Indian Institute of Technology Indore

Curriculum and
Courses of Study
for
Bachelor of Technology in Mathematics and Computing
and Minor Programs

April 2026
[After incorporating decisions of 62nd meeting of the Senate held on April 20, 2026]

CONTENTS

Course Structure of Sections and Course Structure of 1st year BTech (from AY 2023-24 onwards)

Section-A (CSE+CE+MEMS+CH+EP)			
Semester-I	**Autumn Semester**		
Course Code	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**
EE 101	Basic Electrical Engineering	1-1-0	2
ME 101	Engineering Mechanics	2-0-0	2
PH 107	Basics of Physics	2-1-0	3
PH 157	Physics Lab- I	0-0-2	1
MA 101N	Calculus-I (half Semester)	3-1-0 (=4/2)	2
MA 103N	Calculus-II (half Semester)	3-1-0 (=4/2)	2
HS 109	Language and Composition	2-0-0	2
HS XXX	Flexible Elective (HSS)	1-0-0	1
IC 152	Makerspace	1-0-6	4
CS 103	Computer Programming	2-0-0	2
IC 151	Computer Programming Lab	0-0-3	1.5
NO 101	National Sports Organization (NSO)	0-0-0	P/NP

Section-B (EE+ME+MC+SSE)			
Semester-I	**Autumn Semester**		
Course Code	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**
EE 101	Basic Electrical Engineering	1-1-0	2
ME 101	Engineering Mechanics	2-0-0	2
CH 105	Chemistry	3-0-0	3
CH 155	Chemistry Lab	0-0-2	1
MA 101N	Calculus-I (half Semester)	3-1-0 (=4/2)	2
MA 103N	Calculus-II (half Semester)	3-1-0 (=4/2)	2
HS 109	Language and Composition	2-0-0	2
HS XXX	Flexible Elective (HSS)	1-0-0	1
CS 103	Computer Programming	2-0-0	2
IC 151	Computer Programming Lab	0-0-3	1.5
NO 101	National Sports Organization (NSO)	0-0-0	P/NP

Total	**14-3-11**	**22.5**

Total	**14-2-5**	**18.5**

Semester-II	Spring Semester		
Course Code	Course Title	Weekly Contact Hours (L-T-P)	Credits
BSE 102	Biosciences	2-1-0	3
MA 102N	Linear Algebra (half Semester)	2-1-0 (=3/2)	1.5
MA 104N	Differential Equations-I (half Semester)	2-1-0 (=3/2)	1.5
ES 102	Environmental Studies: Scientific and Engineering Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 102	Environmental Studies: Social Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 104	Fundamentals of Economics	2-0-0	2
CH 105	Chemistry	3-0-0	3
CH 155	Chemistry Lab	0-0-2	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective (HSS)	1-0-0	1
NO 102	National Sports Organization (NSO)	0-0-0	P/NP

Semester-II	Spring Semester		
Course Code	Course Title	Weekly Contact Hours (L-T-P)	Credits
BSE 102	Biosciences	2-1-0	3
MA 102N	Linear Algebra (half Semester)	2-1-0 (=3/2)	1.5
MA 104N	Differential Equations-I (half Semester)	2-1-0 (=3/2)	1.5
ES 102	Environmental Studies: Scientific and Engineering Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 102	Environmental Studies: Social Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 104	Fundamentals of Economics	2-0-0	2
IC 152	Makerspace	1-0-6	4
PH 107	Basics of Physics	2-1-0	3
PH 157	Physics Lab- I	0-0-2	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective (HSS)	1-0-0	1
NO 102	National Sports Organization (NSO)	0-0-0	P/NP

Total	**14-3-2**	**18**

Total	**14-4-8**	**22**

Curriculum of 2nd Year B.Tech. (Mathematics and Computing)
From AY 2024-25 Onwards (Batch admitted in and after AY 2023-24)

Semester III

Course Code	Course Title	Weekly contact hours (L-T-P)	Credits
ZZ 2XX	Course-I for Minor Program	X-X-X	3
MA 205	Complex Analysis	3-1-0 (1/2 semester)	2
MA 207	Differential Equations-II	3-1-0 (1/2 semester)	2
MA 209	Foundations of Mathematical Analysis	2-1-0	3
MA 211/ CS 201	Discrete Mathematical Structures	2-1-0	3
MA 213/ CS 203	Data Structures and Algorithms	2-1-0	3
MA 215	Probability and Statistics	2-1-0	3
MA 253/ CS 253	Data Structures and Algorithms Lab	0-0-3	1.5
MA 2XX	**Department Elective I**	x-x-x	3
	Total	**13-5-5**	**20.5/23.5**

Semester IV
From AY 2024-25 Onwards (Batch admitted in and after AY 2023-24)

Course Code	Course Title	Weekly contact hours (L-T-P)	Credits
ZZ 2XX	Course-II for Minor Program	X-X-X	3
MA 204N	Numerical Methods	2-0-2	3
MA 202	Multivariate Calculus and Measure Theory	2-1-0	3
MA 206	Mathematical Logic and Theory of Computation	2-1-0	3
MA 208/ CS 204	Design and Analysis of Algorithms	2-1-0	3
MA 254/ CS 254	Design and Analysis of Algorithms **Laboratory**	0-0-3	1.5
MA 2XX	Department Elective II		3
ZZ 2XX	Institute Elective I	2-1-0	3
	Total	**12-5-5**	**19.5 / 22.5**

3rd Year B. Tech. (Mathematics and Computing)
From AY 2025-26 Onwards (Batch admitted in and after AY 2023-24)

Semester V

Course Code	Subject Name	Weekly contact hours (L-T-P)	Credits
ZZ 3XX	Course-III for Minor Program	X-X-X	3
MA 301	Matrix Computations	2-0-2	3
MA 305	Data Science	2-0-2	3
MA 307/ CS 307	Optimization Algorithms and Techniques	2-1-0	3
MA 303/ CS 303	Operating Systems	2-1-0	3
MA 313 / CS 313	Computer Networks#	2-0-2	3
MA 357/ CS 357	Optimization Algorithms and Techniques Lab	0-0-2	1
MA 353/ CS 353	Operating Systems Lab	0-0-2	1
MA 3XX	Department Elective III		3
ZZ 3XX	Institute Elective II	2-1-0	3
	Total	**13-4-10**	**23/26**

