	The Director, Centre for Distance and Online Education (CDOE), Vidyanagari, director@idol.mu.ac.in
18	Director, Innovation, Incubation and Linkages, Dr. Sachin Laddha pinkumanno@gmail.com
19	Director, Department of Lifelong Learning and Extension (DLLE), dlleuniversityofmumbai@gmail.com

Copy for information :-	
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2	P.A to Pro-Vice-Chancellor pvc@fort.mu.ac.in
3	P.A to Registrar, registrar@fort.mu.ac.in
4	P.A to all Deans of all Faculties
5	P.A to Finance & Account Officers, (F & A.O), camu@accounts.mu.ac.in

To,

1	The Chairman, Board of Deans pvc@fort.mu.ac.in
2	Faculty of Humanities, Offg. Dean 1. Prof.Anil Singh Dranilsingh129@gmail.com Offg. Associate Dean 2. Prof.Manisha Karne mkarne@economics.mu.ac.in 3. Dr.Suchitra Naik Naiksuchitra27@gmail.com
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	Faculty of Science & Technology Offg. Dean 1. Prof. Shivram Garje ssgarje@chem.mu.ac.in Offg. Associate Dean 2. Dr. Madhav R. Rajwade Madhavr64@gmail.com 3. Prin. Deven Shah sir.deven@gmail.com
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6	The Director, Department of Information & Communication Technology, director.dict@mu.ac.in

As Per NEP 2020

University of Mumbai



Syllabus for B.A./B.Sc. (Hons.) in Mathematics UG Fourth Year

Faulty	Science & Technology
Board of Studies	Mathematics
Semester	VII & VIII
From the Academic Year	2026-27

University of Mumbai



(As per NEP 2020)

Sr. No.	Heading	Particulars
1	Title of program O: _____	B.A./B.Sc. (Hons.) in Mathematics
2	Exit Degree	B.A./B.Sc. (Hons.) in Mathematics
3	Scheme of Examination R: _____	NEP 50% Internal 50% External, Semester End Examination Individual Passing in Internal and External Examination
4	Standards of Passing R: _____	40%
5	Credit Structure R: SU-530 G R: SU-530 H	Attached herewith
6	Semesters	Sem. VII & VIII
7	Program Academic Level	6.0
8	Pattern	Semester
9	Status	New
10	To be implemented from Academic Year	2026-27

Sd/-

Sign of the BOS
Name Prof. B. S. Desale
Chairman
BOS in Mathematics

Sd/-

Sign of the
Offg. Associate Dean
Dr. Madhav R. Rajwade
Faculty of Science &
Technology

Sd/-

Sign of the Offg. Dean
Prof. Shivram S. Garje
Faculty of Science &
Technology

B.A./B.Sc. (Hons.) in Mathematics
Credit Structure (Sem. VII & VIII)

	R: SU-530 G										
Vertical		1		1A	2	3	4	5	6		
Level	Semester	Major		RM	Minor	OE/	VSC, SEC (VSEC)	AEC, VEC, IKS	OJT, FP, CEP, CC,RP	Cum. Cr. / Sem.	Degree/ Cum. Cr.
		Mandatory	Electives								
6.0	VII	14 (4+4+4+2) Algebra I (4) Real Analysis (4) Ordinary Differential Equation (4) Discrete Mathematics & Number Theory (2)	4 Commutative Algebra/ Graph Theory/ Programming in Python/ Linear & Non Linear Programming	RM (4) Research Methodology (4)	---	---	---	----	--	22	UG Honours Degree 176
	R: SU-530 H										
	VIII	14 (4+4+4+2) Algebra II (4) Topology (4) Complex Analysis (4) Partial Differential Equations (2)	4 Algebraic Number Theory/ Advanced Counting Techniques/ Algebraic Topology / Numerical Analysis	---	---	----	----	----	OJT: On Job Training (4)	22	
	Cum Cr.	68	16	4	18	12	14	14	30	44	176
	Exit option: Award of Four year UG Honours with Research Degree in Major and Minor with 176 credits										

[Abbreviation - OE – Open Electives, RM – Research Methodology, VSC – Vocation Skill Course, SEC – Skill Enhancement Course, (VSEC), AEC – Ability Enhancement Course, VEC – Value Education Course, IKS – Indian Knowledge System, OJT – On Job Training, FP – Field Project, CEP – Community Engagement Project, CC – Co-Curricular, RP – Research Project]

Program Structure for Sem. VII & VIII

(NEP 2020)

B.A./B.Sc. (Hons.) in Mathematics

Vertical No		Paper Title	Credits
Sem. VII			
1.	Mandatory	1. Algebra I	4
		2. Real Analysis	4
		3. Ordinary Differential Equations	4
		4. Discrete Mathematics and Number Theory	2
	Electives (Choose any one)	1. Commutative Algebra	4
		2. Graph Theory	4
		3. Programming in Python	4
		4. Linear & Non Linear Programming	4
1A.	Research Methodology		4
Credits			22
Sem. VIII			
1	Mandatory	1. Algebra	4
		2. Topology	4
		3. Complex Analysis	4
		4. Partial Differential Equations	2
	Electives (Choose any one)	1. Algebraic Number Theory	4
		2. Advanced Counting Techniques in Discrete Mathematics	4
		3. Algebraic Topology	4
		4. Numerical Analysis	4
6	OJT	OJT (On Job Training)	4
Credits			22
Total Credits			44

Sem. - VII

Sem. - VII

Vertical – 1

Major

Mandatory

(4+4+4+2)

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VII)
Title of Paper: 1111462701 : Algebra I

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	Subject Algebra-I covers linear algebra, which is the backbone for learning further algebra courses. This subject is specially essential for modern day applications in data science and machine learning.
2	Vertical :	Major
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours & 8 – 10 Practicals
6	Marks Allotted:	100 Marks
7	Course Objectives: 1. Students will be introduced to the notion of dual space and double dual. 2. Students will be equipped to comprehend the annihilator of a subspace and its application to counting the dimension of a finite dimensional vector space. 3. The course aims equip students to identify the basic properties of determinants and understand their applications to solving system of equations. 4. The course aims equip students to identify the basic properties of determinants and	

	understand their applications to solving system of equations too. 5. On completion, the course will enable students to compare if the given forms are bilinear forms. The course will prove the spectral theorem with examples of spectral resolution. Symmetric bilinear forms and Sylvester's law, which are useful in applications will be spelt out too.
8	Course Outcomes: 1. The students will be able to demonstrate how the isomorphism between the dual space and the double dual works. 2. They will be able to employ the techniques of the theorems to compute the dual basis with respect to a given one. Also they will be analyze properties of determinants and use them for computation of determinants. 3. Students will be able to differentiate between invariant and non-invariant subspaces. 4. Students will be able to examine if a given form is a bilinear form. 5. Students will be able to convert a given matrix into the correct canonical form so that the signature of the symmetric form can be determined using Sylvester's law.

9	Modules:- All results have to be done with proof unless otherwise stated.
	Module 1: Dual spaces
	1. Linear functionals, dual spaces of a vector space, dual basis (for finite dimensional vector spaces) 2. <i>Annihilator</i> W^0 in the dual space V^* of a subspace W of a vector space V and dimension formula, a k-dimensional subspace of an n-dimensional vector space is intersection of $n-k$ many hyperspaces. 3. Double dual V^{**} of a vector space V and canonical embedding of V into V^{**}. V^{**} is isomorphic to V when V is of finite dimension. (ref:[1] Hoffman K. and Kunze R.). 4. Transpose T^t of a linear transformation T. For finite dimensional vector spaces: $\text{rank } T^t = \text{rank } T$, $\text{range } (T^t)$ is the annihilator of kernel (T), matrix representing T^t (ref:[1] Hoffman K and Kunze R)

Module 2: Determinants & Characteristic Polynomial

1. Rank of a matrix. Matrix of a linear transformation, change of basis, similar matrices.
2. Determinants as alternating n-forms, existence and uniqueness, Laplace expansion of determinant, determinants of products and transposes.
3. Adjoint of a matrix, determinants and invertible linear transformations, determinant of a linear transformation. Solution of system of linear equations using Cramer's rule.

Eigenvalues and eigenvectors of a linear transformation, Annihilating polynomial, Characteristic polynomial, minimal polynomial, Cayley-Hamilton theorem. (Reference for Unit II: [1] Hoffman K and Kunze R, Linear Algebra).

Module 3: Triangulation of matrices

1. Triangulable and diagonalizable linear operators, invariant subspaces and simple matrix representation (for finite dimension). (ref: [5] N.S. Gopalkrishnan & [3] Serge Lang)
2. Nilpotent linear transformations on finite dimensional vector spaces, index of a Nilpotent linear transformation. Linear independence of $\{u, Nu, \dots, N^{(k-1)}u\}$ where N is a nilpotent linear transformation of index $k \geq 2$ of a vector space V and $u \in V$ with $Nu \neq 0$. (Ref: 2] I.N.Herstein).
3. For a nilpotent linear transformation N of a finite dimensional vector space V and for any subspace W of V which is invariant under N , there exists a subspace V_1 of V such that $V = W \oplus V_1$. (Ref:[2] I.N.Herstein).

Computations related to 3×3 matrices, their minimal polynomials and Jordan canonical forms.

Module 4: Bilinear forms

1. Adjoint of a linear operator on an inner product space, unitary operators, self adjoint operators, normal operators. (ref:[1] Hoffman K and Kunze R).
2. Spectral theorem for a normal operator on a finite dimensional complex inner product space. (ref:[4] Michael Artin, Ch. 8). Spectral resolution (examples only). (ref:[1] Hoffman K and Kunze R, sec 9.5).
3. Bilinear form, rank of a bilinear form, non-degenerate bilinear form and equivalent statements. (ref:[1] Hoffman K and Kunze R).

Symmetric bilinear forms, orthogonal basis and Sylvester's Law, signature of a Symmetric bilinear form. (ref:[4] Michael Artin).

10 List of Practicals :

1. Computation of Dual basis, annihilators and transpose.
2. Computations of determinants using theoretical properties.
3. Eigenvalues, eigenvectors, minimal and characteristic polynomial.
4. Computations on diagonalizable and triangulable linear operators.
5. Invariant subspaces, nilpotent transformations and examples on Jordan canonical forms.
6. Inner product spaces, Gram-Schmidt process, computing adjoint of a linear transformation.
7. Test the properties of Normal and unitary operator. Verify Spectral theorem.
8. Bilinear forms, non-degenerate forms and applications of Sylvester's law to find the signature of symmetric bilinear form.

11 Reference Books:

1. Hoffman K and Kunze R: Linear Algebra, Prentice-Hall India.
2. I.N.Herstein: Topics in Algebra, Wiley-India
3. Serge Lang: Linear Algebra, Springer-Verlag Undergraduate Text in Mathematics.
4. Michael Artin: Algebra, Prentice-Hall India.
5. N.S. Gopalkrishnan: University Algebra, New Age International, third edition, 2015.

