

**CURRICULUM FOR THREE YEAR DEGREE COURSE
IN
MATHEMATICS
(WITH MULTIPLE ENTRY/EXIT OPTION)**

Based on N.E.P.-2020

(2026-2027)



2026

**SCHOOL OF MATHEMATICS
GANGADHAR MEHER UNIVERSITY, AMRUTA VIHAR
SAMBALPUR, ODISHA, INDIA-768004**

<https://www.gmuniversity.ac.in>



VISION

To take the leadership in setting the standard of Mathematics Education in terms of Teaching and Research in the State and in the Country that will have a transformative impact on society through continual innovation in education, research and creativity.

MISSION

M-1-: To excel in providing high quality Mathematical skills to undergraduate

M-2-: To attend the mathematical needs of the institute and the community.

M-3-: To provide students (UG/PG) with a wide spectrum of valuable courses with rigorous training/tutorials that enables them to pursue their future.

M-4-: To encourage both research scholars and faculty members of the department to be the exposures of different research environments in India and abroad.

PROGRAMME OUTCOMES (PO's)

The programme outcomes and attributes are attained by the graduate students of Gangadhar Meher University through learning acquired on completion of a programme of study. Individual programmes of study have a defined programme specific learning outcomes which needs to be attained for the award of a specific degree. The programme learning outcomes of Gangadhar Meher University focus on various aspects of knowledge and skills that prepare students for further study, employment, and citizenship. Therefore, the UG programme of the Gangadhar Meher University has been designed with the objective to develop in-depth knowledge of students in frontier areas of concerned subject and seeks to achieve the following:

- **PO-1: Disciplinary Knowledge:** Undergraduate students will demonstrate knowledge and understanding of one or more discipline knowledge.
- **PO-2: Critical Thinking:** Apply their analytical thoughts to evaluate evidences, claims, theories and arguments of the discipline; formulate coherent arguments, evaluate practices and policies in the academic field
- **PO-3: Problem Solving:** Solve the non-familiar problems based upon his/her knowledge and understanding about the discipline knowledge, including real life problems
- **PO-4: Communication Skills:** Ability to express thoughts and ideas effectively verbally and written. Develops the capacity to listen patiently, express himself or herself.
- **PO-5: Research Related Skills:** A sense of Enquiry, and capacity for asking relevant/appropriate questions. Ability to recognize cause-effect relationship, define problem, formulate hypothesis, analyze, interpret and draw conclusions; generate and test hypothesis; conduct experiment and draw conclusion from findings scientifically.
- **PO-6: Co-Operative/Team Work:** Ability to work effectively and respectfully with diverse team; facilitate or co-ordinate efforts within group activities; work together within a team
- **PO-7: Multicultural Competencies:** Possess knowledge of the values and beliefs of multiple culture and a global perspective; capacity to work effectively in multiple socio-cultural contexts and interact respectfully with diverse social groups
- **PO-8: Digital Literacy:** Capacity to use ICT in a variety of learning situations; demonstrate ability to access, evaluate and use variety of relevant information sources; use appropriate software for data analysis.

PROGRAMME OBJECTIVES

(Set by School of Mathematics)

- Create deep interest in learning mathematics;
- To develop broad and balanced knowledge, and understanding of definitions, concepts, principles and theorems;
- To familiarize the students with suitable tools of mathematical analysis to handle issues and problems in mathematics and related sciences;
- To enhance the ability of learners to apply the knowledge and skills acquired by them during the programme to solve specific theoretical and applied problems in mathematics;
- To provide students sufficient knowledge and skills enabling them to undertake further studies in mathematics and its allied areas on multiple disciplines concerned with mathematics;
- To encourage the students to develop a range of generic skills helpful in employment, internships and social activities.

PROGRAMME SPECIFIC OUTCOMES(PSO's)

(Set by School of Mathematics)

- **PSO-1:** A student should be able to recall basic facts about mathematics and should be able to display knowledge of conventions such as notations, terminology.
- **PSO-2:** A student should get adequate exposure to global and local concerns that explore them many aspects of mathematical sciences.
- **PSO-3:** Student is equipped with mathematical modeling ability, problem solving skills, creative talent and power of communication necessary for various kinds of employment.
- **PSO-4:** Student should be able to apply their skills and knowledge that is translate information presented verbally into mathematical form, select and use appropriate mathematical formulae or techniques in order to process the information and draw the relevant conclusion.
- **PSO-5:** Enabling students to develop a positive attitude towards mathematics as an interesting and valuable subject of study.

MATCHING

Matching Percentage	Level Indicator
> 70%	3
= 60 %	2
< 50%	1

MISSION TO PO MAPPING

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
M1	3	3	3	3	3	3	3	3
M2	3	2	3	3	3	2	2	3
M3	3	2	2	3	2	2	3	2
M4	1	2	1	3	1	1	1	2

PSO TO PO MAPPING

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
PSO1	3	3	2	3	3	3	3	2
PSO2	1	3	3	2	3	3	2	3
PSO3	3	2	2	2	2	3	3	3
PSO4	1	2	3	3	3	2	1	3
PSO5	2	3	3	2	3	2	2	2

THREE YEAR DEGREE COURSE WITH SINGLE MAJOR AND TWO MINOR

COURSE STRUCTURE OF UG MATHEMATICS HONOURS UNDER N.E.P.-2020						
Sl No	Semester	Course	Type	Paper Code	Nomenclature	Credit
1	I	Core	Major	Major-I-P-I	Calculus & Analytic Geometry	4
2		Core	Major	Major-I-P-II	Introduction to Algebra & Number Theory	4
3		Core	Minor	Minor-I-P-I	Calculus & Analytic Geometry	4
4		Multidisciplinary Course	Multidisciplinary	MDC-I	Discrete Mathematics	3
5		Ability Enhancement Courses	Compulsory	AEC-I	Odia	4
6		Value Added Course	Compulsory	VAC-I	Environmental Studies and Disaster Management	3
					Total	22
7	II	Core	Major	Major-I-P-III	Real Analysis-I	4
8		Core	Major	Major-I-P-IV	Algebra-I	4
9		Core	Minor	Minor-II-P-I	Introduction to Algebra & Number Theory	4
10		Multidisciplinary Course	Multidisciplinary	MDC-II	Numerical Methods	3
11		Ability Enhancement Courses	Compulsory	AEC-II	English	4
12		Skill Enhancement Courses	Compulsory	SEC-I	Programming with Mathematica	3
					Total	22
13	III	Core	Major	Major-I-P-V	Probability	4
14		Core	Major	Major-I-P-VI	Differential Equations-I	4
15		Core	Major	Major-I-P-VII	Linear Algebra	4
16		Core	Minor	Minor-I-P-II	Real Analysis-I	4
17		Multidisciplinary Course	Multidisciplinary	MDC-III	Linear Programming Problem	3
18		Value Added Course	Compulsory	VAC-II	Ethics and Values	3
					Total	22

Sl No	Semester	Course	Type	Paper Code	Nomenclature	Credit	
19	IV	Core	Major	Major-I-P-VIII	Real Analysis-II	4	
20		Core	Major	Major-I-P-IX	Complex Analysis-I	4	
21		Core	Major	Major-I-P-X	Algebra-II	4	
22		Core	Minor	Minor-II-P-II	Linear Algebra	4	
23		Community Engagement & Services/Field Work/ Internship	CES/FW/Interm		Internship	4	
				Total			20
24	V	Core	Major	Major-I-P-XI	Real Analysis-III	4	
25		Core	Major	Major-I-P-XII	Differential Equations-II	4	
25		Core	Major	Major-I-P-XIII	Numerical Analysis & Scientific Computing	4	
27		Core	Minor	Minor-I-P-III	Differential Equations-I	4	
28		Skill Enhancement Course	Compulsory	SEC-II	Introduction to Python	3	
29		Value Added Course	Compulsory	VAC-III	Artificial Intelligence	3	
				Total			22
30	VI	Core	Major	Major-I-P-XIV	Multivariable Calculus	4	
31		Core	Major	Major-I-P-XV	Differential Geometry	4	
32		Core	Minor	Minor-II-P-III	Numerical Analysis & Scientific Computing	4	
33		Skill Enhancement Course	Compulsory	SEC-III	Typesetting in Latex	3	
34		Value Added Course	Compulsory	VAC-IV	Operation Research	3	
					Total		
Grand Total						126	

Green -: Major Course

Blue -: Minor Course

Dark Red -: Multidisciplinary Course

Purple -: Ability Enhancement Course

Red: Value Added Course

Black -: Skill Enhancement Course

SEMESTER-I

Calculus & Analytic Geometry (Major-I-P-I)

Credit Point:- 4

Full Marks:- 100

Total Hours:- 48

Course Objective:

The main emphasis of this course is to equip the student with necessary analytic and technical skills to handle problems of mathematical nature as well as practical problems. More precisely, main target of this course is to explore the different tools for higher order derivatives to plot the various curves and to solve the problems associated with differentiation and integration of vector functions.

Syllabus:-

Unit-I

(12 Hours)

Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of the type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax + b)^n\sin x$, $(ax + b)^n\cos x$, concavity and inflection points, asymptotes, curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, L'Hospital rule, application in business, economics and life sciences.

Unit-II

(12 Hours)

Riemann integration as a limit of sum, integration by parts, reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin^n x dx$, $\int \cos^n x dx$, $\int \tan^n x dx$, $\int \sec^n x dx$, $\int (\log x)^n dx$, $\int \sin^n x \cos^n x dx$, definite integral, integration by substitution.

Unit-III

(12 Hours)

Volumes by slicing, disks and washers methods, volumes by cylindrical shells, parametric equations, parameterizing a curve, arc length, arc length of parametric curves, area of surface of revolution, techniques of sketching conics, reflection properties of conics, rotation of axes and second degree equations, classification into conics using the discriminant, polar equations of conics.

Unit-IV

(12 Hours)

Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation, partial differentiation, div, curl and integration of vector functions, tangent and normal components of acceleration.

Books Recommended:

1. H. Anton, I. Bivens and S. Davis: *Calculus*, 10th Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. Shanti Narayan, P. K. Mittal: *Differential Calculus*, S. Chand, 2014.
3. R. J. T Bell: *An elementary Treatise on coordinate geometry*, MacMillan and Company Limited, 2005.

Books for Reference:

1. James Stewart: *Single Variable Calculus, Early Transcendental*, 8th edition, Cengage Learning, 2016.
2. G.B. Thomas and R. L. Finney: *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
3. M. J. Strauss, G. L. Bradley and K. J. Smith: *Calculus*, 3rd edition, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
4. Suggested digital platform: NPTEL/SWAYAM/MOOCs.
5. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completing the course, the student will be able to

C01-Trace a curve and find asymptotes.

C02-Calculate integrals of typical type using reduction formulae, etc.

C03-Calculate arc length, surface of revolution and know about conics

C04-Calculate triple products, gradient divergence, curl, etc.

CO-PO Mapping (Major-I-P-I)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	2
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Major-I-P-I

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-I	3	2	3	2	3	2	3	2

CO-PSO Mapping (Major-I-P-I)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Introduction to Algebra & Number Theory (Major-I-P-II)

Credit Points:- 4

Full Marks:- 100

Total Hours:- 48

Course Objectives:

To present a systematic introduction to number theory and a basic course on algebra.

Syllabus:-

Unit-I

(12 Hours)

Integers and equivalence relations, properties of integers, modular arithmetic, mathematical inductions, equivalence relations, Introduction to groups, symmetries of a square, the dihedral groups, definitions and examples of groups, elementary properties of groups, subgroups, examples of subgroups.

Unit-II

(12 Hours)

Cyclic groups, properties of cyclic groups, classification of subgroups of cyclic groups, definitions and examples of normal subgroups, Introduction to rings, definition and examples of rings, properties of rings, subrings, definition and examples of integral domain and fields.

Unit-III

(12 Hours)

Divisibility, division algorithms, prime and composite numbers, Fibonacci and Lucas numbers, Fermat numbers, greatest common divisor, Euclidean algorithm.

Unit-IV

(12 Hours)

Fundamental theorem of arithmetic, least common multiple, linear Diophantine equations, congruence, linear congruence, Chinese remainder theorem, Wilson's theorem, Fermat little theorem, Euler's theorem.