Semester VI
From AY 2025-26 Onwards (Batch admitted in and after AY 2023-24)

Course Code	Subject Name	Weekly Contact Hours (L-T-P)	Credits
ZZ xxx	Course IV - Minor Program	x-x-x	3
MA 302	Statistical Inference	2-0-2	3
MA 306	Monte-Carlo Simulation	2-0-2	3
MA 308	Techniques in Parallel Computing	1-0-2	2
MA 304 /CS 304N	Computational Intelligence	2-1-0	3
MA 354 /CS 354N	Computational Intelligence Lab	0-0-3	1.5
MA xxx	Department Elective IV	x-x-x	3
MA xxx	Department Elective V	x-x-x	3
ZZ xxx	Institute Elective III	x-x-x	3
	Total		21.5/24.5

4th Year B. Tech. (Mathematics and Computing)
From AY 2026-27 Onwards (Batch admitted in and after AY 2023-24)
(Senate resolution 57.4)

Semester VII

Course Code	Subject Name	Weekly Contact Hours (L-T-P)	Credits
ZZ XXX	Course-V for Minor project/field study/white paper/domain comprehension (Seminar)/Lab course	x-x-x	2
ZZ 493N	B. Tech Project (BTP)	0-0-32	16
ZZ 495 ZZ XXX	Internship **OR** Professional/ Societal-Connect basket course	x-x-x	1.5
	Total		**17.5/19.5**

Semester VIII
From AY 2026-27 Onwards (Batch admitted in and after AY 2023-24)

Course Code	Subject Name	Weekly Contact Hours (L-T-P)	Credits
MA 4XX	Department Elective VI	x-x-x	3
MA 4XX	Department Elective VII	x-x-x	3
ZZ 4XX	Institute Elective IV	x-x-x	3
ZZ 4XX	Institute Elective V	x-x-x	3
ZZ 4XX	Institute Elective VI	x-x-x	3
	Total	**x-x-x**	**15**

List of the Elective Courses for B.Tech. in Mathematics

Course Code	Course Title	Weekly Contact Hours (L-T-P)	Credits
MA 217/ CS 217	Linear Programming	2-1-0	3
MA 219/ CS 219	Introduction to Dynamical Systems	2-0-2	3
MA 223	Database Management System	2-0-2	3
MA 225/ CS 213	Matrix Factorization and Applications	2-1-0	3
MA 227/ CS 215	Mathematics for AI and ML	2-1-0	3
MA 228/ CS 212	Foundation of Algebraic Graph Theory	2-1-0	3
MA 210/ CS 220	Elementary Number Theory and Algebra	2-1-0	3
MA 212	Regression Analysis	2-1-0	3
MA 317	Stochastic Calculus for Finance	2-1-0	3
MA 309	Numerical Methods for Partial Differential Equations	2-0-2	3
MA 311/ CS 323	Statistical Distribution Theory	2-1-0	3
MA 310/ CS 320	Algorithmic Techniques and Applications of Data Science	2-1-0	3
MA 312	Analytical methods in Partial Differential Equations	2-1-0	3
MA 314	Random Matrices	2-1-0	3
MA 315/ CS 325	Mathematical Foundations for Cryptography	2-1-0	3
MA 316/ CS 316	Spectral Graph Theory	2-1-0	3
CS 315/ MA 321	Introduction to Complexity Theory	2-1-0	3
MA 319/ CS 319	Foundations of Cryptography	2-1-0	3
MA 327/ CS 327	Mathematical Methods in Risk Theory	2-1-0	3
MA 329/ CS 329	Algebraic Coding Theory	2-1-0	3
MA 452/ MA 652	Theory of Transforms	2-1-0	3
MA 407/ MA 607	Nonlinear Dynamics and Computations	2-0-2	3
MA 456/ MA 656	Stochastic Approximation	2-1-0	3
MA 454/ MA 654	Mathematical Modeling and Simulations	2-0-2	3
MA 405/ MA 605	Differential Equations in Population Dynamics	2-0-2	3
MA 402/MA 602	Industrial Statistics	2-0-2	3
MA 404/MA 604	Foundation of Approximation Theory	2-1-0	3
MA 406/ MA 606	Graph Theory	2-1-0	3

MA 408/ MA 608	Mathematical Theory of Waves	2-1-0	3
MA 414/MA 614	Time Series Analysis	2-1-0	3
MA 416/MA 608	Integral Equations	2-1-0	3
MA 422/ MA 622	Hyperbolic Geometry	2-1-0	3
MA 424/ MA 624	Algebraic Number Theory	2-1-0	3
MA 426/ MA 626	Theory of Modular Forms	2-1-0	3
MA 432/ MA 632	Introduction to Commutative Algebra	2-1-0	3
MA 434 / MA 634	Introduction to Modal Logic	2-1-0	3

Course Structure for the Interdisciplinary Dual Degree Program at the Department of Computer Science and Engineering

i. The exit option will be available to the students to exit from the dual degree program with B.Tech. Degree in the parent department.
ii. Two Degree certificates i.e. B.Tech. and M.Tech. will be conferred.
iii. Seats 30: 15 Mathematics and Computing, Computer Science and Engineering. 15 seats from other departments.

Year	Semester	Course Code	Course	Weekly L-T-P	Credits
Years II and III	Sem 3-6	CS XXX (CS 203)	Data Structures and Algorithms	2-1-0	3
		CS XXX (CS 204)	Design and Analysis of Algorithms	2-1-0	3
		CS XXX (CS 201)	Discrete Mathematical Structures	2-1-0	3
		CS XXX (CS 202)	Automata Theory and Logic	2-1-0	3
Year IV	Sem 7	CS 639	Computing Foundations: Operating Systems	1-0-2	2
		CS 641	Computing Foundations: Compiler Design	2-0-2	1.5 (3/2)
		CS 643	Computing Foundations: Computer Architecture	2-0-2	1.5 (3/2)
		CS 411/611	Advanced Algorithms	2-1-0	3
		ZZ XXX	Interdisciplinary Research Project-I	0-0-8	4
	Sem 8	ZZ XXX	Interdisciplinary Research Project-II	0-0-8	4
		ZZ 6XX	Elective-1	X-X-X	3
		ZZ 6XX	Elective-2	X-X-X	3
		CS	Elective Bucket -1 (AI/ML)	X-X-X	3