12 Internal Continuous Assessment:
50%

External, Semester End Examination
50%

Individual Passing in Internal and External Examination

13 Continuous Evaluation through:

Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc. (at least 3)

Solving Problems, Assignments, Tutorials, Seminar and Practicals

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VII)
Title of Paper: 1111462702 : Real Analysis

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	Subject Real Analysis covers mathematical analysis techniques in the Real domain
2	Vertical :	Major
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours + 8 – 10 Practicals
6	Marks Allotted:	100 Marks
7	Course Objectives: 6. The students will be introduced to Euclidean spaces and topology on them. 7. Students will learn about operator norms and their properties. 8. Students will interpret the concept of differentiability in an abstract manner. 9. The course will equip the students with the knowledge of basic theorems like the inverse function theorem, implicit function theorem and mean value theorem. 10. The course aims to demonstrate explicitly how Riemann integration works and the role of Fubini's theorem in calculations in a wide range of examples.	

8	Course Outcomes: - Students will be able to judge if the given Euclidean spaces are compact or not. - Students will be able to select Euclidean spaces that are compact, connected from the given list of spaces. - They will be able to predict if the given function is continuous/uniformly continuous or not. - Students will be able to test if the hypothesis of the implicit function theorem and implicit function theorem hold. If yes, they will further be able to explain the arising consequences. - Students will be able to evaluate the Riemann integral and illustrate how Fubini's theorem works.
9	Modules:- All results have to be done with proof unless otherwise stated. Module 1: Euclidean space R^n - Euclidean space R^n : inner product $\langle x, y \rangle = \sum_{j=1}^n x_j y_j$ of $x = (x_1, \dots, x_n), y = (y_1, \dots, y_n) \in R^n$ and properties, norm $\ x\ = \sqrt{\sum_{j=1}^n x_j^2}$ of $x = (x_1, \dots, x_n) \in R^n$, Cauchy-Schwarz inequality, properties of the norm function $\ x\$ on R^n. (Ref. W. Rudin or M. Spivak). - Standard topology on R^n : open subsets of R^n, closed subsets of R^n, interior A° and boundary ∂A of a subset A of R^n. (ref. M. Spivak) - Operator norm $\ T\$ of a linear transformation $T: R^n \rightarrow R^m$ ($\ T\ = \sup\{\ T(v)\ : v \in R^n \wedge \ v\ \leq 1\}$) and its properties such as: For all linear maps $S, T: R^n \rightarrow R^m$ and $R: R^m \rightarrow R^k$ $\ S + T\ \leq \ S\ + \ T\$, $\ R \circ S\ \leq \ R\ \ S\$, and $\ cT\ = c \ T\$ ($c \in R$). (Ref. C. C. Pugh or A. Browder) - Compactness: Open cover of a subset of R^n, Compact subsets of R^n (A subset K of R^n is compact if every open cover of K contains a finite subcover), Heine-Borel theorem (statement only), the Cartesian product of two compact subsets of R^n is compact (statement only), every closed and bounded subset of R^n is compact - Bolzano-Weierstrass theorem: Any bounded sequence in R^n has a convergent subsequence.

10. Functions and continuity and uniform continuity.

Module 2: Differentiable functions

4. Differentiable functions on R^n , the total derivative $(Df)_p$ of a differentiable function $f: U \rightarrow R^m$ at $p \in U$ where U is open in R^n , uniqueness of total derivative, differentiability implies continuity.(ref:[1] C.C.Pugh or[2] A.Browder)
5. Chain rule. Applications of chain rule such as:
 - II. Let γ be a differentiable curve in an open subset U of R^n . Let $f: U \rightarrow R$ be a differentiable function and let $g(t) = f(\gamma(t))$. Then $g'(t) = \langle (\nabla f)(\gamma(t)), \gamma'(t) \rangle$.
 - III. Computation of total derivatives of real valued functions such as
 - (a) the determinant function $\det(X), X \in M_n(R)$,
 - (b) the Euclidean inner product function $\langle x, y \rangle, (x, y) \in R^n \times R^n$.(ref. M. Spivak, W. Rudin)
6. Results on total derivative: partial derivatives, directional derivative $(D_u f)(p)$ of a function f at p in the direction of the unit vector, Jacobian matrix, Jacobian determinant. Results such as :
 - I. If the total derivative of a map $f = (f_1, \dots, f_m): U \rightarrow R^m$ (U open subset of R^n) exists at $p \in U$, then all the partial derivatives $\frac{\partial f_i}{\partial x_j}$ exists at p .
 - II. If all the partial derivatives $\frac{\partial f_i}{\partial x_j}$ of a map $f = (f_1, \dots, f_m): U \rightarrow R^m$ (U open subset of R^n) exist and are continuous on U , then f is differentiable.(ref. W. Rudin)
7. Derivatives of higher order, C^k -functions, C^∞ -functions.(ref. T. Apostol)

Module 3: Inverse function theorem and Implicit function theorem

1. Theorem (Mean Value Inequality): Suppose $f: U \rightarrow R^m$ is differentiable on an open subset U of R^n and there is a real number M such that $\|f(Df)_x\| \leq M \forall x \in U$. If the segment $[p, q]$ is contained in U , then $\|f(q) - f(p)\| \leq M\|q - p\|$. (ref. C. C. Pugh or A. Browder).
2. Mean Value Theorem: Let $f: U \rightarrow R^m$ is a differentiable on an open subset U of R^n . Let $p, q \in U$ such that the segment $[p, q]$ is contained in U . Then for every vector $v \in R^n$ there is a point $x \in [p, q]$ such that $\langle v, f(q) - f(p) \rangle = \langle v, (Df)_x(q - p) \rangle$. (ref:T. Apostol) If

$f: U \rightarrow R^m$ is differentiable on a connected open subset U of R^n and $(Df)_x = 0$ for all $x \in U$, then f is a constant map.

3. Contraction mapping theorem. Inverse function theorem, Implicit function theorem.(ref. A. Browder)
4. Taylor expansion for a real valued C^m -function defined on an open subset of R^n , stationary points(critical points), maxima, minima, saddle points, second derivative test for extrema at a stationary point of a real valued C^2 -function defined on an open subset of R^n . Lagrange's method of undetermined multipliers.
(ref. T. Apostol)

Module 4: Riemann Integration

1. Riemann Integration over a rectangle in R^n , Riemann Integrable functions
2. Continuous functions are Riemann integrable,
3. Measure zero sets, Lebesgues Theorem(statement only)
4. Fubini's Theorem and applications. (Reference for Unit IV: M. Spivak, Calculus on Manifolds).

10 List of Practicals :

1. Euclidean spaces, operator norms and compactness.
2. Continuity and uniform continuity of functions, compactness and connectedness.
3. Results on total derivatives.
4. Chain rule and partial derivatives; C^k , C^∞ - functions.
5. Mean value theorem, Inverse function theorem, implicit function theorem.
6. Maxima, minima, Taylor expansion and Lagrange's method of multipliers.
7. Riemann Integration, Measurable sets.
8. Functions and Riemann integrability and Fubini's theorem.

11 Reference Books:

1. C. C. Pugh, Mathematical Analysis, Springer UTM.
2. A. Browder, Mathematical Analysis an Introduction, Springer.
3. T. Apostol, Mathematical Analysis, Narosa.
4. W. Rudin, Principles of Mathematical Analysis, McGraw-Hill India.
5. M. Spivak, Calculus on Manifolds, Harper-Collins Publishers.

12 Internal Continuous Assessment:

50%

External, Semester End Examination

50%

	Individual Passing in Internal and External Examination	
13	Continuous Evaluation through: Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc.(at least 3)	Solving Problems, Assignments, Tutorials, Seminar and Practicals

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VII)

Title of Paper: 1111462703 : Ordinary Differential Equations

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	Subject ordinary differential equations covers theory and examples of existence and uniqueness of solution of ordinary differential equations
2	Vertical :	Major
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours + 8 -10 Practicals
6	Marks Allotted:	100 Marks
7	Course Objectives: 1. Students will be introduced the conditions for existence and uniqueness of the solution of initial value problems. 2. Students will learn various techniques of solving Linear Ordinary Differential Equations with constant and variable coefficients. 3. The course aims to demonstrate the qualitative properties of solution of Ordinary Differential Equations.	

8	Course Outcomes: 1. Through this course students are expected to understand the basic concepts of existence and uniqueness of solutions of Ordinary Differential Equations (ODEs). 2. In case of nonlinear ODEs, students will learn how to construct the sequence of approximate solutions converges to the exact solution if exact solution is not possible. 3. Students will be able to understand the qualitative features of solutions. 4. Students will be able to identify Sturm Liouville problems and to understand the special functions like Legendre's polynomials and Bessel's function. 1. 5. Students will be to understand the applicability of the above concepts in different disciplines of technology.
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9	Modules:- All results have to be done with proof unless otherwise stated. Module 1: Existence and Uniqueness of Solutions 1. Existence and Uniqueness of solutions to initial value problem of first order ODE- both autonomous, non autonomous, ϵ-approximate solutions, 2. Ascoli lemma, Cauchy-Peano existence theorem, 3. Lipschitz condition, Picard's method of successive approximations, 4. Picard-Lindelof theorem, System of Differential equations. Reduction of n-th order differential equations. [Reference Unit-I of Theory of Ordinary Differential Equations; Earl A. Coddington and Norman Levinson, Tata McGraw Hill, India.] Module 2: Linear Equations with constant coefficients 1. The second order homogeneous equations, Initial value problem for second order equations, Uniqueness theorem 2. Linear dependance and independence of solutions, Wronskian,a formula for the Wronskian, 3. The second order non-homogeneous equations, The homogeneous equations of order n, Initial value problem for n th order equations, 4. The nonhomogeneous equations of order n, Algebra of constant coefficient operators. [Reference Unit-II of Earl A. Coddington, An Introduction to Ordinary Differential Equations, Prentice-Hall of India.]
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Module 3: Linear Equations with variable coefficients

1. Initial value problem for the homogeneous equation of order n , Existence and Uniqueness theorem
2. Solution of the homogeneous equations, Wronskian and linear independence
3. Reduction of the order of a homogeneous equation, the non-homogeneous equations of order n .

[Reference III of Earl A. Coddington, An Introduction to Ordinary Differential Equations, Prentice-Hall of India.]

Module 4: Sturm-Liouville Problem & Qualitative Properties of Solutions

1. Eigenvalue problem, Eigenvalues and Eigenfunctions,
2. The vibrating string problem, Sturm Liouville problems, homogeneous and non-homogeneous boundary conditions, orthogonality property of eigenfunctions, Existence of Eigenvalues and Eigenfunctions,
3. Sturm Separation theorem, Sturm comparison theorem. Power series solution of second order linear equations, ordinary points, singular points, regular singular points.
4. Existence of solution of homogeneous second order linear equation, solution of Legendre's equation, Legendre's polynomials, Rodrigues' formula, orthogonality conditions
5. Bessel differential equation, Bessel functions, Properties of Bessel function, orthogonality of Bessel functions.