Books Recommended:

1. Joseph A. Gallian, *Contemporary Abstract Algebra*, 4th edition, Narosa Publishing House, New Delhi, 1999. (IX Edition 2010).
2. Thomas Koshy, *Elementary Number Theory with Applications*, 2nd edition, Academic Press, 2007.

Books for Reference:

1. I. N. Herstein: *Topics in Algebra*, Wiley Eastern Limited, India, 1975.
2. David M. Burton: *Elementary Number Theory*, 6th edition, T a t a McGraw-Hill Edition, Indian Reprint, 2007.
3. Suggested digital platform: NPTEL/SWAYAM/MOOCs.
4. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>.

Course Outcomes:

After completing the course, the student will be able to

- CO1.** Understand the equivalence relations and concept of group with different examples.
- CO2.** Understand the properties of cyclic groups, rings, and integral domain.
- CO3.** Know divisibility and division algorithm and find gcd using Euclidean Algorithm.
- CO4.** Solve linear Diophantine equations, find least common multiples, solve linear congruence applying the Chinese-remainder theorem.

CO-PO Mapping (Major-I-P-II)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	2
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Major-I-P-II

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-II	3	2	3	2	3	2	3	3

CO-PSO Mapping (Major-I-P-II)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Calculus & Analytic Geometry (Minor-I-P-I)

Credit Point:- 4

Full Marks:- 100

Total Hours:- 48

Course Objective:

The main emphasis of this course is to equip the student with necessary analytic and technical skills to handle problems of mathematical nature as well as practical problems. More precisely, main target of this course is to explore the different tools for higher order derivatives to plot the various curves and to solve the problems associated with differentiation and integration of vector functions.

Syllabus:-

Unit-I

(12 Hours)

Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of the type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax + b)^n\sin x$, $(ax + b)^n\cos x$, concavity and inflection points, asymptotes, curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, L'Hospital rule, application in business, economics and life sciences.

Unit-II

(12 Hours)

Riemann integration as a limit of sum, integration by parts, reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin^n x dx$, $\int \cos^n x dx$, $\int \tan^n x dx$, $\int \sec^n x dx$, $\int (\log x)^n dx$, $\int \sin^n x \cos^n x dx$, definite integral, integration by substitution.

Unit-III

(12 Hours)

Volumes by slicing, disks and washers methods, volumes by cylindrical shells, parametric equations, parameterizing a curve, arc length, arc length of parametric curves, area of surface of revolution, techniques of sketching conics, reflection properties of conics, rotation of axes and second degree equations, classification into conics using the discriminant, polar equations of conics.

Unit-IV

(12 Hours)

Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation, partial differentiation, div, curl and integration of vector functions, tangent and normal components of acceleration.

Books Recommended:

1. H. Anton, I. Bivens and S. Davis: *Calculus*, 10th Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. Shanti Narayan, P. K. Mittal: *Differential Calculus*, S. Chand, 2014.
3. R. J. T Bell: *An elementary Treatise on coordinate geometry*, MacMillan and Company Limited, 2005.

Books for Reference:

1. James Stewart: *Single Variable Calculus, Early Transcendental*, 8th edition, Cengage Learning, 2016.
2. G.B. Thomas and R. L. Finney: *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
3. M. J. Strauss, G. L. Bradley and K. J. Smith: *Calculus*, 3rd edition, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
4. Suggested digital platform: NPTEL/SWAYAM/MOOCs.
5. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completing the course, the student will be able to

C01-Trace a curve and find asymptotes.

C02-Calculate integrals of typical type using reduction formulae, etc.

C03-Calculate arc length, surface of revolution and know about conics

C04-Calculate triple products, gradient divergence, curl, etc.

CO-PO Mapping (Minor-I-P-I)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	2
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Minor-I-P-I

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Minor-I-P-I	3	2	3	2	3	2	3	2

CO-PSO Mapping (Minor-I-P-I)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Discrete Mathematics (MDC-I)

Credit Points: 3

Full Marks:- 100

Total Hours:- 48

Course Objective:

The main objectives of this course are to introduce topics and techniques of counting principles, combinatorics, and graph theory to understand problems in almost all areas of knowledge.

Syllabus:-

Unit-I

(12 Hours)

Propositional logic, propositional equivalences, predicates and quantifiers, nested quantifiers, rules of inference, methods of proof, relations and their properties, n-ary relations and their applications.

Unit-II

(12 Hours)

The basic counting principle, The Pigeon-hole principle, generalized permutations and combinations, recurrence relations, counting using recurrence relations, solving linear homogeneous recurrence relations with constant coefficients, generating functions, solving recurrence relations using generating functions.

Unit-III

(12 Hours)

Partially ordered sets, Hasse diagram of partially ordered sets, maps between ordered sets, duality principle, lattices, Boolean algebra.

Unit-IV

(12 Hours)

Graphs, basic concepts and graph terminology, representing graphs and graph isomorphism, distance in a graph, cut vertices and cut edges, connectivity, Euler and Hamiltonian path, shortest-path problems, planar graphs and graph coloring.

Books Recommended:

1. Kenneth H. Rosen, *Discrete Mathematics and Applications (Sixth Edition)*, Tata McGraw Hill Publications, 2007.
2. Edgar G. Goodaire and Michael M. Parmenter, *Discrete Mathematics with Graph Theory (2nd Edition)*, Pearson Education (Singapore) Pte. Ltd., Indian Reprint 2003.

Books for Reference:

- 1.B. A. Davey and H. A. Priestley, *Introduction to Lattices and Order*, Cambridge University Press, Cambridge, 1990.
2. Rudolf Lidl and Gnter Pilz, *Applied Abstract Algebra (2nd Edition)*, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
3. Kevin Ferland-*Discrete Mathematical Structures*, Cengage Learning India Pvt. Ltd., 2009.
4. Suggested digital platform: NPTEL/SWAYAM/MOOCs
5. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

On the completion of this course, students will be able to

CO1: Learn core ideas in logic and relations.

CO2: Know the concept of the Pigeon-hole principle and solve recurrence relations.

CO3: Learn lattices and Boolean algebra.

CO4: Get a good knowledge of the basics of Graph theory.

CO-PO Mapping (MDC-I)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	2
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for MDC-I

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course MDC-I	3	2	3	2	3	2	3	3

CO-PSO Mapping (MDC-1)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

SEMESTER-II

Real Analysis-I(Major-I-P-III)

Credit Point:- 4

Full Marks:- 100

Total Hours: 48

Course Objective:

The objective of the course is to introduce the basics of real number system and the properties of sequence and series of real numbers. The ideas of completeness, least upper bound property, denseness, limit, continuity and uniform continuity will also be introduced. This is one of the core courses essential to start doing mathematics.

Syllabus:-

Unit-I

(12 Hours)

Finite and infinite sets, countable and uncountable sets, examples, algebraic and order Properties of $\mathbb{R}$, uncountability of $\mathbb{R}$, completeness property of $\mathbb{R}$, applications of the supremum property, Intervals, nested interval property, denseness of rational in $\mathbb{R}$.

Unit-II

(12 Hours)

Sequence and their limits, limit theorems, monotone sequences, monotone Convergence theorem, subsequences, divergence criteria, monotone subsequence theorem, Bolzano Weierstrass theorem for sequences, Cauchy sequence, Cauchy's convergence criterion.

Unit-III

(12 Hours)

Infinite series, convergence and divergence of infinite series, Cauchy criterion, Tests for convergence: comparison test, limit comparison test, ratio test, Cauchy's nth root test, Raabe's test, integral test, alternating series, Leibniz test, absolute and conditional convergence.

Unit-IV

(12 Hours)

Limits of functions, limit theorems, some extensions of limit concept, continuous functions and their combinations, continuous functions on intervals, boundedness theorem, maximum minimum theorem, intermediate value theorem, uniform continuity, examples, uniform continuity theorem.

Books Recommended:

- 1 R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, 3rd edition., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. G. Das and S. Pattanayak, *Fundamentals of Mathematical Analysis*, TMH Publishing Co., 30th reprints, 2021.

Books for Reference:

1. S. C. Mallik and S. Arora, *Mathematical Analysis*, New Age International Publications.
2. A. Kumar, S. Kumaresan, *A basic course in Real Analysis*, CRC Press, 2014.
3. Brian S. Thomson, Andrew. M. Bruckner, and Judith B. Bruckner, *Elementary Real Analysis*, Prentice Hall, 2001.
4. Gerald G. Bilodeau, Paul R. Thie, G. E. Keough, *An Introduction to Analysis*, Jones & Bartlett, 2nd edition, 2010.
5. e-Learning Source <http://ndl.iitkgp.ac.in>; <http://ocw.mit.edu> ; <http://mathforum.org>
6. Suggested digital platform: NPTEL/SWAYAM/MOOCs.

Course Outcomes:

On successful completion of this course, students will be able to

C01. Learn basics of real number system and test countability of a set.

C02. Know on sequence of real numbers and their basic properties.

C03. Test convergence of an infinite series.

C04. Find limit and continuity of functions and test uniform continuity of functions.

CO-PO Mapping (Major-I-P-III)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	2
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Major-I-P-III

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-III	3	2	3	2	3	2	3	3

CO-PSO Mapping (Major-I-P-III)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Algebra-I(Major-I-P-IV)

Credit Point:- 4

Full Marks:-100

Total Hours: - 48

Course Objectives:

To present a systematic and rigorous study on algebraic structures like groups, rings and some important results with their applications. After pursuing this course, one can opt for advanced topics in groups, rings and their applications to problems in physics, computer science and engineering.

Syllabus:-

Unit-I

(12 Hours)

Permutation groups, definition and notations, cyclic notation, properties of permutations, isomorphisms, definition and examples, Cayley's theorem, properties of isomorphisms, automorphisms, cosets, properties of cosets, Lagrange's theorem and consequences, an application of cosets to permutation groups, an application of cosets to Rubik's cube.

Unit-II

(12 Hours)

External direct products, definition and examples, properties of external direct products, the group of units modulo n as an external direct product, applications, normal subgroups, factor groups, application of factor groups, internal direct products, group homomorphisms, definition and examples, properties of homomorphisms, the first isomorphism theorem.

Unit-III

(12 Hours)

Characteristic of a ring, ideals, factor rings, prime ideals and maximal ideals, ring homomorphisms, definition and examples, the field of quotients, polynomial rings, notations and terminology, division algorithm and consequences.

Unit-IV

(12 Hours)

Factorization of polynomials, reducibility test, irreducibility test, unique factorization in $\mathbb{Z}[x]$, divisibility in integral domains, irreducible, primes, unique factorization domain, Euclidean domain.

Books Recommended:

1. Joseph A. Gallian, *Contemporary Abstract Algebra*, 9th edition, Narosa Publishing House, New Delhi, 2010.
2. I. N. Herstein, *Topics in Algebra*, Wiley Eastern Limited, India, 1975.

Books for Reference:

1. John B. Fraleigh, *A First Course in Abstract Algebra*, 7th edition., Pearson, 2002.
2. D. S. Dummit, R. M. Foote, *Abstract Algebra*, Wiley-India edition, 2013.
3. Joseph 1. Rotman, *An Introduction to the Theory of Groups*, 4th edition., Springer Verlag, 1995.
4. M. Artin, *Abstract Algebra*, 2nd edition., Pearson, 2011.
5. Suggested digital platform: NPTEL/SWAYAM/MOOCs.
6. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completing this course, students will able to

- C01.** Understand permutation groups with some results and application in Rubik's cube.
- C02.** Understand the concept of homomorphisms, isomorphisms, normal subgroups and factor groups.
- C03.** Explore more properties of rings and ideals rigorously.
- C04.** Get introduced to the concept of reducibility and irreducibility of polynomials and concept of unique factorization domain.

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	1
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Major-I-P-IV

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-IV	3	2	3	2	3	2	2	3

CO-PSO Mapping (Major-I-P-IV)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Introduction to Algebra & Number Theory (Minor-II-P-I)

Credit Points:- 4

Full Marks:- 100

Total Hours:- 48

Course Objectives:

To present a systematic introduction to number theory and a basic course on algebra.

Syllabus:-

Unit-I

(12 Hours)

Integers and equivalence relations, properties of integers, modular arithmetic, mathematical inductions, equivalence relations, Introduction to groups, symmetries of a square, the dihedral groups, definitions and examples of groups, elementary properties of groups, subgroups, examples of subgroups.