		4XX/6XX	-3	Bucket -2 (Networking and Cyber Security)		
		CS 4XX/6XX	Elective -4		X-X-X	3
		CS 4XX/6XX	Elective-5		X-X-X	3
Year V	Sem 9	CS 799	M. Tech. Research Project (Stage I)		0-0-36	18
	Sem 10	CS 800	M. Tech. Research Project (Stage-II)		0-0-36	18
Total						67

Structure of the Minor programs [from AY 2014-15 to AY 2020-21]

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in HSS: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences** ***excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Astronomy (from AY 2016-17):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses*.* Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	**Minor Program in BSBE**	**Minor Program in Chemistry**	**Minor Program in Humanities and Social Sciences**	**Minor Program in Astronomy (from AY 2016-17 onwards)**
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 201: Understanding Philosophy HS 203: Psychology HS 205: Sociology HS 207: French Language-I	AA 201: Introduction to Astronomy
4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 206: Paradigms and Turning Points # HS 208: French Language-II HS 210: Indian Economy HS 211: German Literature and Culture Studies HS 214: History of Indian Culture and Civilization HS 216: Introduction to Hindi Cinema	AA 202N: Astronomical Techniques
5th : Minor 3	BSE 301: Introduction to Molecular Biology	CH 301: Functional Materials	HS 311: Life and Thought of Gandhi HS 313: History of Early Cinema	AA 301: High Energy Astronomy

			HS 315: Sociology of Science and Technology HS 323: International Economics HS 341: Appreciating Indian English Literature	
8th : Two elective courses as Minor 4 and Minor 5	BSE 402: Cancer Diagnosis and Therapy BSE 404/ BSE 604: Biomedical Imaging BSE 405/ BSE 605: Molecular Biophysics BSE 413/ BSE 613: Omics Technologies BSE 417/ BSE 617: Biomolecular Modeling EE 419/ EE 619: Biomedical Optics ME 407/ME 607: Bio-fluid Mechanics	CH 402: Chemistry in Industry CH 404: Chemical Physics CH 406: Nuclear Science	IHS 402: Twentieth Century World History: Critical Perspectives HS 412/ 612: Contemporary Indian Thought HS 418/ 618: Sustainability Studies HS 424/ HS 624: Econometrics-I IHS 422 / HS 622: Development Economics IHS 425: Money and Banking HS 426: Economics of Innovation HS 442/ HS 642: Language and Mind IHS 443/ HS 643: Contemporary Short Fiction IHS 444: Literature of the Twentieth Century IHS 482: Introduction to International Development and Area Studies	AA 404/ AA 604: Spacecraft and Payload Attitude Dynamics, Control and Pointing AA 471N/ AA 671N: Relativity and Cosmology AA 472N/ AA 672N: Galactic and Extragalactic Astronomy AA 474 / AA 674: Basics of Radio Astronomy AA 476/ AA 676: Satellite Based Navigation Systems AA 478/ AA 678: Space Weather

& *A student who takes CH 202 will not be allowed to take ME 416/616 in his/her 8th Semester*

Structure of the Minor programs [For AY 2021-22]

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in HSS: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences *excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Astronomy (from AY 2016-17):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses*.* Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	**Minor Program in BSBE**	**Minor Program in Chemistry**	**Minor Program in Humanities and Social Sciences**	**Minor Program in Astronomy (from AY 2016-17 to AY 2021-22)**
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 201: Understanding Philosophy HS 203: Psychology HS 205: Sociology HS 207: French Language-I	AA 201: Introduction to Astronomy
4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 206: Paradigms and Turning Points # HS 208: French Language-II HS 210: Indian Economy HS 211: German Literature and Culture Studies HS 214: History of Indian Culture and Civilization HS 216: Introduction to Hindi Cinema	AA 202N: Astronomical Techniques AA 204: Introduction to Space Exploration
5th : Minor 3	BSE 301: Introduction to	CH 301: Functional	HS 311: Life and Thought of Gandhi	AA 301: High Energy

	Molecular Biology	Materials	HS 313: History of Early Cinema HS 315: Sociology of Science and Technology HS 323: International Economics HS 341: Appreciating Indian English Literature	Astronomy AA 303: IoT for Space Applications
8th : Two elective courses as Minor 4 and Minor 5	BSE 402: Cancer Diagnosis and Therapy BSE 404/ BSE 604: Biomedical Imaging BSE 405/ BSE 605: Molecular Biophysics BSE 413/ BSE 613: Omics Technologies BSE 417/ BSE 617: Biomolecular Modeling BSE 419/ BSE 619: Renewable Energy Technologies EE 419/ EE 619: Biomedical Optics ME 407/ME 607: Bio-fluid Mechanics	CH 402: Chemistry in Industry CH 404: Chemical Physics CH 406: Nuclear Science	IHS 402: Twentieth Century World History: Critical Perspectives HS 412/ 612: Contemporary Indian Thought HS 418/ 618: Sustainability Studies HS 424/ HS 624: Econometrics-I IHS 422 / HS 622: Development Economics IHS 425: Money and Banking HS 426: Economics of Innovation HS 442/ HS 642: Language and Mind IHS 443/ HS 643: Contemporary Short Fiction IHS 444: Literature of the Twentieth Century IHS 482: Introduction to International Development and Area Studies	AA 404/ AA 604: Spacecraft and Payload Attitude Dynamics, Control and Pointing AA 471N/ AA 671N: Relativity and Cosmology AA 472N/ AA 672N: Galactic and Extragalactic Astronomy AA 474 / AA 674: Basics of Radio Astronomy AA 476/ AA 676: Satellite Based Navigation Systems AA 478/ AA 678: Space Weather

[&] *A student who takes CH 202 will not be allowed to take ME 416/616 in his/her 8th Semester*

Structure of the Minor programs [from AY 2022-23 onwards]

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in Economics: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences *excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Liberal Arts**