[Reference Unit IV (24, 25), Unit V (Review), Unit-VII (40, 43, Appendix A) and Unit VIII (44, 45, 46, 47) : G. F. Simmons, Differential Equations with Applications and Historical Notes, Second Edition, Tata McGraw Hill, India]

10 List of Practicals :

1. The Lipschitz condition.
2. Picard's theorem for solving initial value problems
3. Solving a system of first order differential equations
4. Linear dependence and independence of functions, Wronskian of two or more functions.
5. Solving an n th order homogeneous/non-homogeneous equation with constant

	coefficients. The particular integral may be evaluated using operator method or by the method of variation of parameters. 6. Solving linear, homogeneous differential equations of order n with variable coefficients, solving initial value problems. Reduction of the order of a homogeneous 7. Differential equation and solving the same. Solution of the corresponding nonhomogeneous differential equation. 8. Solving eigenvalue problem, eigenvalues and eigenfunctions, solving vibrating string problem, Sturm Liouville problem, orthogonality of its eigenfunctions. 9. Sturm Separation theorem, Sturm Comparison theorem, Power series solution of second order linear differential equations, ordinary points, singular points, regular singularity. 10. Solution of Legendre's equation, legendre polynomials, Rodrigue's formula, orthogonality of legendre polynomials. 11. Bessel's differential equation, Bessel's functions and their properties, orthogonality of Bessel's functions.	
11	Reference Books: 1. Earl A., Coddington and Norman Levinson, Theory of Ordinary Differential Equations; Tata McGraw Hill, India. 2. Earl A. Coddington, An Introduction to Ordinary Differential Equations, PrenticeHall of India. 3. G. F. Simmons, Differential Equations with Applications and Historical Notes, Second Edition, Tata McGraw Hill, India 4. Hurewicz W., Lectures on ordinary differential equations, M.I.T. Press. 5. Morris W. Hirsch and Stephen Smale, Differential Equations, Dynamical Systems, Linear Algebra, Elsevier.	
12	Internal Continuous Assessment: 50%	External, Semester End Examination 50%
	Individual Passing in Internal and External Examination	
13	Continuous Evaluation through: Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc.(at least 3)	Solving Problems, Assignments, Tutorials, Semnar and Practical

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VII)

Name of the Course: 1111462704 : Discrete Mathematics and Number Theory

Sr. No.	Heading	Particulars
1	Description of the course:	Subject Discrete Mathematics and Number Theory covers various counting principles and related examples
2	Vertical :	Major
3	Type :	Practical
4	Credit:	2 credits (30 Hours of Practical work in a semester)
5	Hours Allotted :	30 Hours
6	Marks Allotted:	50 Marks
7	Course Objectives (CO): 1. The course aims to develop theory of linear diophantine equations and conditions for solving them. 2. To identify arithmetic functions and in particular the multiplicativity of the functions τ, σ and ϕ. 3. To associate various methods of solving recurrence relations 4. To recognize the applications of Polya theory of counting for various enumeration problems including those in other sciences.	
8	Course Outcomes (OC): At the end of the course, the students will be able to 1. Apply mathematical techniques to compute solutions of linear diophantine equations 2. Analyze conditions under which techniques of counting for many real-life problems. 3. Justify/check solutions of real life problems using inclusion-exclusion principle. 4. Construct solutions to coloring problems and enumeration problems in other scientific domains.	
9	Modules:-	

Module 1: Basics of Number theory and counting (8 Lectures and 7 Practicals)

1. Divisibility, Linear Diophantine equations
2. Congruences and their properties
3. Arithmetic functions σ , τ , φ
4. Multiplicative properties of arithmetic functions
5. Permutations (with and without repetition) and combinations,
6. Equivalence to solving equations with non-negative integral solutions.
7. Selections with Repetitions from multisets.

Module 2: Techniques of counting and Polya theory (7 Lectures and 8 Practicals)

1. Pigeon-hole principle
2. Inclusion Exclusion principle and its applications like counting derangements
3. Methods to solve recurrence relations with constant coefficients: homogeneous recurrence relations
4. Methods to solve non-homogeneous recurrence relations
5. Group action (specially for permutation groups), Orbit stabiliser theorem
6. Burnside Lemma and its applications
7. Cycle index, Polya's Formula
8. Applications of Polya's Formula to counting problems in sciences.

10 List of Practicals

1. Arithmetic functions and congruences.
2. Distribution of distinguishable and indistinguishable objects into distinguishable
3. and indistinguishable boxes (with conditions on distribution), Counting problems
4. from multisets.
5. Inclusion-exclusion principle and recurrence relations.
6. Counting via Burnside's lemma and Polya's formula.

11 Recommended Text Books

1. D. M. Burton, Introduction to Number Theory, McGraw-Hill.
2. Nadkarni and Telang, Introduction to Number Theory
3. V. Krishnamurthy: Combinatorics: Theory and applications, Affiliated East-West Press.
4. Richard A. Brualdi: Introductory Combinatorics, Pearson.
5. A. Tucker: Applied Combinatorics, John Wiley & Sons.
6. Norman L. Biggs: Discrete Mathematics, Oxford University Press.
7. Kenneth Rosen: Discrete Mathematics and its applications, Tata McGraw Hills.

	8. Sharad S. Sane, Combinatorial Techniques, Hindustan Book Agency, 2013.	
12	Internal Continuous Assessment: 25%	External, Semester End Examination 25%
	Individual Passing in Internal and External Examination	
13	Continuous Evaluation through: Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc.(at least 3)	Solving Problems, Assignments, Tutorials, Seminar and Practicals

Research Methodology (4)

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VII)

Title of Paper: 1111462705 : Research Methodology

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	Subject Research methodology covers ethical research and latex typing of mathematical equations
2	Vertical :	1A RM
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours & 8 – 10 Practicals
6	Marks Allotted:	100 Marks
7	Course Objectives: 1. To understand the meaning of research methodology 2. To learn how to define research problems 3. To learn how to review literature and research report 4. To learn how to use various tools available in Latex 5. To learn use of Mathematical softwares.	

8	Course Outcomes: After completion of the course, learners would be able to: 1. Initiate some research work, research project of their own 2. Write Literature review and Research report. 3. Make Question paper, write Thesis, Resume in Latex 4. Draw pictures and Plot graphs in Latex, Make beamer presentation. 5. Use mathematical software for better understanding of Mathematical Concepts.
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9	Modules:-
	Module 1: Introduction to Research Methodology
	1. Meaning of Research, Objectives of Research, Motivations in Research 2. Ethics of research (Legal issues, copyright, plagiarism) 3. Types of Research, Research Approaches 4. Significance of Research, Research Methods v/s Methodology 5. Research and Scientific Methods, Research Process, Criteria of good Research. 6. Defining the Research Problem: What is Research Problem? Selecting the problem, Necessity of and Techniques in defining the problem.
	Module 2: Research literature and review
	1. Review of Literature: Purpose of the Review 2. Identification of the related Literature, Organizing the related Literature, Archive. 3. Research Report: General format of the Research report, writing technical research report, 4. Writing a research proposal, research paper, chapter writing, Ph.D. thesis, Erratum, Proof reading 5. Keywords and Phrases, Mathematical subject Classifications and indexing 6. Short communication, fast track communication of a research paper, Poster/Oral presentation, Plenary talks, Invited talks of a conference/ workshop.
	Module 3: LaTeX
	1. Getting Started with LaTeX: Installing and using LaTeX 2. Working with LaTeX online using Overleaf, Preamble, Basic Syntax: Creating a Title Page, Page Numbering and Headings, Modifying Text, 3. Use packages. Fonts, symbols, indenting, paragraphs, line spacing, word spacing, titles and subtitles

4. Document class, page style, parts of the documents, table of contents, Command names and arguments, environments, declarations , Theorem like declarations, comments within text
5. Writing equations, Matrix, Tables, Math in Latex, Advanced Math in Latex. Page Layout: Titles, Abstract, Chapters, Sections, Equation references, citation. Table of contents, generating new commands,
6. Figure handling, numbering, List of figures, List of tables, Generating bibliography and index.
7. Beamer presentation
8. Tikz: drawing simple pictures, Function plotting, drawing pictures with nodes

Module 4: Mathematics Software

1. Use of Mathematical software Geogebra / Scilab/ wxMaxima/ Mathematica/ Matlab.

10 List of Practicals :

1. Basic of Latex.
2. Practical on mathematical tools.
3. Practical on Table of contents, generating new commands.

11 Reference Books:

1. C.R. Kothari and Gaurav Garg, Research Methodology Methods and Techniques, New Age International Publishers, 2019.
2. Stefan Kottwitz, LaTeX Beginner's Guide, Packt Publications.

12 Internal Continuous Assessment:

50%

External, Semester End Examination

50%

Individual Passing in Internal and External Examination

13 Continuous Evaluation through:

Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc. (at least 3)

Solving Problems, Assignments, Tutorials, Seminar and Practicals

SEM VII

Vertical – 1

Major

Electives

(4)

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VII)

Title of Paper: 11114627061 : Commutative Algebra

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	This classical subject builds the bridge between algebra and geometry and strengthens the notions of idelas, prime ideals and maximal ideals that students have learnt in their undergraduate classes.
2	Vertical :	Major: Elective
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours & 8 – 10 Practicals
6	Marks Allotted:	100 Marks
7	Course Objectives: 1. The course will discuss basics of the theory of ideals and Nakayama's lemma and its applications. 2. The course aims to introduce the notion of noetherian and artinian rings and primary decomposition in such rings. 3. The course aims to equip students with the knowledge of integral extensions and computations in explicit examples. 4. The course will enable students to comprehend the concept of Dedekind domains and factorization therein.	

8	Course Outcomes: 1. The students will be able to demonstrate how the theory of ideals works in various types of rings. 2. They will be able to employ the techniques of localization to construct new rings and study properties therein. 3. Students will be able to learn about integral extensions and associated results. 4. Students will be able to apply their advanced knowledge of the above topics to the study of special kinds of rings: Dedekind domains.
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9	Modules:- All results have to be done with proof unless otherwise stated.
	Module 1: Basics of rings and modules
	Basic operations with commutative rings and modules, Polynomial and power series rings, Prime and maximal ideals, Extension and contractions, Nil and Jacobson radicals, Nakayama's lemma.
	Module 2: Primary decomposition
	Local rings, Localization, Chain conditions: Noetherian and Artinian rings, Hilbert basis theorem, Associated primes, Primary decomposition and primary decomposition under localization.
	Module 3: Integral Extensions
	Integral extensions, Going up and going down theorems, The ring of integers in a quadratic extension of rationals, Noether normalization, Hilbert's nullstellensatz.
10	Module 4: Dedekind Domains
	Discrete valuation rings, Alternative characterizations of discrete valuation rings, Dedekind domains, Fractional ideals, Factorization of ideals in a Dedekind domain, Examples.
10	List of Practicals : 1. Computing prime and maximal ideals, nilradical and Jacobson radical in various rings. 2. Properties of extended and contracted ideals and applications of Nakayama's lemma. 3. Chain conditions and their properties. 4. Localizations and their properties, Examples of primary decompositions. 5. Integral extensions and their properties.