Unit-II

(12 Hours)

Cyclic groups, properties of cyclic groups, classification of subgroups of cyclic groups, definitions and examples of normal subgroups, Introduction to rings, definition and examples of rings, properties of rings, subrings, definition and examples of integral domain and fields.

Unit-III

(12 Hours)

Divisibility, division algorithms, prime and composite numbers, Fibonacci and Lucas numbers, Fermat numbers, greatest common divisor, Euclidean algorithm.

Unit-IV

(12 Hours)

Fundamental theorem of arithmetic, least common multiple, linear Diophantine equations, congruence, linear congruence, Chinese remainder theorem, Wilson's theorem, Fermat little theorem, Euler's theorem.

Books Recommended:

1. Joseph A. Gallian, *Contemporary Abstract Algebra*, 4th edition, Narosa Publishing House, New Delhi, 1999. (IX Edition 2010).
2. Thomas Koshy, *Elementary Number Theory with Applications*, 2nd edition, Academic Press, 2007.

Books for Reference:

1. I. N. Herstein: *Topics in Algebra*, Wiley Eastern Limited, India, 1975.
2. David M. Burton: *Elementary Number Theory*, 6th edition, Tata McGraw-Hill Edition, Indian Reprint, 2007.
3. Suggested digital platform: NPTEL/SWAYAM/MOOCs.
4. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>.

Course Outcomes:

After completing the course, the student will be able to

- CO1. Understand the equivalence relations and concept of group with different examples.
- CO2. Understand the properties of cyclic groups, rings, and integral domain.
- CO3. Know divisibility and division algorithm and find gcd using Euclidean Algorithm.
- CO4. Solve linear Diophantine equations, find least common multiples, solve linear congruence applying the Chinese-remainder theorem

CO-PO Mapping (Minor-II-P-I)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
CO1	3	2	1	1	2	1	1	2
CO2	3	1	3	2	2	1	2	2
CO3	2	3	3	3	2	2	3	3
CO4	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Minor-II-P-I

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Minor-II-P-I	3	2	3	2	3	2	3	3

CO-PSO Mapping (Minor-II-P-I)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Numerical Methods (MDC-II)

Credit Points:- 3

Full Marks:- 100

Total Hours:- 48

Course Objective:

Calculation of error and approximation is necessity in all real life, industrial and scientific computing. The objective of this course is to acquaint students with various numerical methods of finding solution of different type of problems, which arises in different branches of science like locating roots of equations, finding solution of nonlinear equations, systems of linear equations, differential equations, Interpolation, differentiation, evaluating integration.

Syllabus:-

Unit-I

(12 Hours)

Algorithms, convergence, Bisection method, false position method, fixed point iteration method, Newton's method, Secant method. Gauss elimination and Gauss Jordan methods, LU decomposition, Gauss-Jacobi, Gauss-Siedel.

Unit-II

(12 Hours)

Lagrange and Newton interpolation: linear and higher order, finite difference operators.

Unit-III

(12 Hours)

Numerical differentiation: forward difference, backward difference and central difference operators..

Unit-IV

(12 Hours)

Integration: trapezoidal rule, Simpson's rule, Euler's method, Runge-Kutta methods of orders two and four.

Books Recommended:

1. M.K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 5th Ed.

Books For Reference:

1. S.S. Sastry, *Introductory method for Numerical Analysis*, PHI New Delhi, 2012.
2. S.D. Conte and Carl De Boor, *Elementary Numerical Analysis*, Mc Graw Hill,
3. e-Learning Source <http://ndl.iitkgp.ac.in>; <http://ocw.mit.edu>; <http://mathforum.org>
4. Suggested digital platform: NPTEL/SWAYAM/MOOCs

Course Outcomes:

On the completion of this course, students will be able to

CO1-Learn different techniques to find the zeros of algebraic and transcendental equations, numerical solutions of system of equations.

CO2-Get the idea to find the numerical solutions of polynomial equations .

CO3-Learn to find the numerical differentiation by means of different operators

CO4-Learn to find numerical integration which will help to find the numerical solution of ODE and PDE

CO-PO Mapping (MDC-II)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
CO1	3	2	1	1	2	1	1	2
CO2	3	1	3	2	2	1	2	3
CO3	2	3	3	3	2	2	3	3
CO4	2	2	3	2	3	2	2	3

Programme articulation Matrix row for MDC-II

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course	3	2	3	2	3	2	3	2

MDC-II								
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CO-PSO Mapping (MDC-II)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Programming with Mathematica (SEC-I)

Credit Points: 3

Full Marks:- 100

Total Hours:- 36

Course Objective:

The objective of this course is to aware the students for Mathematica language and the programing as well as to create a learning platform to apply for complex mathematical problems.

Syllabus:- Unit-I

(12 Hours)

User interface, mathematica language and syntax, functions manipulation, plotting mathematical functions and data. plotting 2D, 3D functions and manipulation, solving algebraic equation: root finding, transcendental equation.

Unit-II

(12 Hours)

Solving ordinary differential equation (ODE), solving partial differential equation (PDE).

Unit-III

(12 Hours)

Vectors and matrices, limits, integration and differentiation, numerical computation, symbolic manipulation.

Books Recommended:

1. Stephen Wolfram, *The Mathematica Book*, 5th edition, Wolfram Media Inc, 2003.
2. José Guillermo Sánchez León, *Mathematica Beyond Mathematics: The Wolfram Language in the Real World*, 1st edition, Chapman and Hall/CRC, 2017.
3. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCs.
4. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completion of this course, the students will be able to:

CO1-Understand basic principles of programming language, plotting mathematical functions and solving algebraic equations.

CO2-Learn the technique to find the solutions of ODE and PDE equations.

CO3-Learn the numerical computation for differentiation and integration

CO-PO Mapping (SEC-I)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
CO1	3	2	1	1	2	1	1	2
CO2	3	1	3	2	2	1	2	3
CO3	2	3	3	3	2	2	3	3

Programme articulation Matrix row for SEC-I

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course SEC-I	3	2	3	2	3	2	3	2

CO-PSO Mapping (SEC-I)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
CO1	3	3	3	3	3
CO2	3	2	3	2	2
CO3	3	3	3	3	2

SEMESTER-III

Probability (Major-I-P-V)

Credit Points: 4

Full Marks:- 100

Total Hours: - 48

Course Objective:

The objective of the course is to make the student understand basics of probability which is of use in everyday life.

Syllabus:-

Unit-I

(12 Hours)

Sample space and events, probability axioms, probability defined on events, conditional probabilities, independent events, Bayes formula, real random variables, discrete and continuous random variables, probability distribution function, probability mass/density functions, mathematical expectation, and properties, variance and standard deviation.

Unit-II

(12 Hours)

Discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential, their expectations and variance, moments, moment generating function, characteristic function and computation of these for the distributions, joint distribution function and its properties, joint probability density functions, marginal and conditional distributions, independent random variables.

Unit-III

(12 Hours)

Limit theorems: Markov inequality, Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers, application to problems, conditional probability and conditional expectation, discrete case, continuous case, applications, expectation of function of two random variables, conditional expectations, bivariate normal distribution, correlation coefficient, joint moment generating function and calculation of covariance, linear regression for two variables.

Unit-IV

(12 Hours)

Central limit theorem for independent and identically distributed random variables with finite variance, Markov chains, Chapman-Kolmogorov equations, classification of states, Gambler Ruin problem.

Book Recommended:

1. Sheldon Ross, *Introduction to Probability Models* (9th Edition), Academic Press, Indian Reprint, 2007.
2. Robert V. Hogg, Joseph W. McKean and Allen T. Craig, *Introduction to Mathematical Statistics*, Pearson Education, Asia, 2007.
3. Kai Lai Chung, *Elementary Probability Theory with Stochastic Process*, Springer International Students Edition, (Narosa Publ.)

Book for Reference:

1. Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, *Introduction to the Theory of Statistics*, 3rd edition, Tata McGraw- Hill, Reprint 2007.
2. Chow Y S, Teicher H, *Probability theory*, Springer International edition.
3. Irwin Miller and Marylees Miller, John E. Freund's *Mathematical Statistics with Applications*, 7th edition, Pearson Education, Asia, 2006.
4. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>
5. Suggested digital platform: NPTEL/SWAYAM/MOOCs.

Course Outcomes:

After completing the course, the student will be able to

- C01.** Learn the basics of probability and random variables with axioms of probability.
- C02.** Know the discrete and continuous distributions and learn how to calculate mean, variance and moments of them.
- C03.** Learn on limit theorems with their applications and know about the conditional expectations.
- C04.** Learn on Markov chains and their applications.

CO-PO Mapping (Major-I-P-V)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	2

Programme articulation Matrix row for Major-I-P-V

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-V	3	2	3	2	3	2	2	3

CO-PSO Mapping (Major-I-P-V)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Differential Equations-I (Major-I-P-VI)

Credit Points:- 4

Full Marks:- 100

Total Hours:- 48

Course Objective:

Differential Equations introduced by Leibnitz in 1676 models almost all Physical, Biological, Chemical systems in nature. The objective of this course is to familiarize the students to various methods of solving differential equations, partial differential equations and to have a qualitative application through models. The students have to solve problems to understand the methods.

Syllabus:-

Unit-I

(12 Hours)

Differential equations and mathematical models, general, particular, explicit, implicit and singular solutions of a differential equation, exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equations and Bernoulli's equation, compartmental model, population model for single species.

Unit-II

(12 Hours)

General solution of homogeneous equation of second order, principle of superposition, Wronskian, its properties and applications, method of undetermined coefficients, method of variation of parameters, linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equations.

Unit-III

(12 Hours)

Partial Differential Equations - Basic concepts and definitions, origin of first order PDEs, Classification of first order PDEs, Pfaffian differential forms and equations, solution of Pfaffian differential equations in three variables, Cauchy's problem for first order PDEs, linear equations of first order, integral surfaces passing through a given curve, Cauchy's method of characteristics, compatible systems, method of separation of variables for solving first order and second order partial differential equations.

Unit-IV (Practical)

(12 Hours)

The students will implement the following problems in the computer Lab using *Matlab* / *Mathematica* / *Maple* etc.

1. Plotting of second order solution family of differential equations.
2. Plotting of third order solution family of differential equations.
3. Population growth model (exponential case only).
4. Population decay model (exponential case only).
5. Solution of Cauchy problem for first order PDEs.
6. Finding the characteristics for the first order PDEs.
7. Plot the integral surfaces of a given first order PDE with initial data.

Books Recommended:

1. J. Sinha Roy and S. Padhy: *A course of Ordinary and Partial differential equations*, Kalyani Publishers, New Delhi, 2018.
2. Belinda Barnes and Glenn R. Fulford, *Mathematical Modeling with Case Studies, A Differential Equation Approaching Maple and Matlab*, 2nd edition. Taylor and Francis group, London and New York, 2009.
3. Sneddon; *Elements of Partial Differential Equations*, McGraw-Hill, International Students Edition, 1957.

Books for Reference:

1. G. F. Simmons, *Differential equation*, Tata McGraw Hill, 1991.
2. J. N. Sharma and Kehar Singh, *PDE for Engineers and Scientists*, Narosa, New Delhi, 2009.
3. Martin Braun, *Differential Equations and their Applications*, Springer International Student Ed.1978.
4. S. L. Ross, *Differential Equations*, 3rd edition, John Wiley and Sons, India, 2014.
5. C.Y. Lin, *Theory and Examples of Ordinary Differential Equations*, World Scientific, 2011.
6. Suggested digital platform: NPTEL/SWAYAM/MOOCs.
7. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completing the course, the student will be able to

- C01.** Get the idea to solve first order linear ordinary differential equations of different types those are arising in physical problems.
- C02.** Get the idea to solve second order linear ordinary differential equations of different types those are arising in physical problems.
- C03.** Get basic ideas of first order partial differential equations, its formulation in two, three variables and variable separable method for identify the solutions.
- C04.** Get idea to solve various mathematical models of ODEs and PDEs which may be helpful for simulation process.

CO-PO Mapping (Major-I-P-VI)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	1
C04	2	2	3	2	3	2	2	2

Programme articulation Matrix row for Major-I-P-VI

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-VI	3	2	3	2	3	2	2	3

CO-PSO Mapping (Major-I-P-VI)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Linear Algebra (Major-I-P-VII)

Credit Points: 4

Full Marks:- 100

Total Hours:- 48

Course Objective:

The objective of this course is to acquaint students with matrix operations, solution of system of equations, vector spaces and linear transformations. In addition, the student will learn about eigenvalues, diagonalization, canonical forms, etc., which has many applications in almost all areas of science and engineering.