5. **Minor Program in Astronomy and Space Engineering (from AY 2022-23):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses*.* Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	**Minor Program in BSBE**	**Minor Program in Chemistry**	**Minor Program in Economics** **(from AY 2022-23 onwards with BTech batch admitted in AY 2021-22)**	**Minor Program in Liberal Arts (from AY 2022-23 onwards with BTech batch admitted in AY 2021-22)**	**Minor Program in Astronomy (from AY 2016-17 to AY 2021-22)** **Minor Program in Astronomy and Space Engineering (from AY 2022-23 onwards with BTech batch admitted in AY 2021-22)**
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 209: Intermediate Microeconomics	HS 201: Understanding Philosophy HS 203: Psychology HS 205: Sociology HS 207: French Language-I Psychology	AA 201: Introduction to Astronomy

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4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 210: Indian Economy	HS 206: Paradigms and Turning Points HS 208: French Language-II HS 211: German Literature and Culture Studies HS 212: History of India after Independence, 1947-2000 HS 213: Cognitive HS 214: History of Indian Culture and Civilization HS 216: Introduction to Hindi Cinema	AA 202N: Astronomical Techniques AA 204: Introduction to Space Exploration
5th : Minor 3	BSE 301: Introduction to Molecular Biology	CH 301: Functional Materials	HS 323: International Economics HS 325: Industrial Organization	HS 311: Life and Thought of Gandhi HS 313: History of Early Cinema HS 315: Sociology of Science and Technology HS 321: History of Modern Indian Business HS 327: Mind, Action, and Technology HS 341: Appreciating Indian English Literature	AA 301: High Energy Astronomy AA 303: IoT for Space Applications

8th : Two elective courses as Minor 4 and Minor 5	BSE 402: Cancer Diagnosis and Therapy BSE 404/ BSE 604: Biomedical Imaging BSE 405/ BSE 605: Molecular Biophysics BSE 413/ BSE 613: Omics Technologies BSE 417/ BSE 617: Biomolecular Modeling BSE 419/ BSE 619: Renewable Energy Technologies EE 419/ EE 619: Biomedical Optics ME 407/ME 607: Bio-fluid Mechanics	CH 402: Chemistry in Industry CH 404: Chemical Physics CH 406: Nuclear Science	HS 418/ 618: Sustainability Studies IHS 422 / HS 622: Development Economics IHS 425: Money and Banking HS 426: Economics of Innovation HS 424/ HS 624 Econometrics-I HS 431: Innovation and Intellectual Property Rights	IHS 402: Twentieth Century World History: Critical Perspectives HS 412/ 612: Contemporary Indian Thought HS 442/ HS 642: Language and Mind IHS 443/ HS 643: Contemporary Short Fiction IHS 444: Literature of the Twentieth Century IHS 482: Introduction to International Development and Area Studies HS 446: Music and Literary Modernism HS 481/ HS 681: Language, Mind and Society	AA 404/ AA 604: Spacecraft and Payload Attitude Dynamics, Control and Pointing AA 410/ AA 410: Spatial Informatics AA 412/ AA 612: Microwave Remote Sensing AA 471N/ AA 671N: Relativity and Cosmology AA 472N/ AA 672N: Galactic and Extragalactic Astronomy AA 474 / AA 674: Basics of Radio Astronomy AA 476/ AA 676: Satellite Based Navigation Systems AA 478/ AA 678: Space Weather

Structure of the Minor programs for AY 2024-25 onwards (For all UG batches admitted in and after AY 2023-24)

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in Economics: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences** ***excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Liberal Arts**

5. **Minor Program in Astronomy and Space Engineering (from AY 2022-23):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses*.* Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	**Minor Program in BSBE**	**Minor Program in Chemistry**	**Minor Program in Economics From AY 2024-25 (Batch Admitted in and after AY 2023-24)**	**Minor Program in Liberal Arts From AY 2024-25 (Batch Admitted in and after AY 2023-24)**	**Minor Program in Astronomy and Space Engineering From AY 2024-25 (Batch Admitted in and after AY 2023-24)**
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 209: Intermediate Microeconomics	HS 211: German Literature and Culture Studies HS 212: History of India after Independence, 1947-2000 HS 203: Psychology HS 205: Sociology HS 221 Fundamentals of	AA 201: Introduction to Astronomy

				Linguistics HS 223 Language Variation: Culture and Society	
4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 210: Indian Economy	HS 206: Paradigms and Turning Points HS 214: History of Indian Culture and Civilization HS 213: Cognitive Psychology HS 224 Contemporary Short Fiction HS 226 Sociology of Cinema	AA 202N: Astronomical Techniques AA 204: Introduction to Space Exploration
5th : Minor 3	BSE 301: Introduction to Molecular Biology	CH 301: Functional Materials	HS 323: International Economics HS 321: History of Modern Indian Business	HS 311: Life and Thought of Gandhi HS 327: Mind, Action, and Technology HS 341: Appreciating Indian English Literature	AA 301: High Energy Astronomy AA 303: IoT for Space Applications
6TH : Minor 4			HS 325: Industrial Organization	HS 315: Sociology of Science and Technology HS 328 Philosophy and Film HS 330 Graphic Literature	

7th : (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)

Syllabi
of
B. Tech. in Mathematics and Computing
(From AY 2023-24 onwards)

Course Code	**MA 202**
Title of the Course	**Multivariate Calculus and Measure Theory**
Course Category	Department Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of calculus and linear algebra
Objective of the Course	First part of this course introduces basic concepts and results related to continuity and differentiability in the finite dimensional setting. The second part introduces concepts related to Lebesgue integral and some of their important properties.
Course Outcomes	The student is able to generalize all the results and techniques learned in the first year calculus course and their applications.
Course Content	• Functions of several variables - Continuity and differential calculus for functions from R^n to R^m Jacobian matrix, Mean Value Theorem, higher order derivatives, Taylor series for function from R^n to R, inverse function theorem, implicit function theorem. • Lebesgue measure and integral - sigma-algebra of sets, measure space, Lebesgue measure, measurable functions, Lebesgue integral, Fatou's lemma, dominated convergence theorem, monotone convergence theorem, *Lp* spaces.

Suggested Books	Text Books: 1. T. M. Apostol, ***Mathematical Analysis***, Narosa Publishers, 2002, ISBN: 978-8185015668. 2. R. G. Bartle, ***The Elements of Integration and Lebesgue Measure,*** Wiley, 1995, ISBN: 0471042226. Reference Books: 3. W. Rudin, ***Principles of Mathematical Analysis,*** McGraw Hill, 1983, ISBN: 0-07-054235-X. 4. M. Capinski and E. Kopp, ***Measure, Integral and Probability***, Springer, 2007, ISBN: 9781852337810. 5. G. de Barra, ***Measure Theory and Integration***, New Age International, 1981, ISBN: 9788122435023.