	6. Calculating integral closures of various rings. 7. Discrete valuations and their properties. 8. Dedekind domains and their properties.	
11	Reference Books: 1. D. S. Dummit and R. M. Foote, Abstract Algebra, John Wiley and Sons. 2. Michael Artin: Algebra, Prentice-Hall India. 3. N.S. Gopalkrishnan: Commutative Algebra, New Age International, third edition, 2015. 4. M. F. Atiyah and I. G. McDonald, Introduction to Commutative Algebra, Addison Wesley	
12	Internal Continuous Assessment: 50%	External, Semester End Examination 50%
	Individual Passing in Internal and External Examination	
13	Continuous Evaluation through: Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc. (at least 3)	Solving Problems, Assignments, Tutorials, Seminar and Practicals

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VII)
Title of Paper: 11114627062 : Graph Theory

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	This subject developed from many real life problems, gives interesting mathematical insights for existence of solutions to problems arising in daily life. The algorithmic nature of the subject helps in solving problems that involve very large data sets too.
2	Vertical :	Major : Elective
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours & 8 – 10 Practicals
6	Marks Allotted:	100 Marks
7	Course Objectives: 1. The course will discuss basic concepts in graph theory like adjacency matrix, incidence matrix, types of graphs and isomorphisms between them. 2. The course aims to introduce the notion of shortest path and algorithms for finding it in the given graph. Trees and their properties will be discussed along with algorithms for finding spanning trees. 3. The course aims to equip students with the knowledge of two important types of graphs:	

	Eulerian and Hamiltonian. Necessary and sufficient conditions for the existence - of these types of graphs will also be covered. - The course will enable students to comprehend the idea of matching, augmenting paths and associated theorems. - Further, students will be exposed to the definition of Ramsey numbers and their properties.
8	Course Outcomes: - The students will be able to demonstrate how to compute eigenvalues of graphs and verify Whitney's theorem in the given examples. - They will be able to employ the techniques introduced by Cayley and construct trees from Prufer sequences and vice-versa. Also, they will be able to apply various algorithms taught, to determine shortest path in the given graph. - Students will be able to learn about Eulerian and Hamiltonian graphs. - They will also be able to compute the Hamiltonian closure of the given graph. - Students will be able to apply their advanced knowledge on matchings and solve real-life problems. They will also be able to evaluate Ramsey numbers and determine their properties.

9	Modules:- All results have to be done with proof unless otherwise stated.
	Module 1: Connectivity
	Definition of basic concepts such as Graph, Subgraphs, Adjacency and incidence matrix, Eigen values of graph Friendship Theorem, Degree, Connected graph, Components, Isomorphism, Bipartite graphs etc. Shortest path problem-Dijkstra's algorithm, Vertex and Edge connectivity-Result $\kappa \leq \kappa' \leq \delta$; Blocks, Block-cut point theorem, Construction of reliable communication network, Menger's theorem.
	Module 2: Trees
	Trees-Cut vertices, Cut edges, Bond, Characterizations of Trees, Spanning trees Fundamental cycles, Vector space associated with graph, Cayley's formula Connector problem- Kruskal's algorithm, Proof of correctness, Binary and rooted trees, Huffman coding Searching algorithms BFS and DFS algorithms

Module 3: Eulerian and Hamiltonian Graphs

Eulerian Graphs- Characterization of Eulerian Graph, Randomly Eulerian graphs
Chinese post- man problem- Fleury's algorithm with proof of correctness Hamiltonian graphs,
Necessary condition, Dirac's theorem, Hamiltonian closure of a graph.

Module 4: Matching and Ramsey Theory

Matching augmenting path, Berge theorem, Matching in bipartite graph, Halls theorem,
Konig's theorem, Tutte's theorem, Personal assignment problem, Independent sets and
covering $\alpha + \beta = p$; Gallai's theorem, Ramsey theorem-Existence of $r(k; l)$; Upper and Lower
bounds of $r(k; l)$. $r(k; l) \geq 2m/2$ where $m = \min\{k, l\}$; Generalize Ramsey numbers $r(k_1, k_2, \dots, k_n)$; Graph Ramsey theorem, Evaluation of $r(G; H)$ when for simple graphs $G = P_3$; $H = C_4$.

10 List of Practicals :

1. Adjacency, incidence matrix and eigenvalues
2. Computations based on Whitney's theorem, Dijkstra's algorithm
3. Trees and their properties, Prufer sequences, Cayley's theorem
4. Huffman coding, Kruskal algorithm, BFS, DFS algorithms.
5. Eulerian graphs, Fleury's algorithm
6. Hamiltonian graphs and problems based on associated theorems
7. Matchings, properties of augmenting path and associated theorems
8. Ramsey theory and properties and computation of Ramsey numbers

11 Reference Books:

1. J.A. Bondy and U.S.R. Murty, Graph Theory with Applications, Elsevier.
2. J. A. Bondy and U.S. R. Murty, Graph Theory, GTM 244 Springer, 2008.
3. M. Behzad and A. Chartrand, Introduction to the Theory of Graphs, Allyn and Becon Inc., Boston, 1971.
4. K. Rosen, Discrete Mathematics and its Applications, Tata-McGraw Hill, 2011.
5. D. B. West, Introduction to Graph Theory, PHI, 2009.

12 Internal Continuous Assessment:**50%****External, Semester End Examination****50%**

	Individual Passing in Internal and External Examination	
13	Continuous Evaluation through: Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc. (at least 3)	Solving Problems, Assignments, Tutorials, Seminar and Practicals

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VII)
Title of Paper: 11114627063 : Programming in Python

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	Subject programming in python covers use of python programming in the mathematical computational skills.
2	Vertical :	Major: Elective
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours & 8 – 10 Practicals
6	Marks Allotted:	100 Marks
7	Course Objectives: Learn Basics of programming through Python Programming.	

8	Course Outcomes: Students will learn: 1. Problem Solving strategies to solve problem with help of computer. 2. Variables, operators, data types and expressions in Python. 3. Iterations and Conditional statements, functions. 4. Create Strings & File, File Handling operations. 5. Data Structures, Handling data using SQL, MySQL.
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9	Modules:-
	Module 1: Problem solving strategies (7 Lectures, 8 Practicals)
	1. Problem Solving strategies: Problem analysis, formal definition of problem, Solution, top-down design, breaking a problem into sub problems, overview of the solution to the sub problems by writing step by step procedure (algorithm), flowcharts, pseudocodes 2. Python programming language: (a) Variables, expressions and statements Values and types:int, float and str Variables: assignment statements, printing variable values, types of variables. (b) Operators, operands and precedence: +, -, *, **, % PEMDAS (Rules of precedence) (c) String operations: + : Concatenation, * : Repetition (d) Boolean, Comparison and Logical operators: Boolean operator: == Comparison operators: ==, !=, >, <, >=, <= Logical operators: and, or, not Mathematical functions: sin, cos, tan, log, sqrt etc. Keyboard input: raw input statement
	Module 2: Iterations and Conditional statements (7 Lectures, 8 Practicals)
	1. Conditional and alternative statements, Chained and Nested Conditionals: if, ifelse, if-elif-else, nested if, nested if-else looping statements such as while, for etc Tables using while. 2. Functions: Calling functions: type, id Type conversion:int, float, str Type coercion Composition of functions User defined functions, Parameters and arguments

Module 3: Strings & File Handling (7 Lectures, 8 Practicals)

1. Elementary Python Graphics
2. Strings and Lists in Python, Strings: Compound data types, Length(len function), String traversal: Using while statement, Using for statement, Comparison operators (>, <, ==), Lists and List operations, Use of range function, Accessing list elements, List membership and for loop, List operations, List updation: addition, removal or updation of elements of a list, Introduction to files and types of files (text, binary and CSV file): Relative and absolute paths, Text file: Opening, Modes (r, r+,w,w+, a, a+) : Closing and opening a file with Clause, Writing/ Appending data using write () and writelines (): Reading text file using read(), readline() and readlines(), Seek and tell methods: Manipulation of data, Binary file: basic operations: Open using file open modes, Close a binary file: Import pickle module, dump() and load() method: Append and update operations, CSV file: import csv module, open/ close, write: Read from a csv file using csv.reader ().

Module 4: Data Structures, SQL, MySQL (7 Lectures, 8 Practicals)

1. Data Structure:
Stack and operations : Implementation Of Stack Using List
Introduction To Queue: Operations On Queue
Implementation Of Queue Using List.
2. SQL Commands
Database concepts: introduction and its need, Relational Data Model: relation, attribute, tuple, domain, degree, cardinality and keys, Structured Query Language: Introduction Data Definition Language and Data Manipulation Language, Data Type: Create, Use and Show and Drop database, Show, Create, Describe, Alter and Drop Table: Insert, Delete, Select, Operators, Aliasing, Distinct Clause, Where Clause : Meaning Of Null, Like, Update Command, Delete Command, Aggregate Functions, Joins: Cartesian Product On Two Tables: Equi-join And Natural Join.
3. Interface Python with mySQL Interface of python with an SQL database: Connecting SQL with Python, Performing Insert, Update, Delete Queries using Cursor: Display Data By Using fetchone(), fetchall(), Rowcount, Creating Database: Connectivity applications.

10 List of Practicals :

1. Find factorial of non negative number n
2. Find largest among a given set of numbers
3. Generating Fibonacci sequences.
4. Arrange n numbers in increasing order.
5. Type a Python code to accept an integer and check whether it's even , odd or prime.
6. Using Python evaluate Mathematical expressions similar to the following:
 - (a) $\sqrt{\quad}$
 - (b) $\sin(\pi/2)$
 - (c) $\cos(\theta + \pi/2)$ where θ is entered by the user.
 - (d) $(\log_{10}(x))$ where x is entered by the user.
7. Circles, lines drawing.
8. Roots of quadratic equations.
9. Type a python code to display integers ranging from 1 to n. (value of n is entered by the user)
10. Type a Python code that displays integers 1 to 10 and their squares in the table format using while statement.
11. Type a Python code to display all odd numbers from 1 to 20 using lists and for statement.
12. Define a 3×3 matrix using lists in Python. Type a code to display each row of the matrix and each element of the matrix.
13. Type a Python code to define a function for swapping the two variable values using tuples
14. Type a Python statement to create a file object test.dat
15. Type a Python statement to put data "Hello World!" in the file test.dat
16. Type a Python statement to close the file test.dat.
17. Type a Python statement to read the file test.dat.
18. Type a Python statement to read the file test.dat in a directory named test, which resides in share, which resides in user, which resides in the top-level directory of the system, called /.
19. Type a Python code to prompt the user for the name of a file and then try to open it. If the file doesn't exist, we don't want the program to crash.(Use try and except statements).
20. Creating Records from Python Lists.
21. Creating re-usable functions to do all of this for us in the future.