Syllabus:-

Unit-I

(12 Hours)

Vector spaces, subspaces, span of a set, more about subspaces, linear dependence, independence, product and quotient space, dimension and basis, linear transformations, range and kernel of a linear map, rank and nullity of linear map.

Unit-II

(12 Hours)

Inverse of linear transformation, consequences of rank – nullity theorem, the space $L(U, V)$, composition of linear maps, matrix associated with linear map, linear map associated with matrix, rank and nullity of a matrix, determinant minors and rank of a matrix, transpose of a matrix and special type of matrices, elementary row operations

Unit-III

(12 Hours)

System of linear equations, matrix inversion, application of determinant to linear equations, eigenvalues and eigenvectors, similarity of matrices, invariant subspaces, minimal polynomial (eigenvalues and the minimal polynomial), upper triangular matrices, diagonalizable operators (diagonal matrices, conditions for diagonalizability).

Unit-IV

(12 Hours)

Inner product space: inner products and norms, orthonormal bases, orthogonal complements, self-adjoint and normal operators, spectral theorems, isometries, unitary operators, characteristic polynomial, Cayley – Hamilton theorem, Jordan form, trace, quadratic form, application to reduction of quadrics.

Books Recommended:

1. V. Krishnamurthy, V.P. Mainra, J. L. Arora, *An introduction to linear algebra*, Affiliated East – West press Pvt. Ltd., New Delhi, 1976.
2. Sheldon Axler, *Linear algebra done right*, 4th edition, Springer, 2024.

Books for References:

1. Seymour Lipschutz and Marc Lars Lipson, *Linear Algebra (Schaum's outlines)*, 4th edition, McGraw Hill, New York, 2009.
2. A. Ramachandra Rao and P. Bhimsankaram, *Linear Algebra*, 2nd edition, Hindustan Book Agency, 2000.
3. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra*, 4th edition, Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
4. Gilbert Strang, *Linear Algebra and its Applications*, Thomson, 2007.
- 5 S. Kumaresan, *Linear Algebra- A Geometric Approach*, Prentice Hall of India, 1999.
6. Suggested digital platform: NPTEL/SWAYAM/MOOCs.
7. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org> ; <https://linear.axler.net>; and <https://library.oapen.org/handle/20.500.12657/85067>

Course Outcomes:

After completing the course, the student will be able to

- C01.** Determine basis and the dimension of a finite-dimensional vector space, know the relation between rank and nullity of a linear transformation.
- C02.** The relation between matrix and linear transformation.
- C03.** To find solution of system of linear equations, compute eigenvalues, eigenvectors of a matrix and linear transformation.
- C04.** About orthogonality of vectors and application of it to different form of matrix, introduced to different operators.

CO-PO Mapping (Major-I-P-VII)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Major-I-P-VII

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-VII	3	2	3	2	3	2	3	3

CO-PSO Mapping (Major-I-P-VII)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Real Analysis-I(Minor-I-P-II)

Credit Point:- 4

Full Marks:- 100

Total Hours: 48

Course Objective:

The objective of the course is to introduce the basics of real number system and the properties of sequence and series of real numbers. The ideas of completeness, least upper bound property, denseness, limit, continuity and uniform continuity will also be introduced. This is one of the core courses essential to start doing mathematics.

Syllabus:-

Unit-I

(12 Hours)

Finite and infinite sets, countable and uncountable sets, examples, algebraic and order Properties of $\mathbb{R}$, uncountability of $\mathbb{R}$, completeness property of $\mathbb{R}$, applications of the supremum property, Intervals, nested interval property, denseness of rational in $\mathbb{R}$.

Unit-II

(12 Hours)

Sequence and their limits, limit theorems, monotone sequences, monotone Convergence theorem, subsequences, divergence criteria, monotone subsequence theorem, Bolzano Weierstrass theorem for sequences, Cauchy sequence, Cauchy's convergence criterion.

Unit-III

(12 Hours)

Infinite series, convergence and divergence of infinite series, Cauchy criterion, Tests for convergence: comparison test, limit comparison test, ratio test, Cauchy's nth root test, Raabe's test, integral test, alternating series, Leibniz test, absolute and conditional convergence.

Unit-IV

(12 Hours)

Limits of functions, limit theorems, some extensions of limit concept, continuous functions and their combinations, continuous functions on intervals, boundedness theorem, maximum minimum theorem, intermediate value theorem, uniform continuity, examples, uniform continuity theorem.

Books Recommended:

- 1 R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, 3rd edition., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. G. Das and S. Pattanayak, *Fundamentals of Mathematical Analysis*, TMH Publishing Co., 30th reprints, 2021.

Books for Reference:

1. S. C. Mallik and S. Arora, *Mathematical Analysis*, New Age International Publications.
2. A. Kumar, S. Kumaresan, *A basic course in Real Analysis*, CRC Press, 2014.
3. Brian S. Thomson, Andrew. M. Bruckner, and Judith B. Bruckner, *Elementary Real Analysis*, Prentice Hall, 2001.
4. Gerald G. Bilodeau, Paul R. Thie, G. E. Keough, *An Introduction to Analysis*, Jones & Bartlett, 2nd edition, 2010.
5. e-Learning Source <http://ndl.iitkgp.ac.in>; <http://ocw.mit.edu> ; <http://mathforum.org>
6. Suggested digital platform: NPTEL/SWAYAM/MOOCs.

Course Outcomes:

On successful completion of this course, students will be able to

- C01.** Learn basics of real number system and test countability of a set.
- C02.** Know on sequence of real numbers and their basic properties.
- C03.** Test convergence of an infinite series.
- C04.** Find limit and continuity of functions and test uniform continuity of functions.

CO-PO Mapping (Minor-I-P-II)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	2
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Minor-I-P-II

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Minor-I-P-II	3	2	3	2	3	2	3	3

CO-PSO Mapping (Minor-I-P-II)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Linear Programming Problem (MDC-III)

Credit Points:- 3

Full Marks:- 100

Total Hours:- 48

Course Objective:

The objective of this course is to familiarize industrial problems to students with various methods of solving linear programming problems, transportation problems, assignment problems and their applications. Also, students will know the application of linear programming method in Game theory.

Syllabus:-

Unit-I

(12 Hours)

Introduction to linear programming problems (LPP), solution of LPP by graphical method, canonical forms, theory of simplex method, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, two-phase method, Big-M method.

Unit-II

(12 Hours)

Duality, formulation of the dual problem, primal-dual relationships, examples, fundamental theorem of duality, dual simplex method.

Unit-III

(12 Hours)

Transportation problem and its mathematical formulation, methods for initial basic feasible solution. Vogel approximation algorithm for solving transportation problem, assignment problems and its mathematical formulation, Hungarian method for solving assignment problem.

Unit-IV (Practical)

(12 Hours)

Practical / Lab work to be perform in Computer Lab:

Use of computer algebra system (CAS) software: Python/ Sage Math / Mathematica/MATLAB/ Maple/ Maxima/ Scilab/ R or any other (open source) software etc., for developing at least the following:

- 1) Graphical method
- 2) LPP method
- 3) Two-phase method
- 4) Primal-dual problem
- 5) Dual simplex method
- 6) Vogel's approximation method
- 7) Hungarian method for assignment problem

Books Recommended:

1. Kanti Swarup, *Operations Research*, Sultan Chand & Sons, New Delhi. Books.
2. Hamdy A. Taha, *Operations Research: An Introduction (10th edition)*, Pearson, 2017

Books For Reference:

1. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, *Linear Programming and Network Flows*, 2nd edition, John Wiley and Sons, India, 2004.
2. Hillier and G.J. Lieberman, *Introduction to Operations Research-Concepts and Cases*, 9th edition, Tata Mc Graw Hill, 2010
3. G. Hadley, *Linear Programming*, Narosa Publishing House, New Delhi, 2002.
4. *Suggested digital platform: NPTEL/SWAYAM/MOOCs*
5. *e-Learning Source* <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

On the completion of this course, students will be able to

- C01**-Know how to solve the two-dimensional problems graphically and learn algorithms for higher dimensional problems.
- C02**-Know fundamental theorem of duality, dual simplex method and revised simplex algorithm.
- C03**-Solve the transportation problems in business sectors and job-oriented assignment problems. Also, students will be aware of game theory with different problems and formulation of solutions.
- C04**-Design the programming for the linear programming problems which are essential in industrial sectors.

CO-PO Mapping (MDC-II)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for MDC-II

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course MDC-II	3	2	3	2	3	2	3	2

CO-PSO Mapping (MDC-II)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Mathematica (VAC-II)

Credit Points:- 3

Full Marks:- 100

Total Hours:- 30

Course Objectives:

The objective of this course is to introduce students to mathematica language which is very useful in the simulation process dealing with mathematical modelling and also, in different branches of practical mathematics.

Syllabus:-

List of Practical

1. Solving higher degree equations.
2. Solving system of equations by matrix method and find the eigen values and eigen vectors of a matrix of order 4 by 4 or higher order.
3. Solving system of non-linear equations.
4. Finding the differentiation of different functions of second and third derivatives.
5. Finding the Integration of different functions with limits.
6. Evaluation of double integrals and triple integrals.
7. Solving ordinary differential equations and partial differential equations with initial condition.
8. Solving system of ordinary differential equations.
9. Creating and plotting 2-D and 3-D graphs.
10. Finding the volume of solid of revolution.
11. Solving linear programming problems
12. Solving problems in numerical analysis (Finding roots, interpolations, integration)

Book Recommended:

1. Eugene Don, *Mathematica, Scham's Outline Series, Mc Graw Hill Publisher, New York. (2009)*
2. Pragathi Gautam and Swapnil Verma, *Practical Mathematica, Ane Books Publisher (2019).*

Books For Reference:

1. Ananta Kumar Bora, *Mathematica: A Research Book of Mathematics, Scholarink Publishers (2017)*
2. Sal Mangano, *Mathematica Cookbook, O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, USA (2010)*

Course Outcomes:

After completion of this course, students will be able to:

C01-Learn a new programming language in mathematics.

C02-Increase the problem-solving capability in mathematics, plotting of 2D, 3D graphs and solving LPP problems.

CO-PO Mapping (VAC-II)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3

Programme articulation Matrix row for VAC-II

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course VAC-II	3	2	3	2	3	2	3	2

CO-PSO Mapping (VAC-II)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2

SEMESTER-IV

Real Analysis-II (Major-I-P-VIII)

Credit Points: 4

Full Marks:- 100

Total Hours:- 48

Course Objective:

As a second course in real analysis, the objective is to learn on the concept of differentiation, Riemann Integration and their applications. The series of functions and the improper integrals have also been introduced.

Syllabus:-

Unit-I

(12 Hours)

Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions, relative extrema, interior extremum theorem. Rolle's theorem, Mean value theorems, Cauchy's mean value theorem, Lagrange mean value theorem, intermediate value property of derivatives, Darboux's theorem, applications of mean value theorem, Taylor's theorem and applications.

Unit-II

(12 Hours)

Riemann integration: partitions, conditions of integrability, definition of Riemann integral properties of the Riemann integral, Riemann integral as limit of a sum, mean value theorem for integrals, integration by parts, Fundamental theorems of calculus, Taylor theorem with remainder.

Unit-III

(12 Hours)

Pointwise and uniform convergence of sequence of functions, Cauchy criterion for uniform convergence and Weierstrass M-test, uniform convergence and continuity, term by term integration and differentiation of a series, power series, Abel's theorem, Weierstrass approximation theorem, Taylor series

Unit-IV

(12 Hours)

Improper integrals, integration of unbounded functions with finite limits of integration, comparison tests of convergence, infinite range of integration, integrand as product of functions convergent at infinity, absolutely convergent integral, tests of convergence, convergence of Beta and Gamma functions, applications.

Books Recommended:

1. R.G. Bartle D.R. Sherbert, *Introduction to Real Analysis*, John Wiley and Sons (Asia) Pvt. Ltd., Singapore
2. G. Das and S. Pattanayak, *Fundamentals of Mathematics Analysis*, TMH Publishing Co.
3. S. C. Mallik and S. Arora, *Mathematical Analysis*, New Age International Ltd., New Delhi.