Course Code	**MA 204N**
Title of the Course	**Numerical Methods**
Course Category	Institute Core
Credit Structure	L-T- P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	None
Objective of the Course	This is a foundation course on numerical methods for UG students.
Course Outcomes	Students will be trained to evaluate integration and differentiation, and to solve numerically system of linear equations and differential equations.
Course Syllabus	• Interpolation by polynomials, divided differences, error of the interpolating polynomial. • Solution of a system of linear equations, Cholesky's method, Gauss-Seidel methods, partial pivoting, row echelon form, norms, ill-conditioning. Eigen-value problem, power method. • Solution of a nonlinear equation, bisection and secant methods, Newton's method, rate of convergence, solution of a system of nonlinear equations. • Numerical integration, composite rules, error formulae. • Numerical solution of ordinary differential equations, Euler and Runge-Kutta methods, multi-step methods, predictor-corrector methods, order of convergence. • Finite difference methods, numerical solutions of elliptic, parabolic, and hyperbolic partial differential equations.
Suggested Books	Text Books: 1. S. S. Sastry, ***Introductory Methods of Numerical Analysis,*** PHI Learning, ISBN-978-81-203-4592-8, 2012. 2. E. Kreyszig, ***Advanced Engineering Mathematics***, John Wiley & Sons, 2020, ISBN: 9781119455929. 3. S. D. Conte and Carle de Boor, ***Elementary Numerical Analysis - An Algorithmic Approach***, SIAM, 2018, ISBN: 9781611975208 Reference Books: 4. B. Bradie, ***A Friendly Introduction to Numerical Analysis,*** Pearson Prentice Hall, 2007, ISBN: 8131709426. 5. W. Cheney, D. Kincaid, ***Numerical Mathematics and Computing***, Cengage Learning, 2020, ISBN: 9780357670842. 6. D. Watkinson, ***Fundamentals of Matrix Computations***, Wiley Inter Science, 2010, ISBN: 9780470528334.

Course Code	**MA 205**
Title of the Course	**Complex Analysis**
Course Category	Institute Core
Credit Structure	L-T- P-Credits 3-1-0-2 (half semester)
Name of the Concerned Department	Mathematics
Pre-requisite, if any	None
Objective of the Course	This is a foundation course on complex analysis for UG students.
Course Outcomes	Students will understand the concepts, like analytic functions, harmonic functions, Cauchy's theorem, residue formula and their applications.
Course Syllabus	• Definitions and properties of analytic functions. • Cauchy-Riemann equations, harmonic functions. • Power series and their properties. Elementary functions. • Cauchy's theorem and its applications, Taylor series and Laurent expansion. • Residues and Cauchy's residue formula, Evaluation of improper integrals.
Suggested Books	Text Books: 1. E. Kreyszig, ***Advanced Engineering Mathematics***, John Wiley & Sons, 2020, ISBN: 9781119455929. 2. R.V. Churchill and J.W. Brown, ***Complex Variables and Applications***, McGraw-Hill Inc. New York, 2014, ISBN: 9780073383170. Reference Books: 3. J.M. Howie, ***Complex Analysis***, Springer-Verlag, Berlin, 2012, ISBN: 9781447100270. 4. M.J. Ablowitz and A.S. Fokas, ***Complex Variables: Introduction and Applications***, Cambridge University Press, 2008, ISBN: 9787506291804.

Course Code	**MA 206**
Title of the Course	**Mathematical Logic and Theory of Computation**
Course Category	Department Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Discrete mathematical structures
Objective of the Course	At the end of the course, students should be exposed to fundamental knowledge in mathematical Logic and theory of computations.
Course Outcomes	● Exhibit a strong foundation in formal computation, mathematical logic, formal reasoning, and formal semantics. ● Distinguish various computing languages, and effectively engage in logical argumentation, discussion, and communication of essential logic concepts in the context of computer science.
Course Content	• **Propositional Logic:** Language of propositional logic, Tautological consequence • **First Order Logic:** A language for arithmetic, First order languages, Examples of first-order languages for some mathematical structures, Tarski's definition of truth. • **Automata and Language Theory:** Finite automata, Regular expressions, Push-down automata, Context-free grammars, Pumping lemmas. • **Computability Theory:** Turing machines, Church-Turing thesis, Decidability, Halting problem, Reducibility.
Suggested Books	Text Books: 1. H. R. Lewis and C. H. Papadimitriou, ***Elements of Theory of Computation***, Prentice-Hall, 2nd Edition, Englewood, New Jersey, 1997, ISBN: 0-13-26247&-8. 2. R. E. Hodel, ***An Introduction to Mathematical Logic***, PWS Publishing Company, Boston, 1995, ISBN: 9780534944407. Reference Books: 3. J. Hopcroft, R. Motwani, and J. Ullman, ***Introduction to Automata Theory, Language, and Computation***, Pearson

	Education, 2nd Edition, 2001. ISBN:0201441241. 4. M. Sipser, ***Introduction to the Theory of Computation***, Cengage India Private Limited, 3rd Edition, 2014, ISBN: 8131771865.

Course Code	**MA 207**
Title of the Course	**Differential Equations-II**
Course Category	Institute Core
Credit Structure	L-T- P-Credits 3-1-0-2 (half semester)
Name of the Concerned Department	Mathematics
Pre-requisite, if any	None
Objective of the Course	This is a foundation course on differential equations for UG students.
Course Outcomes	• Students will be trained to solve various types of higher ordinary differential equations and partial differential equations. • Students will also be exposed to the real-life applications of Laplace, wave, and heat equations.
Course Syllabus	• Review of power series and series solutions of ODEs. • Regular singular points, method of Frobenius, Bessel equation and Bessel function. • Legendre equation and Legendre Polynomials. • Strum-Liouville problems, Fourier series. • Classification of linear second order PDEs in two variables, D'Alembert solution to the wave equations, Laplace, Wave, and Heat equations with applications.
Suggested Books	Text Books: 1. E. Kreyszig, ***Advanced Engineering Mathematics***, John Wiley & Sons, 2020, ISBN: 9781119455929. 2. W.E. Boyce and R. Diprima, ***Elementary Differential Equations***, John Wiley & Sons, 2022, ISBN: 9781119820512. Reference Books: 3. R.V. Churchill and J.W. Brown, ***Fourier Series and Boundary Value Problems***, McGraw-Hill Inc., 2019, ISBN: 9787560381251. 4. G. Simmons, ***Differential Equations with Applications and Historical Notes*****,** Taylor & Francis, 2017, ISBN: 9781498702591.