11	Reference Books: 1. Downey, A. et al., How to think like a Computer Scientist: Learning with Python, John Wiley, 2015. 2. Goel, A., Computer Fundamentals, Pearson Education. 3. Lambert K. A., Fundamentals of Python - First Programs, Cengage Learning India, 2015. 4. Rajaraman, V., Computer Basics and C Programming, Prentice-Hall India.	
12	Internal Continuous Assessment: 50%	External, Semester End Examination 50%
	Individual Passing in Internal and External Examination	
13	Continuous Evaluation through: Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc. (at least 3)	Solving Problems, Assignments, Tutorials, Seminar and Practicals

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VII)

Title of Paper: 11114627064 : Linear & Non Linear Programming

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	The subject linear and non linear programming covers techniques of optimization and determination of feasible region of linear and non linear programming problems.
2	Vertical :	Major: Elective
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours & 8 – 10 Practicals
6	Marks Allotted:	100 Marks
7	Course Objectives: 1. Students will be introduced the concept of optimization and feasible solution. 2. Students will learn various techniques of solving linear programming problems with and without constraints. 3. Students will learn various techniques of solving non-linear programming problems with and without constraints.	

8	Course Outcomes: After the completion of the course the student will be able to 1. Formulate real world problems into mathematical models and apply the theory of linear programming. 2. Understand the simplex method, Big-M method, Dual simplex method for linear programming. 3. Learn nonlinear programming with constraints and without constraints.
9	Modules:- Module 1: Linear Programming (7 Lectures, 8 Practicals) Operations research and its scope, Necessity of operations research in industry, Linear programming problems, Convex sets, Simplex method, Theory of simplex method, Duality theory and sensitivity analysis, Dual simplex method. Module 2: Transportation Problems (7 Lectures, 8 Practicals) Transportation and Assignment problems of linear programming, Sequencing theory and Travelling salesperson problem. Module 3: Unconstrained Optimization (7 Lectures, 8 Practicals) First and second order conditions for local optima, One-Dimensional Search Methods: Golden Section Search, Fibonacci Search, Newtons Method, Secant Method, Gradient Methods, Steepest Descent Methods. Module 4: Constrained Optimization Problems (7 Lectures, 8 Practicals) Problems with equality constraints, Tangent and normal spaces, Lagrange Multiplier Theorem, Second order conditions for equality constraints problems, Problems with inequality constraints, Karush-Kuhn-Tucker Theorem, Second order necessary conditions for inequality constraint problems.
10	List of Practicals : 1. The theoretical workings of the simplex method, Big-M method and Dual simplex method for making effective decision on variables so as to optimize the objective function. 2. To solve complex problems involved in various industries.

	- Demonstrate the optimized material distribution schedule using transportation model to minimize total distribution cost. - The theoretical workings of sequencing techniques for effective scheduling of jobs on machines. - The appropriate algorithm for allocation of resources to optimize the process of assignment - Understand and apply unconstrained optimization theory for continuous problems. - Single Variable Optimization Problems: Fibonacci Search Method, Golden Section Method, Newton's Method, Secant Method, steepest descent method. - Understand and apply constrained optimization theory for continuous problems. - Lagrange multipliers method necessary and sufficient conditions for optimality. - Problems with equality constraints, inequality constraints Kuhn-Tucker conditions.	
11	Reference Books: H. A. Taha, Operations Research-An introduction, Macmillan Publishing Co. Inc., NY. K. Swarup, P. K. Gupta and Man Mohan, Operations Research, S. Chand and sons, New Delhi. S. S. Rao, Optimization Theory and Applications, Wiley Eastern Ltd, New Delhi. G. Hadley, Linear Programming, Narosa Publishing House, 1995. F. S. Hillier and G. J. Lieberman, Introduction to Operations Research (Sixth Edition), McGraw Hill - Chong and Zak, Introduction to Optimization, Wiley-Interscience, 1996. - Rangarajan and K. Sundaram, A First Course in Optimization Theory, Cambridge University Press.	
12	Internal Continuous Assessment: 50%	External, Semester End Examination 50%
	Individual Passing in Internal and External Examination	
13	Continuous Evaluation through: Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc. (at least 3)	Solving Problems, Assignments, Tutorials, Seminar and Practicals

Sem. – VIII

Sem. – VIII

Vertical – 1

Major

Mandatory

(4+4+4+2)

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VIII)
Title of Paper: 1111462801 : Algebra II

Sr. No.	Heading	Particulars
1	Description the course : Including but Not limited to :	This subject captures the role symmetry plays in analyzing many problems. The mathematical notion for making this precise is that of groups. The second half of the course involves the concept of rings, which are essential in applications like coding theory, which have applications world wide today.
2	Vertical :	Major
3	Type :	Theory
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours
6	Marks Allotted:	100 Marks
7	Course Objectives: 1. To introduce students to various groups like dihedral groups, matrix groups, automorphism group, inner automorphisms. 2. To make the students appreciate the structure theorem for finite abelian groups via examples. 3. To introduce the concepts of group actions and the orbit-stabilizer formula. 4. To prove classical theorems like the Sylow theorems and apply them for classification of various types of groups.	

	5. The course aims that students earn the knowledge of prime avoidance theorem, Chinese remainder theorem, and specialized rings like Euclidean domains, principal ideal domains, unique factorization domains, their inclusions and counter examples.
8	Course Outcomes: 1. Students will be able to compute subgroups, normal subgroups and centers in various groups. 2. The students will check and ascertain if a given group is a direct product of two subgroups. 3. After the course, the students will be able to compute orbits and stabilizers in many examples of group actions. 4. The students will learn applications of Sylow theorems like classification of various types of groups or checking simplicity of groups etc. 5. Students will be able to understand the Chinese remainder theorem and use it to solve a system of congruences. 6. Students will be able to test if the given rings are Euclidean domains, principal ideal domains or unique factorization domains.

9	Modules:- All results have to be done with proof unless otherwise stated.
	Module 1: Groups and Group Homomorphisms (8 Lectures and 7 Practicals)
	1. Review: Groups, subgroups, normal subgroups, center $Z(G)$ of a group. The kernel of a homomorphism is a normal subgroup. Cyclic groups. Lagrange's theorem. The product set $HK = \{hk \mid h \in H \text{ \& \; } k \in K\}$ of two subgroups of a group G: Examples of groups such as Permutation groups, Dihedral groups, Matrix groups, Un-the group of units of $\mathbb{Z}_n$ (no questions be asked). 2. Quotient groups. First Isomorphism Theorem and the following two applications (reference: Algebra by Michael Artin): (i) Let C be the multiplicative group of non-zero complex numbers and $R > 0$ be the multiplicative group of positive real numbers. Then the quotient group C/U is isomorphic to $R > 0$: (ii) The quotient group $GL_n(R)/SL_n(R)$ is isomorphic to the multiplicative group of non-zero real numbers R

3. Second and third isomorphism theorem for groups.
4. Product of groups. The group $Z_m \times Z_n$ is isomorphic to Z_{mn} if and only if $\gcd(m, n) = 1$. Internal direct product (A group G is an internal direct product of two normal subgroups H, K if $G = HK$ and every $g \in G$ can be written as $g = hk$ where $h \in H; k \in K$ in a unique way).
5. If H, K are two finite subgroups of a group, then $HK \cong H \times K \iff H \cap K = \{e\}$. If H, K are two normal subgroups of a group G such that $H \cap K = \{e\}$ and $HK = G$, then G is internal direct product of H and K . If a group G is an internal direct product of two normal subgroups H and K then G is isomorphic to $H \times K$. (Reference: Algebra by Michael Artin)
6. Inner automorphisms, Automorphisms of a group. If G is a group, then $A(G)$; the set of all automorphisms of G , is a group under composition. If G is a finite cyclic group of order r ; then $A(G)$ is isomorphic to U_r ; the groups of all units of Z_r under multiplication modulo r . For the infinite cyclic group Z ; $A(Z)$ is isomorphic to Z_2 . (Reference: Topics in Algebra by I.N.Herstein).
7. Structure theorem of Abelian groups (statement only) and applications (Reference: A first Course in Abstract Algebra by J. B. Fraleigh).

Module 2: Groups acting on sets and Sylow theorems (7 Lectures and 8 Practicals)

1. Center of a group, centralizer or normalizer $N(a)$ of an element $a \in G$; conjugacy class $C(a)$ of a in G : In finite group G ; $|C(a)| \mid o(G)$ and $|C(a)| \mid o(N(a))$ and $o(G) = \sum |C(a)|$ where the summation is over one element in each conjugacy class.
2. Applications such as:
 - (i) If G is a group of order p^n where p is a prime number, then $Z(G) \neq \{e\}$:
 - (ii) Any group of order p^2 ; where p is a prime number, is Abelian. (Reference: Topics in Algebra by I. N. Herstein).
3. Groups acting on sets, Class equation, Cauchy's theorem: If p is a positive prime number and $p \mid o(G)$ where G is finite group, then G has an element of order p . (Reference: Topics in Algebra by I. N. Herstein).
4. Simple groups, p -groups, Sylow theorems and applications (like testing simplicity of groups and)
 - (i) There are exactly two isomorphism classes of groups of order 6:
 - (ii) Any group of order 15 is cyclic

(Reference for Sylow's theorems and applications: Algebra by Michael Artin).

Module 3: Rings and Fields (8 Lectures and 7 Practicals)

1. Review: Rings (with unity), ideals, quotient rings, prime ideals, maximal ideals, ring homomorphisms, characteristic of a ring, first and second Isomorphism theorems for rings, correspondence theorem for rings (If $f: R \rightarrow R'$ is a surjective ring homomorphism, then there is a 1 – 1 correspondence between the ideals of R containing the $\ker f$ and the ideals of R'). Integral domains, construction of the quotient field of an integral domain. (no questions be asked).
2. For a commutative ring R with unity:
 - (i) An ideal M of R is a maximal ideal if and only if the quotient ring R/M is a field.
 - (ii) An ideal N of R is a prime ideal if and only if the quotient ring R/M is an integral domain.
 - (iii) Every maximal ideal is a prime ideal.
 - (iv) Every proper ideal is contained in a maximal ideal.
 - (v) If an ideal I is contained in union of prime ideals $P_1, P_2, \dots, P_n$, then I is contained in some P_i .
 - (vi) If a prime ideal P contains an intersection of ideals $I_1, I_2, \dots, I_n$, then P contains some ideal I_j .
3. Rings of fractions, inverse and direct images of ideals, Comaximal ideals, Chinese Remainder Theorem in rings and its applications to congruences.
4. Definition of field, characteristic of a field, sub field of a field. A field contains a sub field isomorphic to $\mathbb{Z}_p$ or $\mathbb{Q}$. Polynomial ring $F[X]$ over a field, irreducible polynomials over a field. Prime ideals, and maximal ideals of a Polynomial ring $F[X]$ over a field F : A non-constant polynomial $p(X)$ is irreducible in a polynomial ring $F[X]$ over a field F if and only if the ideal $(p(X))$ is a maximal ideal of $F[X]$: Unique Factorization Theorem for polynomials over a field (statement only).