Book for Reference:

1. K. A. Ross, *Elementary Analysis: The theory of Calculus*, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
2. Charles G. Denlinger, *Elements of Real Analysis*, Jones and Bartlett (Student Edition), 2011.
3. A. Kumar, S. Kumaresan, *A basic course in Real Analysis*, CRC Press, 2014
4. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>
5. Suggested digital platform: NPTEL/SWAYAM/MOOCs.

Course Outcomes:

After completing the course, the student will be able to

- C01.** Learn working out problems on derivatives of function and their applications.
- C02.** Learn about Riemann Integration and their properties including Improper Integrals.
- C03.** Learn on pointwise and uniform convergence of power series.
- C04.** Learn to calculate value of improper integrals.

CO-PO Mapping (Major-I-P-VIII)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Major-I-P-VIII

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-VIII	3	2	3	2	3	2	3	2

CO-PSO Mapping (Major-I-P-VIII)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Complex Analysis-I(Major-I-P-IX)

Credit Points:- 4

Full Marks:- 100

Total Hours:- 48

Course Objectives:

The objective of the course is to introduce the theories for functions of a complex variable. The concepts of analyticity and complex integration and its applications, are discuss in detail. This course is prerequisite to many other advance analysis courses such as advanced complex analysis, geometric functions, theory, potential theory, theory of entire and meromorphic functions, etc.

Syllabus:-

Unit-I

(12 Hours)

Basic properties of complex number and, Stereographic projection, power series, absolute convergence, uniform convergence, Cauchy-Hadamard formula for the radius of convergence, circle of convergence, exponential, logarithmic, sine and cosine functions for complex numbers.

Unit-II

(12 Hours)

Continuity and differentiability of a complex valued function, analytic function, necessary and sufficient conditions for analytic functions, Cauchy-Riemann equations (Cartesian and polar form), harmonic and conjugate harmonic functions, construction of analytic function (Milne-Thomson's method).

Unit-III

(12 Hours)

Line integral, path independence, complex integration, Green's theorem, anti-derivative theorem, Cauchy-Goursat theorem, Cauchy integral formula, Cauchy's inequality, derivative of analytic function and its generalizations, Liouville's theorem, Morera's theorem, Taylor's and Laurent's theorem, expansion of analytical function in Taylor and Laurent series.

Unit-IV

(12 Hours)

Zeroes of an analytic function, singularities of complex functions and its classifications, residues, Cauchy's residue theorem, residue at infinity, residues at poles and its examples, maximum modulus theorem.

Books Recommended:

1. Elias M. Stein & Rami Shakarchi: *Complex Analysis*, Princeton University press, Princeton and Oxford, 2003.
2. Joseph Bak and Donald J. Newman: *Complex analysis*, 3rd edition, Undergraduate Texts in Mathematics, Springer-Verlag, New York, 1997.

Books for References:

1. S. Ponnusamy and Herb Silverman: *Complex variables with Applications*: Birkhauser, (2006) (Indian Edition 2012).
2. H. A. Priestly: *Introduction to Complex Analysis*, Oxford University Press, 2008.
3. Donald Sarason: *Complex Function Theory*: AMS, Second Edition, 2007.
4. James Ward Brown and Ruel V. Churchill: *Complex Variables and Applications*, 8th edition, McGraw-Hill International Edition, 2009.
5. Suggested digital platform: NPTEL/SWAYAM/MOOCs
6. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completing the course, the student will be able to

CO1. Understand the geometric aspects of complex numbers system, convergence of

series of complex numbers.

- C02.** Understand the significance of complex differentiability, analyticity and construction of analytic functions from given harmonic functions.
- C03.** Relate the notion of line integral, Cauchy fundamental theorems on integrals and its applications.
- C04.** Classify the nature of singularities, properties of zeros and poles and be able to know the applications of residue theorem.

CO-PO Mapping (Major-I-P-IX)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Major-I-P-IX

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-IX	3	2	3	2	3	2	2	2

CO-PSO Mapping (Major-I-P-IX)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Algebra-II(Major-I-P-X)

Credit Points:- 4

Full Marks:- 100

Total Hours:- 48

Course Objective:

To present a systematic study on finite abelian groups, Sylow's theorems and Modules.

Syllabus:-

Unit-I

(12 Hours)

Fundamental theorem of finite abelian groups, isomorphism classes of abelian groups, proof of the fundamental theorem, Sylow's theorems, conjugacy classes, the class equation, Sylow's first theorem, Cauchy theorem, Sylow's second and third theorems.

Unit-II

(12 Hours)

Application of Sylow's theorem, finite simple groups, non-simplicity tests, the simplicity of alternating group A_5 , free groups, classification of groups of order up to 15, characterization of dihedral groups.

Unit-III

(12 Hours)

Group actions and permutation representations, composition series and holder programs, nilpotent groups, solvable groups.

Unit-IV

(12 Hours)

Introduction to modules, definition and examples, direct sum, free modules, quotient modules, homomorphisms, simple modules, modules over PIDs.

Books Recommended:

1. Joseph A. Gallian, *Contemporary Abstract Algebra*, 4th edition, Narosa Publishing House, New Delhi, 1999. (IX Edition 2010).
2. D. S. Dummit, R. M. Foote, *Abstract Algebra*, Wiley-India edition, 2013.
3. C. Musili, *Introduction to Rings and Modules*, Narosa Publishing House.

Books for References:

1. John B. Fraleigh, *A First Course in Abstract Algebra*, 7th edition., Pearson, 2002.
2. I.N. Herstein, *Topics in Algebra*, Wiley Eastern Limited, India, 1975.
3. M. Artin, *Abstract Algebra*, 2nd edition., Pearson, 2011.
4. S. Nanda, *Topics in Algebra*, Allied Publishers, New Delhi.
5. Suggested digital platform: NPTEL/SWAYAM/MOOCs
6. e-Learning Source <http://ndl.iitkgp.ac.in>; <http://ocw.mit.edu>; <http://mathforum.org>

Course Outcomes:

After completing the course, the student will be able to

- C01.** Know on finite abelian groups, the class equation and Sylow's theorems.
- C02.** Know on applications of Sylow's theorems and test the simplicity of groups.
- C03.** Learn on group action, composition series, nilpotent groups and solvable groups.
- C04.** Solve problems in modules and related results.

CO-PO Mapping (Major-I-P-X)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	2

Programme articulation Matrix row for Major-I-P-X

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-X	3	2	3	2	3	2	2	3

CO-PSO Mapping (Major-I-P-X)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Linear Algebra(Minor-II-P-II)

Credit Points: 4

Full Marks:- 100

Total Hours:- 48

Course Objective:

The objective of this course is to acquaint students with matrix operations, solution of system of equations, vector spaces and linear transformations. In addition, the student will learn about eigenvalues, diagonalization, canonical forms, etc., which has many applications in almost all areas of science and engineering.

Syllabus:-

Unit-I

(12 Hours)

Vector spaces, subspaces, span of a set, more about subspaces, linear dependence, independence, product and quotient space, dimension and basis, linear transformations, range and kernel of a linear map, rank and nullity of linear map.

Unit-II

(12 Hours)

Inverse of linear transformation, consequences of rank – nullity theorem, the space $L(U, V)$, composition of linear maps, matrix associated with linear map, linear map associated with matrix, rank and nullity of a matrix, determinant minors and rank of a matrix, transpose of a matrix and special type of matrices, elementary row operations

Unit-III

(12 Hours)

System of linear equations, matrix inversion, application of determinant to linear equations, eigenvalues and eigenvectors, similarity of matrices, invariant subspaces, minimal polynomial (eigenvalues and the minimal polynomial), upper triangular matrices, diagonalizable operators (diagonal matrices, conditions for diagonalizability).

Unit-IV

(12 Hours)

Inner product space: inner products and norms, orthonormal bases, orthogonal complements, self-adjoint and normal operators, spectral theorems, isometries, unitary operators, characteristic polynomial, Cayley – Hamilton theorem, Jordan form, trace, quadratic form, application to reduction of quadrics.

Books Recommended:

1. V. Krishnamurthy, V.P. Mainra, J. L. Arora, *An introduction to linear algebra*, Affiliated East – West press Pvt. Ltd., New Delhi, 1976.
2. Sheldon Axler, *Linear algebra done right*, 4th edition, Springer, 2024.

Books for References:

1. Seymour Lipschutz and Marc Lars Lipson, *Linear Algebra (Schaum's outlines)*, 4th edition, McGraw Hill, New York, 2009.
2. A. Ramachandra Rao and P. Bhimsankaram, *Linear Algebra*, 2nd edition, Hindustan Book Agency, 2000.
3. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra*, 4th edition, Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
4. Gilbert Strang, *Linear Algebra and its Applications*, Thomson, 2007.
5. S. Kumaresan, *Linear Algebra- A Geometric Approach*, Prentice Hall of India, 1999.
6. Suggested digital platform: NPTEL/SWAYAM/MOOCs.
7. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org> ; <https://linear.axler.net>; and <https://library.oapen.org/handle/20.500.12657/85067>

Course Outcomes:

After completing the course, the student will be able to

- C01.** Determine basis and the dimension of a finite-dimensional vector space, know the relation between rank and nullity of a linear transformation.
- C02.** The relation between matrix and linear transformation.
- C03.** To find solution of system of linear equations, compute eigenvalues, eigenvectors of a matrix and linear transformation.
- C04.** About orthogonality of vectors and application of it to different form of matrix, introduced to different operators.

CO-PO Mapping (Minor-II-P-II)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Minor-II-P-II

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Minor-II-P-II	3	2	3	2	3	2	3	3

CO-PSO Mapping (Minor-II-P-II)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

SEMESTER-V

Real Analysis-III(Major-I-P-XI)

Credit Points:- 4

Full Marks;- 100

Total Hours:- 48

Course Objectives:

After a first course in real analysis in undergraduate program, the ideas of uniform continuity, uniform convergence and approximation by polynomials are crucial in analysis. In addition to the functions of bounded variation and their integrators, the student has to learn differentiating functions from $\mathbb{R}^n$ to $\mathbb{R}^m$. The techniques of integration of a function with respect to another function and the basic ideas of finding a Fourier series are also included.

Syllabus:-

Unit-I

(12 Hours)

Basic concepts of Fourier series, Fourier series of even and odd functions, half range series, Fourier series on other intervals, orthogonal systems of functions, theorem on best approximation, properties of Fourier coefficients, Riesz-Fisher theorem, Riemann-Lebesgue lemma, Dirichlet integral, Integral representation for the partial sum of a Fourier series, convergence of Fourier series.

Unit-II

(12 Hours)

Function of bounded variation, examples, total variation, function of bounded variation expressed as difference of increasing functions, rectifiable paths, Riemann-Stieltjes integrals, properties and techniques, necessary and sufficient condition for existence of the integral, mean value theorem for Riemann-Stieltjes integrals, reduction to Riemann integrals.

Unit-III

(12 Hours)

Differentiation in $\mathbb{R}^n$, partial derivatives, directional derivatives, sufficient condition for differentiability, chain rule, mean value theorem, Jacobians, contraction mapping principle, inverse function theorem, implicit function theorem, rank theorem, differentiation of integrals, Taylor theorem in many variables.

Unit-IV

(12 Hours)

Metric spaces, definitions and examples, open and closed sets, interior and exterior points, convergence and completeness, continuity and uniform continuity, compactness, connectedness.

Books Recommended:

1. W. Rudin, *Principles of Mathematical Analysis*, McGraw Hill, 3rd edition.
2. T. Apostol, *Mathematical Analysis*, Pearson, 2nd edition.
3. S C Malik and Savita Arora, *Mathematical Analysis*, New Age International, 5th edition

Books for References:

1. Terrence Tao, *Analysis-I*, Hindustan book agency.
2. Terrence Tao, *Analysis-II*, Hindustan book agency
3. K. A. Ross, *Elementary Analysis: The theory of Calculus*, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
4. Charles G. Denlinger, *Elements of Real Analysis*, Jones and Bartlett, Student Edition, 2011.
5. Suggested digital platform: NPTEL/SWAYAM/MOOCs
6. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completing the course, the student will be able to

- C01.** Find the Fourier series of a function.
- C02.** Calculate Riemann Stieltjes integrals and know whether a function is of bounded variation or not.
- C03.** Learn how to define derivatives on $\mathbb{R}^n$ including the existence of partial derivatives, inverse function theorem and implicit function theorem.
- C04.** Learn about metric spaces and their topological properties.