Course code	**MA 208 /CS 204**
Title of the Course	**Design and Analysis of Algorithms**
Course Category	Department Core
Credit Structure	L - T - P - Credits: 2-1-0-3
Name of the Concerned Discipline	Mathematics/Computer Science and Engineering
Pre-requisite, if any	Knowledge of Data Structures and Algorithms
Objective of the Course	This is an introductory course in the field of computer algorithms.
Course Outcomes	At the end of the course, students will know the basics of ∉ algorithm analysis, ∉ algorithm design, and ∉ different problem classes.
Course Syllabus	• **Algorithm Analysis:** Time and Space Complexity; Computational Tractability (Best, Average & Worst Cases), Asymptotic Bounds (Lower, Upper & Tight Bounds). • **Algorithm Design**: Divide and Conquer; Greedy, Dynamic Programming, Branch and Bound. • **Problem Classes:** Reducibility and Intractability, P, NP, PSPACE, NP-Complete, and NP-Hard.
Suggested Books	Textbooks: 1. T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, ***Introduction to Algorithms*** (Eastern Economy Edition), 3rd Edition, PHI Learning Pvt. Ltd. (Originally MIT Press), 2010. ISBN: 978-8120340077 Reference books: 2. J. Kleinberg and E. Tardos, ***Algorithm Design***, 2nd Edition, Pearson Education, 2022. ISBN: 978-0132131087

Course Code	**MA 209**
Title of the Course	**Foundations of Mathematical Analysis**
Course Category	Department Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of calculus and linear algebra
Objective of the Course	Students will have fundamental knowledge and problem-solving skills in analysis in metric space and convergence criteria in sequences and series of functions.
Course Outcomes	● Students will have knowledge of different topologies on Euclidean spaces. ● They will have an understanding of the space of continuous functions.
Course Content	• Review of calculus and highlights of its applications • Introduction to metric space, Finite-dimensional normed space $(R^n, \|.\|_p)$ as l_p^n with l_p-norms, real word implication of l_p norms, illustration of unit balls in l_p^n, Finite-dimensional inner product space • Topology on l_p^n: Uniform continuity, convergence and completeness in l_p^n, properties of compact sets in l_p^n, Extreme Value Theorem and approximation result for closest point, Intermediate Value Theorem on a connected subset of l_p^n, Cantor set • *p*-norm on C[0,1], sequence, series and their convergence in C[0,1], Weierstrass theorem, topological properties of C[0,1], Nowhere differentiable function
Suggested Books	Text Books: 1. N. L. Carothers, ***Real Analysis***, Cambridge University Press, 2009, ISBN: 0521497566. 2. W. Rudin, ***Principles of Mathematical Analysis***, McGrawHill,

	1983, ISBN: 0-07-054235-X. Reference Books: 3. K. R. Davidson and A. P. Donsig, ***Real Analysis with Real Applications***, Prentice Hall, 2002, ISBN: 978-0-387-98097-3. 4. T. M. Apostol, ***Calculus: Volumes 1 and 2***, Wiley Eastern, 1980, ISBN: 978-0-471-00005-1. 5. T. M. Apostol, ***Mathematical Analysis***, Narosa Publishers, 2002, ISBN: 9788185015668. 6. S. Kumaresan, ***Topology of Metric Spaces***, Narosa Publishers, 2011, ISBN: 978-8184870589.

Course Code	**MA 210/ CS 220**
Title of the Course	**Elementary Number Theory and Algebra**
Course Category	Department Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of linear algebra
Objective of the Course	To expose the students to the basic ideas of algebra. At the end of the course, students should be exposed to fundamental knowledge and problem-solving skills in number theory and groups.
Course Outcomes	Making students familiar with groups, ring and fields which will help them in cryptography and coding theory.
Course Content	• **Number theory:** Integers, divisibility in integers, GCD, LCM, Bezout's identity, modular arithmetic, Chinese remainder theorem, Fermat's little theorem, Euler Phi-function. • **Group theory:** Cyclic, dihedral, symmetric, matrix groups, normal subgroups and quotient groups, conjugacy classes, isomorphism theorems, group automorphisms, symmetric group and alternating group, class equations, Cauchy's theorem (without proof), rings, integral domains, ideals, quotient rings, prime and maximal ideals, ring homomorphisms, polynomial rings, factorization in polynomial rings, fields, characteristic of a field, field extensions.
Suggested Books	Text Books: 1. N. Herstein, ***Topics in Algebra***, John Wiley & Sons, 2005, ISBN: 997151253X. 2. D. Burton, ***Elementary Number Theory***, McGraw Hill Education, 2017, ISBN: 9355325126. Reference Books: 3. D. S. Dummit and R.M. Foote, ***Abstract Algebra***, John Wiley & Sons, 2003, ISBN: 812651776X. 4. M. Artin, ***Algebra***, Prentice Hall of India, 1999, ISBN: 8184956754. 5. I. Niven, H. S. Zuckerman, and H. L. Montgomery, ***An***

	Introduction to the Theory of Numbers, John Wiley & Sons, 1991, ISBN: 9788126518111.