Module 4: Divisibility in integral domains (7 Lectures and 8 Practicals)

1. Prime elements, irreducible elements, Unique Factorization Domains, Principle Ideal Domains.
 2. Gauss's lemma, $\mathbb{Z}[X]$ is a UFD.
 3. Irreducibility criterion, Eisenstein's criterion
 4. Euclidean domains
 5. $\mathbb{Z}[\sqrt{-5}]$ is not a UFD.
- (Reference for Unit IV: Michael Artin: Algebra, Prentice-Hall India.)

10 List of Practicals

1. Examples of groups, subgroups and applications of isomorphism theorems.
2. Quotient groups, products of groups.
3. Applications of structure theorem for abelian groups and existence of elements of certain order.
4. Group actions and computations of Sylow subgroups and elements of certain orders.
5. Applications of Sylow theorems.
6. Basic properties of different types of rings, quotient rings and ideals.
7. Prime elements, irreducible elements: their examples and counter-examples.
8. Eisenstein's criterion and details of special rings like Euclidean domains, Principal ideal domains and Unique factorization domains.

10 Recommended Text Books :

1. Hoffman K and Kunze R: Linear Algebra, Prentice-Hall India.
2. I.N.Herstein: Topics in Algebra, Wiley-India.
3. J. B. Fraleigh, A first Course in Abstract Algebra, Narosa.
4. Michael Artin: Algebra, Prentice-Hall India.
5. David Dummit, Richard Foote: Abstract Algebra, Wiley-India.
6. N. Jacobson, Basic Algebra I (2nd Ed.), Dover Publication.

12 Internal Continuous Assessment:
50%

External, Semester End Examination
50%

Individual Passing in Internal and External Examination

13 Continuous Evaluation through:

Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc.(at least 3)

Solving Problems, Assignments, Tutorials, Semnar and Practicals

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VIII)
Title of Paper: 1111462802 : Topology

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	The way to distinguish between objects geometrically without any techniques can be difficult, if one does not attach appropriate invariants for this distinction. Topology offers these tools and in this basic course, various important concepts will be introduced for classifying various types of spaces.
2	Vertical :	Major
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours & 8 – 10 Practicals
6	Marks Allotted:	100 Marks
7	Course Objectives: 1. To understand a formation of new spaces from old one using product, box and quotient topology. 2. To make student understand different spaces with different kinds of measuring relations (i.e. different kinds of open sets.) 3. Students will grasp the concepts of connectedness and compactness having different kinds of open sets.	

8	Course Outcomes: 1. Students will learn different topological spaces on same set. 2. Student will understand identification process to achieve Quotient space. 3. They will perceive an idea of connectedness and compactness in all kinds of open sets. 4. Students will learn concept of metrization of a topological space.
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9	Modules:- All results have to be done with proof unless otherwise stated.
	Module 1: Topology and Topological spaces
	1. Topological spaces, basis, topology generated by basis, sub-basis 2. Order topology, product topology, subspace topology 3. Closed sets, limit points, closure, interior, continuous functions, homeomorphism 4. Box topology, comparison of the box and product topologies 5. T_0, T_1 spaces, For a T_1 space X, $x \in A \subset X$ is limit point of A if and only if every neighbourhood of x contains infinitely many points of A. Hausdorff space.
	Module 2: Connected topological spaces
	1. Quotient spaces. 2. Connected topological spaces, separation of a topological space, continuity and connected-ness, path-connected topological spaces, topologist's sine curve, 3. The order square I_0^2 is connected but not path connected. For real numbers R equipped with usual topology, the infinite cartesian product R^ω in the product topology is connected but in box topology it is not. 4. Connected components of a topological space, Path components of a topological space. 5. Countability Axioms, first and second countable spaces 6. Separable spaces, Lindeloff spaces.
	Module 3: Compact topological spaces
	1. Compact spaces, continuity and compactness, tube lemma, finite product of compact topological spaces is compact. 2. Finite intersection property, the Lebesgue number lemma, uniform continuity theorem, 3. Compact Hausdorff space with no isolated points is uncountable. Limit point compact spaces, 4. Local compactness, one point compactification, Tychonoff theorem (statement only).

Module 4: Metrizable spaces and Tychonoff theorem

1. Metrizable spaces, Sequence lemma and metrizability criterion
2. Separation axioms (regular and normal spaces). Every metrizable space is normal.
3. A compact T_2 space is a normal space. Urysohn lemma
4. Tietze extension theorem, Urysohn metrization theorem (Statement only).

10 List of Practicals :

1. Generate basis from subbasis and topology from basis.
2. Determine limit points, closure and interior continuity of a function.
3. Using given identification form Quotient topology.
4. Check connectedness.
5. Check compactness.
6. Test features of one-point compactification.
7. Apply proof of Urysohn metrization theorem to specific problems.
8. Metrizability and separation axioms.

11 Reference Books:

1. J. F. Munkres: Topology, Pearson; 2 edition (January 7, 2000).
2. G. F. Simmons: Introduction to Topology and Modern Analysis, Tata McGraw Hill, 2004.

12 Internal Continuous Assessment:

50%

External, Semester End Examination

50%

Individual Passing in Internal and External Examination

13 Continuous Evaluation through:

Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc. (at least 3)

Solving Problems, Assignments, Tutorials, Seminar and Practicals

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VIII)

Title of Paper : 111462803 : Complex Analysis

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	Subject Complex Analysis covers theory and examples of mathematical analysis in complex domain
2	Vertical :	Major
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours & 8 – 10 Practicals
6	Marks Allotted:	100 Marks
7	Course Objectives: 1. Students will be introduced the difference of complex differentiation and real differentiation. 2. Students will be made to understand the smoothness of holomorphic maps. 3. The objective is to see how to simplify real integration through complex one.	
8	Course Outcomes: 1. In this course the students will learn about series of functions and power series. The concept of radius of convergence will be introduced and calculated. 2. This course gives insight of complex integration which is different from integration of real valued functions. In particular, Cauchy integral formula will be proved. 3. The students will learn that if a function is once (complex) differentiable then it is infinitely many times differentiable. This will be a sharp contrast with the theorems of real analysis.	

	4. The various properties of Möbius transformations that have a wide variety of applications along with major theorems of theoretical interest like Cauchy-Goursat theorem, Morera's theorem, Rouché's theorem and Casorati-Weierstrass theorem will be studied.
9	Modules:- Module 1: Holomorphic functions (8 Lectures and 7 Practicals) 1. Note: A complex differentiable function defined on an open subset of $\mathbb{C}$ is called a holomorphic function. 2. Review: Complex numbers, Geometry of the complex plane, Weierstrass's M-test and its application to uniform convergence, Ratio and root test for convergence of series of complex numbers. (no questions to be asked). 3. Stereographic projection, Sequence and series of complex numbers, Sequence and series of functions in $\mathbb{C}$, Complex differential functions, Chain rule for holomorphic function. 4. Power series of complex numbers, Radius of convergence of power series, Cauchy-Hadamard formula for radius of convergence of power series. Abel's theorem: let $\sum_{n \geq 0} a_n(z - z_0)^n$ be a power series of radius of convergence $R > 0$. Then the function $f(z)$ defined by $f(z) = \sum a_n(z - z_0)^n$ is holomorphic on the open ball $z - z_0 < R$ and $f'(z) = \sum_{n \geq 1} n a_n(z - z_0)^{n-1}$ for all $z - z_0 < R$. Trigonometric functions, Applications of Abel's theorem to trigonometric functions. 5. Applications of the chain rule to define the logarithm as the inverse of exponential, branches of logarithm, principle branch $l(z)$ of the logarithm and its derivative on $\mathbb{C} \setminus \{z \in \mathbb{C} \vee \Re(z) \leq 0, \Im(z) = 0\}$. Module 2: Contour integration, Cauchy-Goursat theorem (7 Lectures and 8 Practicals) 1. Contour integration, 2. Cauchy-Goursat Theorem for a rectangular region or a triangular region. 3. Cauchy's theorem (general domain), 4. Cauchy integral formula, Cauchy's estimates, 5. The index (winding number) of a closed curve, 6. Primitives. Existence of primitives, 7. Morera's theorem.

8. Power series representation of holomorphic function (Taylor's theorem).

Module 3: Properties of Holomorphic functions (8 Lectures and 7 Practicals)

1. Entire functions,
2. Liouville's theorem.
3. Fundamental theorem of algebra.
4. Zeros of holomorphic functions,
5. Identity theorem.
6. Counting zeros;
7. Open Mapping Theorem,
8. Maximum modulus theorem,
9. Schwarz's lemma.
10. Automorphisms of unit disc.
11. Isolated singularities: removable singularities and Removable singularity theorem, poles and essential singularities.
12. Laurent Series development.
13. Casorati-Weierstrass's theorem.

Module 4: Residue calculus and Mobius transformation (7 Lectures and 8 Practicals)

1. Residue Theorem and evaluation of standard types of integrals by the residue calculus method. Argument principle.
2. Rouché's theorem,
3. Mobius Transformation.

10 List of Practicals

1. Weierstrass M-test, root test, ratio test and computations of radius of convergence.
2. Abel's theorem and branch of the logarithm.
3. Cauchy Goursat theorem and applications of Cauchy's theorem.
4. Winding number, primitives and power series representation of functions.
5. Entire functions and zeroes of holomorphic functions.
6. Isolated singularities, removable singularities, essential singularities and poles.
7. Residue theorem and evaluation of integrals.
8. Möbius transformations.