CO-PO Mapping (Major-I-P-XI)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	2	1	2	2	3	2
C02	3	1	3	2	2	3	2	3
C03	2	3	2	3	3	3	3	3
C04	2	3	3	2	2	2	3	3

Programme articulation Matrix row for Major-I-P-XI

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-XI	3	3	3	3	3	2	2	2

CO-PSO Mapping (Major-I-P-XI)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	2	3	3	3	3
C02	3	2	3	3	2
C03	3	2	3	3	3
C04	3	3	3	2	3

Differential Equations-II(Major-I-P-XII)

Credit Points: 4

Full Marks:- 100

Total Hours:- 48

Course Objectives:

The objective of this course is to understand basic methods for solving nonlinear first order ordinary differential equations and existence of solutions along with some special type of second order ordinary differential equations of mathematical physics. Also, students will be exposed to second order partial differential equations arising in thermal physics and thermodynamics.

Syllabus:-

Unit-I

(12 Hours)

Existence and Uniqueness of Solutions: Lipschitz condition, Gronwall type inequality, successive approximations, Picard's theorem, non-uniqueness of solutions, continuation and dependence on initial conditions, existence of solutions in the large.

Unit-II

(12 Hours)

Solution of second order ODE with constant coefficients, power series solutions of ordinary and singular points, and special functions of Legendre's differential equations, Bessel's differential equations and their properties.

Unit-III

(12 Hours)

Charpit's method, special types of first order PDE, Jacobi's method, Linear second order PDE, canonical forms of second order PDE and characteristics curves, one dimensional wave equation, its origin and elementary solutions, vibration of an infinite string, vibration of a semi finite string, vibration of a string of finite length, existence of unique solution.

Unit-IV (Practical)

(12 Hours)

Laboratory work for the following problems using **MATLAB / Mathematica / Maple** etc.

(1) Plot the Fourier series of the following functions:

(i). $f(x) = x^2, x \in [-1, 1]$

(ii). $f(x) = \begin{cases} 1, & 0 < x < \pi \\ -1, & -\pi < x < 0 \end{cases}$

(iii). $f(x) = \sin x, 0 < x < \frac{\pi}{2}$

(2) Solution of wave equation $\frac{\partial^2 u}{\partial t^2} - c^2 \frac{\partial^2 u}{\partial x^2} = 0$ for the following associated conditions:

(i) $u(x, 0) = \varphi(x), u_t(x, 0) = \sigma(x), x \in \mathbb{R}, t > 0$

(ii) $u(x, 0) = \varphi(x), u_t(x, 0) = \sigma(x), u(0, t) = 0, x \in (0, \infty), t > 0$

(iii) $u(x, 0) = \varphi(x), u_t(x, 0) = \sigma(x), u_x(0, t) = 0, x \in (0, \infty), t > 0$

(iv) $u(x, 0) = \varphi(x), u_t(x, 0) = \sigma(x), u(0, t) = 0, u(l, t) = 0, 0 < x < l, t > 0$

(3) Solution of one-dimensional heat equation $\frac{\partial u}{\partial t} - k \frac{\partial^2 u}{\partial x^2} = 0$ for the following conditions

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

(ii) $u(x, 0) = \varphi(x), x \in \mathbb{R}, 0 < t < T$

(iii) $u(x, 0) = \varphi(x), u(0, t) = a, x \in (0, \infty), t \geq 0.$

Books Recommended:

1. Deo and Raghavendra, *Text Book of Ordinary Differential Equations*, Tata McGraw-Hill Pub. Company Ltd, New Delhi, 2017.
2. Simmons G F, *Differential equation*, Tata McGrawHill, 1991. (Ch-5. 28-30, Ch-8. 44-47, Ch-6, 33-36)
3. I. Sneddon, *Elements of Partial Differential Equations*, McGraw-Hill, International Students Edition. (Ch-2. 10, 11, 13; Ch-3. 4-7; Ch-5. 1, 2), 2006.
4. Tyn Myint-U and Lokenath Debnath, *Linear Partial Differential Equations for Scientists and Engineers*, 4th edition, Birkhauser, Indian reprint, 2014.

Books for References:

1. J. N. Sharma and Kehar Singh, *PDE for Engineers and Scientists*, Narosa, New Delhi, 2009.
2. T Amarnath, *An Elementary Course in Partial Differential Equations*, Narosa Publications, 2003.
3. Martin Braun, *Differential Equations and their Applications*, Springer International Student Ed. 1978.
4. S. L. Ross, *Differential Equations*, 3rd edition, John Wiley and Sons, India, 2014.
5. C.Y. Lin, *Theory and Examples of Ordinary Differential Equations*, World Scientific, 2011.
6. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>
7. Suggested digital platform: NPTEL/SWAYAM/MOOCs

Course Outcomes:

After completing the course, the student will be able to

- CO1.** Understand first order nonlinear ordinary differential equations and existence of solutions
- CO2.** Learn the methods to find solutions of second order linear ordinary differential equations with constant coefficients and variable coefficients.
- CO3.** The different methods for solving first and second order partial differential equations and can take more courses on wave equation, heat equation, diffusion equation, gas dynamics, nonlinear evolution equations etc. All these courses are important in engineering and industrial applications for solving boundary value problems.
- CO4.** Get idea to solve various mathematical models of ODE and PDE which may be helpful for Simulation process.

CO-PO Mapping (Major-I-P-XII)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
CO1	3	2	1	1	2	1	1	1
CO2	3	1	3	2	2	1	2	2
CO3	2	3	3	3	2	2	3	3
CO4	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Major-I-P-XII

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-XII	3	2	3	2	3	2	2	2

CO-PSO Mapping (Major-I-P-XII)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
CO1	3	3	3	3	3
CO2	3	2	3	2	2
CO3	3	3	3	3	2
CO4	2	3	3	2	3

Numerical Analysis & Scientific Computing (Major-I-P-XIII)

Credit Points: 4

Full Marks:- 100

Total Hours:- 48

Course Objectives:

The objective of this course is to acquaint the students with a wide range of numerical methods to solve algebraic and transcendental equations, linear system of equations, interpolation and curve fitting problems, numerical integration, initial and boundary value problems, etc. Develop adequate skills to apply those methods in real world problems.

Syllabus:-

Unit-I

(12 Hours)

Errors in approximation, absolute, relative and percentage errors, round-off error, solution of algebraic and transcendental equations: bisection method, Regula-Falsi method, secant method, method of iteration, Newton Raphson method, order of convergence, systems of simultaneous equations: Gauss elimination method, Gauss Jordan method, LU decomposition method, Iterative methods: Jacobi method and Gauss-Seidel method.

Unit-II

(12 Hours)

Finite differences, interpolation techniques for equal intervals-Newton forward and backward, Gauss forward, Gauss backward, interpolation, interpolation with unequal intervals-Newton's divided difference method, Lagrange method, Hermite interpolation, Numerical differentiation using Newton forward and backward formulae, numerical integration using Newton-Cotes formulas, trapezoidal rule, Simpson rules, Gauss-Legendre, Gauss-Chebyshev formulas.

Unit-III

(12 Hours)

Solution of ordinary differential equations: Taylor series method, Picard's method, Euler method, Euler modified method, Runge-Kutta methods.

Unit-IV (Practical)

(12 Hours)

Practical / Lab work to be perform in Computer Lab:

Use of computer algebra system (CAS) software: Python/ Sage Math / Mathematica/ MATLAB/ Maple/ Maxima/ Scilab/ R or any other (open source) software etc., for developing at least the following numerical programs:

1. Bisection method, Newton-Raphson method and Secant method.
2. LU decomposition method.
3. Gauss-Jacobi method and Gauss-Seidel method.
4. Lagrange interpolation and Newton interpolation.
5. Trapezoidal rule and Simpson's rules.
6. Taylor series method, Picard's method, Euler method, Euler modified method and Runge-Kutta Methods.

Note: Non-programmable scientific calculator is allowed in the examination.

Books Recommended:

1. M. K. Jain, S. R. K. Iyengar & R. K. Jain: *Numerical Methods for Scientific and Engineering Computation*, New Age International Publisher, India, 2016.
2. R. K. Gupta: *Numerical Methods: Fundamentals and Applications*, Cambridge University Press, 2019.

Books for References:

1. Brian Bradie: *A Friendly Introduction to Numerical Analysis*. Pearson Education India. Dorling Kindersley (India) Pvt. Ltd. Third impression, 2011.
2. Curtis F. Gerald & Patrick O. Wheatley: *Applied Numerical Analysis*, Pearson Education. India, 2007.
3. S. D. Conte & S. de Boor: *Elementary Numerical Analysis: An Algorithmic Approach*, 1980.
4. Suggested digital platform: NPTEL/SWAYAM/MOOCs
5. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completing the course, the student will be able to

- C01.** Understand the errors in computation, find the roots of algebraic and transcendental equations, familiarize with convergence, advantages and limitations of those numerical techniques, learn to apply Gauss–Jacobi, Gauss–Seidel methods to solve system of linear equations.
- C02.** Get aware of using interpolation techniques to solve polynomials.
- C03.** Learn numerical differentiation and integrations by using different techniques.
- C04.** Understand the techniques to find approximate solutions of ODE and PDE.

CO-PO Mapping (Major-I-P-XIII)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	2
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Major-I-P-XIII

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-XIII	3	2	3	2	3	2	2	3

CO-PSO Mapping (Major-I-P-XIII)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Differential Equations-I(Minor-I-P-III)

Credit Points:- 4

Full Marks:- 100

Total Hours:- 48

Course Objective:

Differential Equations introduced by Leibnitz in 1676 models almost all Physical, Biological, Chemical systems in nature. The objective of this course is to familiarize the students to various methods of solving differential equations, partial differential equations and to have a qualitative application through models. The students have to solve problems to understand the methods.

Syllabus:-

Unit-I

(12 Hours)

Differential equations and mathematical models, general, particular, explicit, implicit and singular solutions of a differential equation, exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equations and Bernoulli's equation, compartmental model, population model for single species.

Unit-II

(12 Hours)

General solution of homogeneous equation of second order, principle of superposition, Wronskian, its properties and applications, method of undetermined coefficients, method of variation of parameters, linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equations.

Unit-III

(12 Hours)

Partial Differential Equations - Basic concepts and definitions, origin of first order PDEs, Classification of first order PDEs, Pfaffian differential forms and equations, solution of Pfaffian differential equations in three variables, Cauchy's problem for first order PDEs, linear equations of first order, integral surfaces passing through a given curve, Cauchy's method of characteristics, compatible systems, method of separation of variables for solving first order and second order partial differential equations.

Unit-IV (Practical)

(12 Hours)

The students will implement the following problems in the computer Lab using *Matlab* / *Mathematica* / *Maple* etc.

1. Plotting of second order solution family of differential equations.
2. Plotting of third order solution family of differential equations.
3. Population growth model (exponential case only).
4. Population decay model (exponential case only).
5. Solution of Cauchy problem for first order PDEs.
6. Finding the characteristics for the first order PDEs.
7. Plot the integral surfaces of a given first order PDE with initial data.

Books Recommended:

1. J. Sinha Roy and S. Padhy: *A course of Ordinary and Partial differential equations*, Kalyani Publishers, New Delhi, 2018.
2. Belinda Barnes and Glenn R. Fulford, *Mathematical Modeling with Case Studies, A Differential Equation Approaching Maple and Matlab*, 2nd edition. Taylor and Francis group, London and New York, 2009.
3. Sneddon; *Elements of Partial Differential Equations*, McGraw-Hill, International Students Edition, 1957.

Books for Reference:

1. G. F. Simmons, *Differential equation*, Tata McGraw Hill, 1991.

2. J. N. Sharma and Kehar Singh, *PDE for Engineers and Scientists*, Narosa, New Delhi, 2009.
3. Martin Braun, *Differential Equations and their Applications*, Springer International Student Ed.1978.
4. S. L. Ross, *Differential Equations*, 3rd edition, John Wiley and Sons, India, 2014.
5. C.Y. Lin, *Theory and Examples of Ordinary Differential Equations*, World Scientific, 2011.
6. Suggested digital platform: NPTEL/SWAYAM/MOOCs.
7. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completing the course, the student will be able to

- C01.** Get the idea to solve first order linear ordinary differential equations of different types those are arising in physical problems.
- C02.** Get the idea to solve second order linear ordinary differential equations of different types those are arising in physical problems.
- C03.** Get basic ideas of first order partial differential equations, its formulation in two, three variables and variable separable method for identify the solutions.
- C04.** Get idea to solve various mathematical models of ODEs and PDEs which may be helpful for simulation process.