Course code	**MA 211 / CS 201**
Title of the course	**Discrete Mathematical Structures**
Course category	Department Core
Credit Structure	L - T - P – Credits 2-1-0-3
Name of the Concerned Department	Mathematics / Computer Science and Engineering
Pre-requisite, if any	Basic courses on mathematics
Objective of the Course	This course will introduce the basic concepts of discrete mathematics and its applications.
Course Outcome	● Students will learn about discrete mathematical structures like sets, relations, functions, groups, graphs, etc. ● They will also learn about proof techniques and how to apply them to prove lemmas, theorems, etc.
Course Syllabus	• Elementary counting techniques • Propositions and predicates, proofs and proof techniques. • Sets, relations and functions, cardinality • Posets and lattices: Dilworth`s theorem, inversion and distributive lattices • Graph theory basics: paths, cycles, trees, connectivity • Group theory: Lagrange`s theorem, homomorphisms, applications
Suggested Books	Textbooks: 1. K. H. Rosen, ***Discrete Mathematics and Its Applications***, Mc Graw Hill, 2019, ISBN: 9781259676512 Reference books: 2. R. P Grimaldi, ***Discrete and Combinatorial Mathematics***, Pearson, 2017, ISBN: 9788177584240

Course Code	**MA 212**
Title of the Course	**Regression Analysis**
Course Category	Department Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Probability and Statistics
Objective of the Course	Understanding of data modelling and forecasting concepts. It has several applications in the fields of machine learning and data science.
Course Outcomes	● understand and apply regression techniques to model and analyse the relationship between variables, ● interpret the coefficients of regression models, and predict the new observations.
Course Syllabus	● Simple Linear Regression: Least-squares and maximum likelihood estimation of the parameters, hypothesis testing on the slope and intercept, interval estimation, prediction of new observations, coefficient of determination, regression through the origin. ● Multiple Linear Regression: Estimation of the model parameters, hypothesis testing, confidence intervals, prediction of new observations. ● Model Adequacy Checking: Residual analysis, methods for scaling residuals, residual plots, detection and treatment of outliers, lack of fit of the regression model. ● Model Inadequacies Corrections: Variance-stabilizing transformations, transformations to linearize the model, box–cox method, generalized and weighted least squares. ● Multicollinearity, variance inflation factors, ridge regression, variable selection and model building, logistic regression models, Poisson regression.

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Suggested Books	Text Books: 1. D. C. Montgomery, E. A. Peck, G. G. Vining, ***Introduction to Linear Regression Analysis***, Wiley, India, 2012, ISBN: 978-0470542811. 2. M. H. Kutner, C. J. Nachtsheim, J. Neter, W. Li, ***Applied Linear Statistical Models***, McGraw-Hill, Irwin, 2005, ISBN: 0-07-238688-6. Reference Books: 3. N. R. Draper, H. Smith, ***Applied Regression Analysis***, Wiley, 1998, ISBN: 978-0471170822.

Course code	**MA 213/ CS 203**
Title of the course	**Data Structures and Algorithms**
Course Category	Department Core
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Mathematics / Computer Science and Engineering
Pre-requisite, if any	Computer Programming
Objective of the Course	• This Course is designed to provide an introduction to the theory and practice of different data structures. • This course will also provide familiarity with the algorithms for those data structures.
Course Outcomes	Students will learn the uses of data structures to make efficient algorithms
Course Syllabus	• Introduction to data structures, Abstract data types, Analysis of algorithms, Introduction to complexity analysis and measures. • Arrays – operations and addressing, Linked list (singly, doubly, and circular), Stack ADT and its applications in expression evaluation and recursion, Queue ADT and its variants such as circular queues and double-ended queues. Hashing and hash tables, Recursion. • Tree ADT, Binary trees – properties and traversals, Binary search trees, Height balanced trees -- AVL trees, Binary heaps, and priority queues. • Graph ADT, Graph representation, Graph traversal – breadth-first search, depth-first search, and topological ordering, Connected components, cut-vertices, 2-connected components • Algorithms and data structures for sorting and searching, Order statistics.
Suggested Books	Textbooks: 1. S. Sahni, ***Data structures, algorithms, and applications in C++***, McGraw-Hill, 1998, ISBN: 978-0929306322 2. T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, ***Introduction to Algorithms***, (3rd Edition),

	Prentice Hall, 2009. ISBN: 978-81-203-4007-7 Reference Books: 3. D. E. Knuth, ***The Art of Computer Programming: Fundamental Algorithms***, Vol. 1 (3rd Edition, 1997) and Vol 3, (2nd Edition, 1998), Addison-Wesley Professional. ISBN: 978-0137935109 4. M.T. Goodrich, R. Tamassia, and D. Mount, ***Data Structures and Algorithms in C++***, 2^{nd} Edition, Wiley, ISBN: 978-0-470-38327-8

Course Code	**MA 215**
Title of the Course	**Probability and Statistics**
Course Category	Department Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Nil
Objective of the Course	This is a foundation course on probability and statistics for UG students.
Course Outcomes	● understand the techniques of data collection, analysis, and interpretation, enabling them to make informed decisions in diverse fields, ● learn a solid foundation in probability and statistics, empowering them to analyze data, and draw meaningful conclusions.
Course Content	• **Descriptive Statistics:** Data collection techniques, organizing and presenting data, frequency distributions, measures of central tendency, variation, skewness, and kurtosis. • **Probability and Random Variable:** Axiomatic definition of probability, conditional probability and Bayes rule, random variables, cumulative distribution function, and its properties, histogram density estimation and bootstrap, discrete random variables, probability mass function, continuous random variables, probability density function, functions of random variables, expectation and moment of a random variable, moment generating function, probability integral transform. • **Probability Distributions:** Bernoulli, binomial, geometric, negative binomial, hypergeometric, Poisson, exponential, gamma, Weibull, beta, Cauchy, normal. • **Random Vectors:** Joint distributions, marginal and conditional distributions, independence of random variables, covariance and correlation. • **Inequalities and Limit Theorems:** Markov's inequality, Chebyshev's inequality, Jensen's inequality, convergence in probability and convergence in distribution, weak law of large numbers and central

	limit theorem.
Suggested Books	Text Books: 1. S. M. Ross, ***Introductory Statistics***, Academic Press, USA, 2017, ISBN: 978-0-12-804317-2. 2. D. C. Montgomery and G. C. Runger, ***Applied Statistics and Probability for Engineers***, Wiley, 2016, ISBN: 978-8126562947. Reference Books: 3. S. M. Ross, ***Introduction to Probability and Statistics for Engineers and Scientists***, Academic Press, 2004, ISBN: 9780123704832. 4. J. A. Rice, ***Mathematical Statistics and Data Analysis***, Duxbury Press, 2006, ISBN: 0-534-39942-8. 5. I. R. Miller, J.E. Freund, R. Johnson, ***Probability and Statistics for Engineers***, Prentice-Hall (I) Ltd, India, 2011, ISBN: 9788177581843.