10	Recommended Text Books 1. J.B. Conway, Functions of one Complex variable, Springer. 2. A.R. Shastri: An introduction to complex analysis, Macmillan. 3. Serge Lang: Complex Analysis. Springer. 4. L.V. Ahlfors:Complex analysis, McGraw Hill. 5. R. Remmert: Theory of complex functions, Springer. 6. J.W. Brown and R.V. Churchill:Complex variables and Applications, McGraw-Hill.	
11	Internal Continuous Assessment: 50%	External, Semester End Examination 50%
	Individual Passing in Internal and External Examination	
12	Continuous Evaluation through: Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc. (at least 3)	Solving Problems, Assignments, Tutorials, Seminar and Practicals

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VIII)

Name of the Course: 1111462804 : Partial Differential Equations

Sr. No.	Heading	Particulars
1	Description of the course:	Subject Partial Differential Equations theory of first order and second order PDE and related examples
2	Vertical :	Major
3	Type :	Practical
4	Credit:	2 credits (30 Hours of Practical work in a semester)
5	Hours Allotted :	30 Hours
6	Marks Allotted:	50 Marks
7	Course Objectives (CO): 1. Students will be introduced the geometrical interpretation of the solution of Partial Differential Equations. 2. Students will learn the Cauchy's initial value problems. 3. The course aims to demonstrate the classification and properties of second order Partial Differential Equations.	
8	Course Outcomes (OC): 1. Students are expected to understand the basic concepts and method of finding the solution of first and second order Partial Differential Equations 2. Students will be able to know the classification of second order PDEs, singularity and fundamental solution. 3. Students will be able to know the role of Green's function in the solution of Partial Differential Equations.	

Module 1: First Order Partial Differential Equations (8 Lectures and 7 Practicals)

1. First order partial differential equations in two independent variables,
2. Semilinear and Quasilinear equations in two independent variables,
3. method of characteristics,
4. Cauchy Problem, General solutions.
5. Non-linear equations in two independent variables: Monge Strip and Charpit Equations,
6. Solution of Cauchy problem, Determination of Complete integral, solution of Cauchy problem,

[Reference Unit-I (1.1,1.2, 1.3, 1.4)of Phoolan Prasad & Renuka Ravindran, Partial Differential Equations, Wiley Eastern Limited, India]

Module 2: Second Order Partial Differential Equations (8 Lectures and 7 Practicals)

1. Classifications of second order partial differential equations in two and more than two independent variables,
 2. Method of reduction to normal form,
 3. The Cauchy problem.
 4. Potential theory and elliptic differential equations,
 5. Boundary value problems and Cauchy problem,
 6. Poisson's theorem, the mean value and the Maximum-Minimum properties
- [Reference Unit-II (2.1, 2.2) of Phoolan Prasad & Renuka Ravindran, Partial Differential Equations, Wiley Eastern Limited, India]
7. Singularity functions and the fundamental solution,
 8. Green functions, Greens identities, Green's function for m-dimensions sphere of radius R, Green's functions
 9. Dirichlet problem in the plane, Neumann's function in the plane.

[Reference Unit-II (2.2.2):1. Phoolan Prasad & Renuka Ravindran, Partial Differential Equations, Wiley Eastern Limited, India and 2. Unit VIII of Yehuda Pinchover and Jacob Rubinstein, An Introduction to Partial Differential Equations, Cambridge University Press]

10	List of Practicals 1. Designing and analytical Solution of the Cauchy problem 2. Problems based on Monge Strip and Charpit Equations 3. Classification of the second order PDE by reducing into normal forms 4. Designing and the solution of the boundary value problems using Green's function.
11	Recommended Text Books 1. Phoolan Prasad & Renuka Ravindran, Partial Differential Equations, Wiley Eastern Limited, India. 2. Yehuda Pinchover and Jacob Rubinstein, An Introduction to Partial Differential Equations, Cambridge University Press. 3. T.Amaranath, An Elemetary Course in Partial Differential Equations, Narosa. 4. F. John, Partial Differential Equations, Springer publications. 5. G.B. Folland, Introduction to partial differential equations, Prentice Hall.

12	Internal Continuous Assessment: 25%	External, Semester End Examination 25%
	Individual Passing in Internal and External Examination	
13	Continuous Evaluation through: Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc.(at least 3)	Solving Problems, Assignments, Tutorials, Seminar and Practicals

SEM VIII

Vertical – 1

Major

Electives

(4)

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VIII)

Title of Paper: 11114628061 : Algebraic Number Theory

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	After a first introduction to rings, this course develops many more techniques for giving explicit criteria to determine when a unique factorization domain is a principal ideal domain. The course involves the study of historically significant idea of class numbers which has come up from the works of Kronecker, Weber, Gauss, Noether. This course is necessary to understand research problems currently open in this area, as well as gain an insight into the techniques available for future use.
2	Vertical :	Major : Elective
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours & 8 – 10 Practicals
6	Marks Allotted:	100 Marks

7	Course Objectives: 1. Students will be introduced to number fields and their properties. 2. Students will be trained to compute fundamental unit in given rings of integers of algebraic number fields. 3. The course aims equip students to apply quadratic reciprocity for computation of Legendre and Gauss symbols. 4. The instructor will discuss how factorization of ideals occurs and provide explicit criteria for the factorization in the case of quadratic number fields using Legendre symbols. 5. On completion, the course will enable students to compute certain class groups.
8	Course Outcomes: 1. The students will be able to demonstrate the existence of fundamental unit and compute rings of integers of quadratic number fields. 2. They will be able to employ the techniques of quadratic reciprocity to calculate the given Legendre and Jacobi symbols. 3. Students will be able to identify the groups of units and factorize rational primes in quadratic number fields. 4. Students will be able to examine if the given ring of integers is a unique factorization domain or a principal ideal domain using the idea of class groups.
9	Modules:- All results have to be done with proof unless otherwise stated.
	Module 1: Number Fields
	Field extensions, Number fields, Algebraic numbers, Integral extensions, Ring of integers in algebraic number fields, Fractional ideals, Prime factorization of ideals, Norm of an ideal, The group of units, Fundamental unit.
	Module 2: Quadratic Reciprocity
	The Legendre symbol, Jacobi symbols, The laws of quadratic reciprocity with proof.

Module 3: Quadratic Fields: Factorization

Quadratic fields, Real and imaginary quadratic fields, Ring of integers in a quadratic field, The group of units, Ideal Factorization in a quadratic field, Examples: The ring of Gaussian integers, The ring $\mathbb{Z}[\sqrt{5}]$, Factorization of rational primes in quadratic fields.

Module 4: Imaginary Quadratic Fields: The Class Group

The ideal class group of a quadratic field, Class groups of imaginary quadratic fields, The Minkowski lemma, Finiteness of the class group, Computation of class groups, Application to solving certain Diophantine equations.

10 List of Practicals :

1. Algebraic extensions and their properties.
2. Computations of rings of integers and examples.
3. Quadratic reciprocity and computations of Legendre and Jacobi symbols.
4. Rings of integers of quadratic number fields and units therein.
6. Examples of ideal factorization in quadratic number fields.
7. Imaginary quadratic number fields and computations of class group.
8. Solving certain Diophantine equations.
9. Computations of class groups using Minkowski lemma.

11 Reference Books:

1. P. Samuel, Algebraic Theory of Numbers, Dover, 1977
2. M. Artin, Algebra, Prentice-Hall, India, 2000.
3. Marcus, Number Fields, Springer.
4. Algebraic Number Theory, T.I.F.R. Lecture Notes, 1966

12 Internal Continuous Assessment:**50%****External, Semester End Examination****50%****Individual Passing in Internal and External Examination****13 Continuous Evaluation through:**

Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc. (at least 3)

Solving Problems, Assignments, Tutorials, Seminar and Practicals

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VIII)

Title of Paper: 11114628062 : Advanced Counting Techniques in
Discrete Mathematics

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	This subject is an addendum to the first semester discrete mathematics course. The aim of the course is to introduce students to the Gauss's quadratic reciprocity law, a historically important point in number theory. Also, continued fractions and their properties, which have many applications are introduced. The remaining course then goes on to explain the applications like design theory, coding theory and primality testing which are key tools in today's world for any kind of secure communication or confidential financial transaction.
2	Vertical :	Major : Elective
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours & 8 – 10 Practicals
6	Marks Allotted:	100 Marks

7	Course Objectives: 1. The students will be introduced to the classical Gauss's law of quadratic reciprocity. Along with this various applications of Moebius inversion will be studied along with applications. 2. Continued fractions will be introduced to the students. The important method of factorization, called the Pollard method will be introduced as a real-life application. 3. Students will be taught a topic of current research interest: designs. Basics of design theory will enable students to take up interesting projects. 4. The course aims to introduce the students to coding theory which is linear algebra over finite fields. This is also an area of interest of current research and students will be able to take up many further projects in the area.
8	Course Outcomes: 1. The students will be able to check if the given integer is a quadratic residue or not. 2. After the course, the students will be able to compute the continued fraction expansion of rational numbers and quadratic surds. 3. The students will learn applications of designs in everyday life. 4. Students will be able to understand cyclic codes and their relation to quotient rings. 5. Students will be able to test if the given codes error correcting or detecting.
9	Modules:- All results have to be done with proof unless otherwise stated.
	Module 1: Quadratic Reciprocity and Further Combinatorics
	1. Cardano's and Ferrari's method 2. Quadratic congruences, Lifting congruences modulo higher prime powers, Gauss's quadratic reciprocity law 3. Moebius inversion, Applications of Moebius inversion. 4. Permutations with Forbidden positions and Rook polynomials.
	Module 2: Cryptography in real life

1. Continued fractions, Properties of continued fractions
2. Lucas theorem, Primality testing.
3. Factorization using Pollard's ρ -method.

Module 3: Design Theory

1. Incidence structures, t-designs
2. Hadamard matrices
3. Steiner systems
4. Fischer's inequality
2. Fano plane and Symmetric 2-designs

Module 4: Coding Theory

1. Terminology of coding theory, Hamming bound, Singleton bound,
2. Error-correction and detection, Linear codes
3. Cyclic codes
4. Weight enumerators and MacWilliam's theorem.

10 List of Practicals :

1. Quadratic congruences and reciprocity law
2. Moebius inversion and its applications.
3. Continued fractions and their properties.
4. Application to cryptography.
5. Examples of designs and classification of their types.
6. Fischer's inequality and symmetric designs.
7. Linear codes, cyclic codes, error correction and detection.
8. Bounds in various codes and weight enumerators.

11 Reference Books:

1. D. M. Burton, Introduction to Number Theory, McGraw-Hill.
2. S. Ling And C. Xing: Coding Theory: A first course.
3. J. H. van Lint, R. M. Wilson: A Course in Combinatorics, Cambridge.
4. Richard A. Brualdi: Introductory Combinatorics, Pearson.
5. A. Tucker: Applied Combinatorics, John Wiley & Sons.
6. Norman L. Biggs: Discrete Mathematics, Oxford University Press.