CO-PO Mapping (Minor-I-P-III)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	1
C04	2	2	3	2	3	2	2	2

Programme articulation Matrix row for Minor-I-P-III

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Minor-I-P-III	3	2	3	2	3	2	2	3

CO-PSO Mapping (Minor-I-P-III)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Introduction to Python (SEC-II)

Credit Points: 3

Full Marks:- 100

Total Hours:- 36

Course Objective:

The objective of this course is to aware the students for Python language and the programming as well as to create a learning platform to apply for slicing to access data and mathematical problems.

Syllabus:-

Unit-I

(12 Hours)

Introduction to Python programming, installation of Python, application of Python, writing Python code, running Python programs, variables, basic input-output operations, operators.

Unit-II

(12 Hours)

Number, string, list, tuple, set, dictionary, arrays and vectors, conditional statements (if, if-else, if- elif-else), loops (for loop, while loop). writing and calling functions, function inputs and outputs, local and global scope of variable, Lamda function , types of errors.

Unit-III

(12 Hours)

Library for mathematics (sympy and numpy), problems on algebraic expression, ordinary and partial derivatives, integral, limit, ordinary differential equations, algebra of matrices, plotting of functions.

Books Recommended:

1. Harsh Bhasin, *Python for Beginners*. New Age International; 1st Edition, 2018.
2. Tim Hall and J-P Stacey, *Python 3 for Absolute Beginners*. Apress, 2009.
3. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCs.
4. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Learning Outcomes:

After completion of this course, students will be able to:

C01-Understand why Python is a useful scripting language for applications.

C02-Learn how to use lists, tuples, and dictionaries in Python programs, learn how to write loops and decision statements in Python, learn how to use indexing and slicing to access data in Python programs.

C03-Learn how to use python for solving mathematical problems.

CO-PO Mapping (SEC-II)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	3

Programme articulation Matrix row for SEC-II

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course SEC-II	3	2	3	2	3	2	3	2

CO-PSO Mapping (SEC-II)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2

SEMESTER-VI

Multivariable Calculus (Major-I-P-XIV)

Credit Points: 4

Full Marks:- 100

Total Hours: - 48

Course Objectives:

The primary objective of this course is to introduce students, the extension of the studies of single variable differential and integral calculus to functions of two or more independent variables with the geometry and visualization of curves and surfaces. To aware the students about the technique's multiple integrations and higher order derivatives.

Syllabus:-

Unit-I

(12 Hours)

Functions of several variables, limit and continuity of functions of two variables: partial differentiation, total differentiability, sufficient condition for differentiability, chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes.

Unit-II

(12 Hours)

Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems, double integration over rectangular region, double integration over non rectangular region, double integrals in polar co-ordinates.

Unit-III

(12 Hours)

Triple integrals, triple integral over a parallelepiped and solid regions, volume by triple integrals, cylindrical and spherical co-ordinates, change of variables in double integrals and triple integrals.

Unit-IV

(12 Hours)

Definition of vector field, divergence and curl, line integrals, applications of line integrals: mass and work, fundamental theorem for line integrals, conservative vector fields, independence of path, Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stokes' theorem, the divergence theorem.

Books Recommended:

1. M. J. Strauss, G. L. Bradley and K. J. Smith: *Calculus*, 3rd edition, Dorling Kindersley (India) Pvt. Ltd. Pearson Education, Delhi, 2007.
2. E. Marsden, A. J. Tromba and A. Weinstein: *Basic Multivariable Calculus*, Springer Student International Edition, Indian reprint, 2005.

Book for References:

1. S. C. Mallik and S. Arora: *Mathematical Analysis*, New Age International Publications, New Delhi, 2005.
2. Tom Apostol: *Mathematical Analysis*, Narosa Publishing House, 2002.
3. G. B. Thomas and R. L. Finney: *Calculus*, 9th edition., Pearson Education, Delhi, 2005.
4. Suggested digital platform: NPTEL/SWAYAM/MOOCs.
5. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completing the course, the student will be able to

- C01.** Learn the concept of limit, continuity and differentiations of functions of more than one.
- C02.** Understand the maximization and minimization of multivariable functions with the given constraints on variables.
- C03.** Learn about inter-relationship amongst the line integral, double, and triple integral formulations.
- C04.** Familiarize with the Green's, Stokes' and Gauss divergence theorems and the applications.

CO-PO Mapping (Major-I-P-XIV)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	2
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Major-I-P-XIV

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-XIV	3	2	3	2	3	2	3	2

CO-PSO Mapping (Major-I-P-XIV)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Differential Geometry (Major-I-P-XV)

Credit Points: 4

Full Marks:- 100

Total Hours:- 48

Course Objective:

The objective of this course is to explore geometry of curves and surfaces in R^2 and R^3 with their intrinsic properties and curvatures.

Syllabus:-

Unit-I

(12 Hours)

Theory of Space Curves: space curves, arc length, tangent, normal and binormal, osculating plane, curvature, torsion, Serret-Frenet formulae, contact between curves and surfaces, osculating circles and spheres, involute and evolutes, existence of space curves, Helices.

Unit-II

(12 Hours)

Theory of surfaces: parametric curves on surfaces, surfaces of revolution, helicoids, metric, direction coefficients. First Fundamental forms.

Unit-III

(12 Hours)

Geodesics, canonical geodesic equations, nature of geodesics on a surface of revolution, normal property of geodesics, Torsion of a geodesic: geodesic curvature, Gauss-Bonnet theorem, Gaussian curvature, surfaces of constant curvature.

Unit-IV

(12 Hours)

Second Fundamental forms, principal curvatures, lines of curvature, Rodrigue's formula, conjugate and asymptotic lines. Developables, developable associated with space curves and curves on surfaces, minimal surfaces. Fundamental Theory of surfaces.

Books Recommended:

1. T.J. Willmore, *An Introduction to Differential Geometry*, Dover Publications, 2012.
2. Pressley, *Elementary Differential Geometry*, Springer International Edition, 2014

Books for References:

1. O'Neill, *Elementary Differential Geometry*, 2nd edition., Academic Press, 2006.
2. C.E. Weatherburn, *Differential Geometry of Three Dimensions*, Cambridge University Press 2003.
3. D.J. Struik, *Lectures on Classical Differential Geometry*, Dover Publications, 1988.
4. Suggested digital platform: NPTEL/SWAYAM/MOOCs.
5. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completing the course, the student will be able to

- C01.** Understand the notion of plane curves, space curves, curvature, torsion and the existence of space curves.
- C02.** Learn the theory of surfaces and learn to calculate first fundamental forms.
- C03.** Learns on geodesics on a surface and learns to calculate curvatures.
- C04.** Learns calculating second fundamental forms, curvatures and discovers minimal surfaces.

CO-PO Mapping (Major-I-P-XV)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	3
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	2

Programme articulation Matrix row for Major-I-P-XV

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Major-I-P-XV	3	2	3	2	3	2	3	2

CO-PSO Mapping (Major-I-P-XV)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Numerical Analysis & Scientific Computing (Minor-II-P-III)

Credit Points: 4

Full Marks:- 100

Total Hours:- 48

Course Objectives:

The objective of this course is to acquaint the students with a wide range of numerical methods to solve algebraic and transcendental equations, linear system of equations, interpolation and curve fitting problems, numerical integration, initial and boundary value problems, etc. Develop adequate skills to apply those methods in real world problems.

Syllabus:-

Unit-I

(12 Hours)

Errors in approximation, absolute, relative and percentage errors, round-off error, solution of algebraic and transcendental equations: bisection method, Regula-Falsi method, secant method, method of iteration, Newton Raphson method, order of convergence, systems of simultaneous equations: Gauss elimination method, Gauss Jordan method, LU decomposition method, Iterative methods: Jacobi method and Gauss-Seidel method.

Unit-II

(12 Hours)

Finite differences, interpolation techniques for equal intervals-Newton forward and backward, Gauss forward, Gauss backward, interpolation, interpolation with unequal intervals-Newton's divided difference method, Lagrange method, Hermite interpolation, Numerical differentiation using Newton forward and backward formulae, numerical integration using Newton-Cotes formulas, trapezoidal rule, Simpson rules, Gauss-Legendre, Gauss-Chebyshev formulas.

Unit-III

(12 Hours)

Solution of ordinary differential equations: Taylor series method, Picard's method, Euler method, Euler modified method, Runge-Kutta methods.

Unit-IV (Practical)

(12 Hours)

Practical / Lab work to be perform in Computer Lab:

Use of computer algebra system (CAS) software: Python/ Sage Math / Mathematica/ MATLAB/ Maple/ Maxima/ Scilab/ R or any other (open source) software etc., for developing at least the following numerical programs:

1. Bisection method, Newton-Raphson method and Secant method.
2. LU decomposition method.
3. Gauss-Jacobi method and Gauss-Seidel method.
4. Lagrange interpolation and Newton interpolation.
5. Trapezoidal rule and Simpson's rules.
6. Taylor series method, Picard's method, Euler method, Euler modified method and Runge-Kutta Methods.

Note: Non-programmable scientific calculator is allowed in the examination.

Books Recommended:

1. M. K. Jain, S. R. K. Iyengar & R. K. Jain: *Numerical Methods for Scientific and Engineering Computation*, New Age International Publisher, India, 2016.
2. R. K. Gupta: *Numerical Methods: Fundamentals and Applications*, Cambridge University Press, 2019.

Books for References:

1. Brian Bradie: *A Friendly Introduction to Numerical Analysis*. Pearson Education India. Dorling Kindersley (India) Pvt. Ltd. Third impression, 2011.
2. Curtis F. Gerald & Patrick O. Wheatley: *Applied Numerical Analysis*, Pearson Education. India, 2007.
3. S. D. Conte & S. de Boor: *Elementary Numerical Analysis: An Algorithmic Approach*, 1980.
4. Suggested digital platform: NPTEL/SWAYAM/MOOCs
5. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completing the course, the student will be able to

- C01.** Understand the errors in computation, find the roots of algebraic and transcendental equations, familiarize with convergence, advantages and limitations of those numerical techniques, learn to apply Gauss–Jacobi, Gauss–Seidel methods to solve system of linear equations.
- C02.** Get aware of using interpolation techniques to solve polynomials.
- C03.** Learn numerical differentiation and integrations by using different techniques.
- C04.** Understand the techniques to find approximate solutions of ODE and PDE.

CO-PO Mapping (Minor-II-P-III)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	2
C03	2	3	3	3	2	2	3	3
C04	2	2	3	2	3	2	2	3

Programme articulation Matrix row for Minor-II-P-III

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course Minor-II-P-III	3	2	3	2	3	2	2	3

CO-PSO Mapping (Minor-II-P-III)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3

Typesetting in Latex (SEC-III)

Credit Points: 3

Full Marks:- 100

Total Hours:- 36

Course Objectives:

The objective of this course is to familiarize students how to write research papers and books using the book format process of type setting by LaTeX, how to prepare for document presentation.

Syllabus:-

This is a practical paper. Students will be externally examined on their expertise on following aspects of typing as per the rules of the university/affiliated institutions:

Installation of LaTeX and different IDEs, Creating the first document using LaTeX, organizing content into sections using article and book class of LaTeX, formatting the page by setting margins, paper size, use package, customizing header and footer, changing the page orientation, dividing the document into multiple columns, reading different types of error messages. Formatting text (styles, size and alignment), adding colors to text and entire page, and adding bullets and numbered items,

Creating basic tables, matrices and arrays, adding simple and dashed borders, merging rows and columns, and handling situations where a table exceeds the size of a page, adding an image, exploring different properties like rotate, scale, etc., writing equations in different formats, creating various form of mathematics documents, create items, add cross-referencing (refer to sections, table, images), add bibliography (references), and create back index, introduction to creating slides, adding frames, dividing the slide into multiple columns, adding different blocks, etc.