	7. Kenneth Rosen: Discrete Mathematics and its applications, Tata McGraw Hills. 8. Sharad S. Sane, Combinatorial Techniques, Hindustan Book Agency, 2013.	
12	Internal Continuous Assessment: 50%	External, Semester End Examination 50%
	Individual Passing in Internal and External Examination	
13	Continuous Evaluation through: Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc. (at least 3)	Solving Problems, Assignments, Tutorials, Seminar and Practicals

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VIII)

Title of Paper: 11114628063 : Algebraic Topology

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	Given a string, can we drag it to that we can collapse it to point? This process of dragging can be made mathematically precise, using the notion of homotopy. The fundamental group is a measure of the obstruction that may come up while this process progresses. Making more such intuitive concepts precise is what the course aims to achieve.
2	Vertical :	Major : Elective
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours & 8 – 10 Practicals
6	Marks Allotted:	100 Marks

7	Course Objectives: 1. To study some features of surfaces and manifolds by using algebra. 2. To grasp covering of spaces through maps which helps to find universal covering. 3. To find chain of singular homology groups with some geometric properties through algebraic study.
8	Course Outcomes: 1. Students will be able to find homotopy groups of some standard geometric objects. 2. Students will be able to understand nature of holes or handles of manifold using fundamental group. 3. Students can envisage nature of holes and handles of abstract object like Klein Bottle, Projective planes, etc. 4. In singular homology group, students will see the application of excision theorem.

9	Modules:- All results have to be done with proof unless otherwise stated.
	Module 1: Fundamental Group
	Homotopy. Path homotopy. The fundamental group. Simply connected spaces. Covering spaces. Path lifting and homotopy lifting lemma. Fundamental group of the circle.
	Module 2: Fundamental group, Applications
	Deformation retracts and Homotopy types. Fundamental group of S^n. Fundamental group of the projective space. Brower fixed point theorem. Fundamental theorem of algebra. Borsuk-Ulam theorem. Free Group, Free Product. Seifert-Van Kampen Theorem (without proof). Fundamental group of wedge of circles. Fundamental group of the torus.
	Module 3: Universal Covering Spaces
	Equivalence of covering maps and Equivalences of covering spaces. The general lifting lemma. The necessary and sufficient condition of equivalence of two covering maps. Universal covering space. Conditional existence of Universal covering space. Example of a space with no universal covering space.
	Module 4: Singular Homology

Singular p-simplex, singular chain complex, singular homology group, reduced singular homology group, acyclic space, zero dimensional singular homology group, induced homomorphism. Axioms for singular theory: Identity axiom, composition axiom, homotopy axiom, exactness axiom and commutativity axiom. Excision Theorem.

10 List of Practicals :

1. Examples of homotopy and path homotopy. Examples of covering maps
2. Determine fundamental group of circle.
3. Determine fundamental group of the circle, the real projective plane, cylinder, etc.
4. Application of Seifert-Van Kampen theorem to find fundamental group of figure eight, wedge of circles, torus, etc.
5. Examples of universal covering spaces for some topological objects.
6. Examples of singular p-simplex , chain complex and singular homology groups.
7. Examples of reduced singular homology group and relative homology group.
8. Example of relative homology group through excision theorem.

11 Reference Books:

1. Alan Hatcher, Algebraic Topology, Cambridge University Press, 2002.
2. John Lee, Introduction to Topological Manifolds, Springer GTM, 2000.
3. James Munkres, Topology, Prentice Hall of India, 1992.
4. James Munkres, Elements of Algebraic Topology, Addison Wesley, 1984.

12 Internal Continuous Assessment:
50%

External, Semester End Examination
50%

Individual Passing in Internal and External Examination

13 Continuous Evaluation through:

Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc. (at least 3)

Solving Problems, Assignments, Tutorials, Seminar and Practicals

Syllabus
B.A./B.Sc. (Hons.) in Mathematics
(Sem.- VIII)

Title of Paper: 11114628064 : Numerical Analysis

Sr. No.	Heading	Particulars
1	Description of the course : Including but Not limited to :	The subject Numerical analysis covers techniques of approximation of functions and evaluation of numerical solution of initial and boundary value problems.
2	Vertical :	Major : Elective
3	Type :	Theory + Practical
4	Credit:	4 credits (1 credit = 15 Hours for Theory or 30 Hours of Practical work in a semester)
5	Hours Allotted :	60 Hours & 8 – 10 Practicals
6	Marks Allotted:	100 Marks
7	Course Objectives: 5. To aware numerical approximation of functions. 6. To teach numerical solution of initial value problems. 7. To teach numerical solution of boundary value problems.	

8	Course Outcomes: 1. Students will be able to grasp the concept of numerical solution of various mathematical problems and corresponding errors. 2. Students will be able to understand the approximation of functions by least square method. 3. Students will be aware about applications of various numerical techniques in the solution of difference equations, ordinary and partial differential equations.
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9	Modules:-
	Module 1: Unit I: Approximation of functions (7 Lectures, 8 Practicals)
	Least squares approximation, Weighted least squares method, Gram-Schmidt orthogonalizing process, Least squares approximation by Chebyshev polynomials. Discrete Fourier Transform and Fast Fourier Transform.
	Module 2: Differential and Difference Equations (7 Lectures, 8 Practicals)
	Differential equations: Solutions of linear differential equations with constant coefficients. Euler's modified method, Runge-Kutta methods. Predictor corrector methods. Stability of numerical methods. Difference Equations: Linear difference equation with constant coefficients and methods of solving them.
	Module 3: Numerical Integration (7 Lectures, 8 Practicals)
	Trapezoidal and Simpson's one third rule in composite forms, Gauss Legendre numerical integration, Gauss-Chebyshev numerical integration, Gauss-Hermite numerical integration, Gauss-Laguerre numerical integration with the derivation of all methods using the method of undetermined coefficients. Romberg's method. Gaussian quadratures, Multiple integrals.
	Module 4: Numerical solutions of Partial Differential Equations (7 Lectures, 8 Practicals)
	Classifications, Finite Difference approximations to derivatives, Finite difference methods of solving elliptic, parabolic and hyperbolic equations.

10	List of Practicals : 1. Approximation of functions by least squares approximation, weighted least squares method and Gram Schmidt orthogonalization. 2. Least squares approximation by Chebyshev polynomials, Discrete Fourier transform. 3. Solving linear differential equations with constant coefficients using Predictor-Corrector methods and Milne's method. 4. Solving two point linear boundary value problem using Galerkin's method, solving linear difference equations with constant coefficients. 5. Evaluating the integral of a function numerically using Trapezoidal rule, Simpson's 1/3rd rule, Simpson's 3/8th rule, Romberg's method. Multiple integration. 6. Numerical integration using Gaussian quadrature: Gauss Legendre integration, Gauss Chebyshev integration, Gauss Laguerre integration and Gauss Hermite integration. 7. Classification of partial differential equations and approximation of derivatives using finite differences methods. 8. Solving elliptic, parabolic and hyperbolic differential equations using finite difference schemes.	
11	Reference Books: 8. Jain, Iyengar, Numerical Methods for Scientific and Engineering Problems, New Age International. 9. S.S. Sastry, Introductory Methods of Numerical Analysis, Prentice-Hall, India. 10. K. E. Atkinson, An Introduction to Numerical Analysis, John Wiley and sons. 11. Erwin Kreyszig, Advanced Engineering Mathematics, Wiley John Wiley & Sons. 12. H. M. Antia, Numerical Analysis Hindustan Publications.	
12	Internal Continuous Assessment: 50%	External, Semester End Examination 50%
	Individual Passing in Internal and External Examination	
13	Continuous Evaluation through: Quizzes, Class Tests, presentation, project, role play, creative writing, assignment etc. (at least 3)	Solving Problems, Assignments, Tutorials, Seminar and Practicals

On Job Training (4)

1111462805 : OJT (On Job Training)

At least four week training at industry required to be completed.

QUESTION PAPER PATTERN

(External and Internal)

1. Scheme of Examination

A. For Four Credit Course

- 50 : 50 scheme for UG Fourth year (Honour's with Research) courses i. e. 50 marks for continuous internal assessment and 50 marks for end semester examination.
- Separate head of passing is required for internal and end semester examination.
- Mid semester examination** shall be of 50 (40+10) marks.

Items	Marks	Duration	Remark
Internal Test (Theory component)	30	40 marks examination of 2 hours duration	Based on Unit-I and II
Internal Test (Practical component)	10		
Journal Certification and Viva (Minimum 75% attendance is compulsory)	10		At the end of semester based on all practical's as per the list provided in syllabus
Total	50		

- The end semester examination shall be of 50 marks and 2.5 hours duration (It consist of two sections. Section-I (Theory 30 marks), Section-II (Practical 20 marks))

Question No	Unit	Theory/Practical	Max. Marks	Total marks including options
Section-I (Theory Component)				
Q1	Unit I and II	Theory	10	15
Q2	Unit III and IV	Theory	10	15
Q3	Common	Theory	10	15
Section-II (Practical Component)				
Q4	Unit III	Practical	10	15
Q5	Unit IV	Practical	10	15

B. For Two Credit Course:

25 : 25 scheme for all PG courses i.e. 25 marks for continuous assessment and 25 marks for end semester examination. Separate head of passing is required for internal and end semester examination.

Mid semester examination shall be of 25 (15+10) marks.

Items	Marks	Duration	Remark
Internal Test (Practical component)	15	15 marks examination of 1 hour duration	Based on Unit-I
Journal Certification and Viva (Minimum 75% attendance is compulsory)	10		At the end of semester based on all practical's as per the list provided in syllabus
Total	25		

The end semester examination shall be of 25 marks and 1.5 hours duration

Question No	Unit	Practical	Max. Marks	Total marks including options
Q1	Unit I	Practical	12	18
Q2	Unit II	Practical	13	20
Total Marks			25	

Scheme of evaluation R8435 for B. Sc. Fourth Year (Honours with Research)**Mathematics:**

- A) 100% internal evaluation scheme for University Department of Mathematics. Both Mid and End semester examinations will be conducted by the Department and answer books will be shown to the students.
- B) For affiliated UG centers end semester examination will be conducted by the University.

Letter Grades and Grade Points:

Semester GPA/ Programme CGPA Semester/ Programme	% of Marks	Alpha-Sign/ Letter Grade Result	Grading Point
9.00 - 10.00	90.0 - 100	O (Outstanding)	10
8.00 - < 9.00	80.0 - < 90.0	A+ (Excellent)	9
7.00 - < 8.00	70.0 - < 80.0	A (Very Good)	8
6.00 - < 7.00	60.0 - < 70.0	B+ (Good)	7
5.50 - < 6.00	55.0 - < 60.0	B (Above Average)	6
5.00 - < 5.50	50.0 - < 55.0	C (Average)	5
4.00 - < 5.00	40.0 - < 50.0	P (Pass)	4
Below 4.00	Below 40.0	F (Fail)	0
Ab (Absent)	-	Ab (Absent)	0

Sd/-

**Sign of the BOS
Name Prof. B. S. Desale
Chairman
BOS in Mathematics**

Sd/-

**Sign of the
Offg. Associate Dean
Dr. Madhav R. Rajwade
Faculty of Science &
Technology**

Sd/-

**Sign of the Offg. Dean
Prof. Shivram S. Garje
Faculty of Science &
Technology**