Book Recommended:

1. Stefan Kottwitz, *LaTeX Beginner's Guide: Create visually appealing texts, articles, and books for business and science using LaTeX*, 2nd edition, Packt Publishing, 2021.
2. Firuza Karmali Aibara: *A short introduction to LaTeX: A book for beginners*, Create space Independent Publishing Platform, 2019.
3. Dilip Datta: *LaTeX in 24 Hours: A Practical Guide for Scientific Writing*, 1st edition., Springer, 2017.
4. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCs.
5. e-Learning Source <http://ndl.iitkgp.ac.in> ; <http://ocw.mit.edu> ; <http://mathforum.org>

Course Outcomes:

After completion of this course, the students will be able to:

- C01**-Handle different types of documents, organize documents into different sections, subsections, etc., learn formatting pages (margins, header, footer, orientation).
- C02**-Learn formatting text and writing of complex mathematical formulae, tables and images.
- C03**-Learn cross-referencing, bibliography writing, indexing, read error messages as and when required, learn to create presentations using Beamer.

CO-PO Mapping (SEC-III)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	3

Programme articulation Matrix row for SEC-III

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course SEC-III	3	2	3	2	3	2	3	2

CO-PSO Mapping (SEC-III)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2

Operations Research (VAC-IV)

Credit Points:- 3

Full Marks:-100

Total Hours:- 45

Course Objective:

This module aims to introduce students to use quantitative methods and techniques for effective decisions-making; model formulation and applications that are used in solving business decision problems

Course Contents:

Unit 1 Introduction To Operations Research

[10 Hours]

Learning Outcome

- ✓ *Understanding the importance and characteristics of operation research.*
- Definition and Scope of Operations Research, Historical Development and Characteristics, Phases of Operations Research.
- Historical development and importance of OR in decision making

Unit 2 Linear Programming And Transportation Problem

[15 Hours]

Learning Outcome:

- ✓ *Formulating Linear Programming to solve Operation Research Problems*
- Formulation of Linear Programming Problems.
- Linear inequalities in two variables. Their graphs as half planes

Unit 3 Assignment Problem And Queuing Theory

[8 Hours]

Learning Outcome:

- ✓ *Using graphs to solve LPP*
- Graphical Solution of Linear Programming Problems, Simplex Method including two phase methods
- Big M Method as a method of solution of LPP

Unit 4 Network Analysis And Decision Theory

[6 Hours]

Learning Outcome:

- ✓ *Applying NWC and LCM methods to solve Transportation problems*
- Transportation Problem: Structure, Basic Feasible Solution
- Solution Methods (NWC Method, LCM,)

Unit 5 Inventory Control

[6 Hours]

Learning Outcome:

- ✓ *Designing decision flow in an organization for optimizing individual efficiencies*
- Network Analysis: PERT and CPM, Construction
- Critical Path, Time Analysis, Decision Theory: Bayes' Theorem, Probability, Decision Trees

Text Books:

1. Introduction to Operational Research by V.K. Kapoor (Sultan Chand & Sons)
2. Operations Research by P.K. Gupta & Man Mohan (Sultan Chand & Sons)

Suggested Reading:

1. Operations Research by P.R. Vittal & V. Malini (Margham Publications)
2. Operations Research Theory and Applications by Sharma J. K (Laxmi Publications)
3. Operations Research by Sridhar Bhat K (Himalaya Publishing House)
4. Operations Research by Hiller F.S. and Lieberman G.J. (McGraw Hill)
5. Operations Research: An Introduction by Hamdy A.T (Pearson)
6. Operations Research by Sharma S. D (Kedar Nath Ram Nath).

Sample Questions:

1. What do you mean by Operations Research? [1mark]
2. Briefly explain any two characteristics of Operation Research? [2 marks] [50 word]
3. Discuss the variables of linear inequalities with suitable examples.[5 marks] [300words]
4. Compare and contrast between PERT and CPM. [8 marks] [Within 800 words]

Course Outcomes:

After completion of this course, students will be able to

C01-Understand the concept and scope of Operation Research

C02-Apply Big M method for solving Linear Programming Problems(LLP)

C03-Identify various phases of Operations Research

C04-Solve Transportation problems by using NWC and LCM methods

C05-Appreciate the necessities to know constraints and objectives of a project

CO-PO Mapping (VAC-IV)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	2	3	3	3	2	2	3	3
C04	1	2	2	3	3	2	3	2
C05	2	3	3	3	2	3	2	3

Programme articulation Matrix row for VAC-IV

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course VAC-III	3	2	3	2	3	2	3	2

CO-PSO Mapping (VAC-IV)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	3	3	3	3	2
C04	2	3	3	2	3
C05	3	2	3	3	2

Environmental Studies & Disaster Management (VAC-I)

For Under Graduate Compulsory Courses for Arts, Science and Commerce

Credit Points: 3

Full Marks:- 100

Total Hours:- 30

Syllabus:

Unit 1: Multidisciplinary nature of environmental studies:

(8 Period)

Definition, scope and importance
Need for public awareness

Environmental Pollution:

Definition

- Cause, effects and control measures of: -
 - a) Air pollution
 - b) Water pollution
 - c) Soil pollution
 - d) Marine pollution
 - e) Noise pollution
 - f) Radiation pollution

Unit 2: Natural Resources:

(8 Period)

Renewable and non-renewable resources:

Natural resources and associated problems.

- a) Forest resources: Use and over-exploitation, deforestation, case studies. Timber extraction, mining, dams and their effects on forest and tribal people.
- b) Water resources: Use and over-utilization of surface and ground water, floods, drought, conflicts over water, dams-benefits and problems.
- c) Mineral resources: Use and exploitation, environmental effects of extracting and using mineral resources, case studies.
- d) Food resources: World food problems, changes caused by agriculture and Overgrazing, effects of modern agriculture, fertilizer-pesticide problems, waterlogging, salinity, case studies.
- e) Energy resources: Growing energy needs, renewable and non-renewable energy sources, use of alternate energy sources. Case studies.

Biodiversity: -

Introduction-Definition; Biogeographically classification of India

India as a mega diversity nation. Hot spots of biodiversity, Threats to biodiversity. Endangered and endemic species of India. Conservation of biodiversity. In Situ and Ex-situ conservation of biodiversity

Unit-3: Disaster Management

(8 Period)

1. **Disaster Management**: Types of disasters (natural and Man-made) and their causes and effect)
2. **Vulnerability Assessment and Risk analysis**: Vulnerability to various disasters (Flood, Cyclone, Earthquake, Heat waves, Desertification and Lightning)
3. **Institutional Framework**: Institutional arrangements for disaster management (National Disaster Management Authority (NDMA), State Disaster Management Authority (SDMA), Disaster Management Act, 2005, District Disaster Management Authority (DDMA), National Disaster Response Force (NDRF) and Odisha Disaster Rapid Action Force (ODRAF)
4. **Preparedness measures**: Disaster Management cycle, Early Warning System, Pre- Disaster and Post-Disaster Preparedness, strengthening of SDMA and DDMA, Community Preparedness for flood cyclone, heat waves, fire safety, lightning and snake biting. Stakeholders participation, Corporate Social Responsibility (CSR)
5. **Survival Skills**: Survival skills adopted during and after disaster (Flood, Fire, Earthquake, Cyclone and Lightning), Disaster Management Act-2005, Compensation and Insurance

Unit 4: Social Issues and the Environment**(6 Period)****A.**

- Environmental Ethics: Issues and possible solutions.
- Climate change, global warming, acid rain, ozone layer depletion, nuclear accidents and holocaust. Case studies
- Environment Protection Act
- Air (Preservation Control of Pollution) Act
- Water (Preservation Control of Pollution) Act
- Wildlife Protection Act
- Forest Conservation Act
- Solid waste management Cause, effect and Control Measure of Urban and Industrial waste (Role of each individual in conservation of Natural resources and prevention of pollution)

B. Human Population and the Environment

Population Ecology: Individuals, species, population, community Human population growth, population control method Urbanisation and its effect on society

Unit 5: Field work**(15 Periods of 30 Hours)**

- Visit to an area to document environmental assets: river/forest/flora/fauna, etc.
- Visit to a local polluted site- Urban/Rural/Industrial/Agricultural
- Study of common plants, insects, birds and basic principles of identification.
- Study of simple ecosystems-pond, river, Delhi Ridge, etc.

Course Outcomes:

After completion of this course, the students will be able to:

C01-Comprehend the importance of ecosystem and sustainable development

C02-Demonstrate interdisciplinary nature of environmental issues

C03-Identify different types of environmental pollution and control measures.

C04-Apply environmental management principles

C05-Set up environmental management systems to assist in ensuring legal compliance.

CO-PO Mapping (VAC-I)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
C01	3	2	1	1	2	1	1	2
C02	3	1	3	2	2	1	2	3
C03	3	3	2	3	2	3	2	3
C04	2	1	2	3	2	2	3	3
C05	1	2	3	2	3	3	2	3

Programme articulation Matrix row for VAC-I

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8
Course VAC-I	3	2	3	2	3	2	3	2

CO-PSO Mapping (VAC-I)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
C01	3	3	3	3	3
C02	3	2	3	2	2
C03	2	3	2	3	3
C04	3	2	3	2	3
C05	3	2	3	3	2

THRUST AREAS FOR DISSERTATION/PROJECT WORK

The student should work for his dissertation in a topic in one of these areas or any area related to these:

1. Topics in Number theory and its applications to Cryptography, Coding theory, etc.
2. Topics in recent development in Group theory, Ring and Field theory
3. Special topics in Number theory like Ramanujan Sum, Distribution of primes
4. Fibonacci and Lucas numbers, Riemann Zeta function, etc.
5. Linear algebra, Matrix theory and applications.
6. Representation theory.
7. Topics in Ordinary Differential Equations such as Stability theory, Oscillation theory.
8. Bifurcation and Catastrophe theory.
9. Finite element method.
10. Initial and boundary value problems in Ordinary and Partial differential equation.
11. Difference equations.
12. Discrete dynamical system such as Julia sets, Horse shoes, Cellular Automata. etc., with topological properties and applications.
13. Fractional calculus.
14. Complex analysis.
15. Fractals and their applications.
16. Geometric function theory including univalent (harmonic) mappings, Quasi-conformal maps in one and several variables.
17. Orthogonal polynomials in $\mathbb{R}$ and $\mathbb{C}$, q -Calculus and Moments problem.
18. p -adic analysis and p -adic fields.
19. Measure theory.
20. Functional analysis and applications.
21. Summability theory.
22. Geometry of Banach spaces.
23. Ergodic theory.
24. Information theory.
25. Fourier analysis.
26. Wavelets.
27. Fixed point theory.
28. General Topology.
29. Combinatorial Topology.
30. Differential Topology.
31. Algebraic topology including Homology, Homotopy theory, Fundamental groups, Covering spaces, CW complexes, etc.
32. Algebraic Geometry and related topics.
33. Normed algebras.
34. Topics in Operator theory and Operator algebras.
35. Operators on function Spaces including Composition operators, Toeplitz operators, Hankel operators, etc.
36. Spectral theory for bounded and unbounded operator on Hilbert space including Scattering theory.
37. Mathematical modeling (Pollution modeling, Epidemic modeling, Population modeling, etc.).
38. Mathematical Biology including Mathematics of life sciences.
39. Differentiable manifolds, differential forms and related topics.
40. Lie Groups and Lie algebras.
41. Knots and Braids.
42. Relativity, Cosmology and Gravitation, etc.
43. Nonlinear programming problems and applications.

- 44. Queuing theory.**
- 45. Optimization and Combinatorial optimization.**
- 46. Topics in Artificial Intelligence, Machine learning, Manifold learning and Principal component analysis, etc.**
- 47. Data structure and Data base management, etc.**
- 48. Fuzzy theory and Rough sets.**
- 49. Topics in applications of Probability, Stochastic models including Markov Process, Brownian process, Birth and Death processes, Renewal and Branching, and Reliability, etc.**
- 50. Time series and Forecasting.**
- 51. Topics in Integrable Models such as KDV and KP equation, Toda Lattice, Veselov Novikov, Davey Stewartson and Benney equations, etc.**
- 52. Topics in Image Processing, Signal processing, discrete Image processing, etc.**
- 53. Topics in Graph theory and Combinatorics.**
- 54. Topics in Numerical analysis, Numerical solution for ODE and PDE, etc.**
- 55. Time scale calculus.**
- 56. Computational fluid dynamics.**
- 57. Projective geometry.**
- 58. Finite Field**