Course code	**MA 217/ CS 217**
Title of the course	**Linear Programming**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basics linear algebra and coordinate geometry
Objective of the Course	This course aims to develop basic understanding of linear programming problems.
Course Outcomes	Students will learn basics of linear programming, solution methods, essence of duality and applications
Course Syllabus	● Introduction to linear programming, formulating a linear program, feasibility and optimality, solution space, some practical examples on feasibility, optimality and sensitivity. ● Graphically solving linear programming problems (LPP) with two variables, canonical and standard form of LPP, formalizing the graphical method, problems with alternate optimal solutions, no solutions, and unbounded feasible regions. ● Simplex method: Computational procedure, use of artificial variables, Big M method, applications of simplex algorithm. ● Duality: Primal-dual pair, formulating a dual problem, duality theorems, complementary slackness theorem. ● Solving linear programming with MATLAB/R, applications to industrial problems.
Suggested Books	Text Books: 1. H. A. Taha, ***Operations Research: An Introduction***, Pearson Education, 2022, ISBN: 9780137625819. 2. S. Bazaraa, J. J. Jarvis and H. D. Sherali, ***Linear Programming and Network Flows***, Wiley, 2011, ISBN: 9781118211328. Reference Books: 3. N. S. Kambo, ***Mathematical Programming Techniques***, Revised Edition, Affiliated East-West Press, 2008, ISBN: 9788185336473. 4. G. Murty, ***Linear Programming***, Wiley, 1983, ISBN: 9780471892496.

Course code	**MA 219/ CS 219**
Title of the course	**Introduction to Dynamical Systems**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic calculus and ordinary differential equations
Objective of the Course	This course introduces relevant tools and techniques used in analysing dynamic equations applied to modelling real-world problems.
Course Outcomes	● Formulating models of electrophysiology, chemical reactions, dynamics of the human heart, etc. ● Analyzing slow-fast dynamics and implement it for the population models.
Course Syllabus	• Introduction to linear and nonlinear autonomous systems, complete solutions, flows, blow-up, equilibrium and local stability, asymptotic stability, quasi-stability, exponential stability, Hartman-Grobman theorem. • Oscillation theory, weakly perturbed linear oscillators, multiple time scale analysis, relaxation oscillations and multiple limit cycles, Stuart–Landau oscillator networks. • Introduction to monotone dynamical systems, Metzler matrices, Kamke's condition, Ji-Fa's theorem, Smillie's theorem, dynamics of cooperative and competitive systems, application to the Ribosome flow model and electrophysiology. • Numerical simulations and applications: Modelling electric circuits, enzyme kinetics, chemical oscillators and the Belousov-Zabitinsky reaction, population models, dynamics of neurons and human heart.
Suggested Books	Text Books: 1. R. C. Hilborn, ***Chaos and Nonlinear Dynamics***, Oxford University Press, 2000, ISBN: 978-0198507239. 2. H. L. Smith, ***Monotone Dynamical Systems: An Introduction to the Theory of Competitive Cooperative Systems***, American Mathematical Society, 2008, ISBN: 978-0821844878. Reference Books: 3. S. H. Strogatz, ***Nonlinear Dynamics and Chaos,*** Westview Press, 2015, ISBN: 978-0-8133-4910-7.

	4. D. W. Jordon, P. Smith, ***Nonlinear Ordinary Differential Equations: An Introduction for Scientists and Engineers***, Oxford University Press, 2007, ISBN: 978-0199208258.

Course code	MA 223
Title of the course	Database Management System
Course Category	Department Elective
Credit Structure	L - T - P - Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Knowledge of data structures and algorithms
Objective(s)	This course will introduce the fundamentals of Database Management Systems and practical solutions to create, manipulate, and optimize databases.
Course outcome	Students will learn about the fundamentals of database management and handling databases.
Course Syllabus	• **Introduction to Databases:** Nature of business systems and data processing, Database architectures, Schema, Data models, XML. • **ER Model:** Entity, Attribute, Relationship, ER diagrams, UML, Class diagrams. • **Relational model and query languages:** Relational algebra and calculus, SQL. • **Database design and normalization**: Integrities, Anomalies, Functional dependencies, Normal forms. • **Transactions:** Introduction to transactions, Serializability, Recoverability, Concurrency control and recovery. • **Physical Organization of Databases:** Indexing and Hashing, Single-level indexing, Multi-level indexing, B and B^+ Trees. • **Query processing and optimization** • Topics for Lab: Basic of shell scripts, Database systems supporting interactive SQL, Design of applications and user interfaces, Data analysis tools.

Suggested Books	Textbooks: 1. A. Silberschatz, H.F. Korth, and S. Sudarshan, ***Database System Concepts***, 7th Edition, McGraw Hill, 2020. ISBN: 9780078022159 2. R. Elmasri and S. Navathe, ***Fundamentals of Database Systems***, 7th Edition, Pearson, 2017. ISBN: 9789332582705 Reference books: 3. R. Ramakrishnan and J. Gehrke, ***Database Management Systems***, 3rd Edition, McGraw Hill, 2002. ISBN: 978-0072465631 4. C. J. Date, ***Introduction to Database Systems***, 8th Edition, Pearson, 2004. ISBN: 978-0321189566

Course code	**CS 213/ MA 225**
Title of the course	**Matrix factorizations and applications**
Course Category	Department Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Computer Science and Engineering
Pre-requisite, if any	Basic linear algebra
Objective(s) (Objectives)	● This Course is designed to provide an introduction to matrix factorizations. ● This course will also provide familiarity with some algorithms related to matrix factorization.
Course Outcomes	Students will learn various matrix factorizations and their applications
Course Content	● Review of vector spaces, bases ● Cayley-Hamilton Theorem, triangulation, diagonalization, LU, LUP, decompositions ● Linear transformations, rotations, reflections, Gram-Schmidt orthogonalization, QR like decompositions, linear least-square problems ● Eigenvalues, Eigenvectors, normal matrices, eigenvalue decomposition, similar matrices ● Spectral theorem for Hermitian matrices, Cauchy-interlace theorem, Singular value decomposition, Moore-Penrose pseudoinverse
Suggested Books	Textbooks: 1. G. H. Golub, Charles F. Van Loan, ***Matrix Computations***, The Johns Hopkins University Press, 2013. ISBN: 978-1421407944. 2. D. S. Watkins, ***Fundamentals of Matrix Computations***, Wiley, 2010. ISBN: 978-0-470-52833-4. Reference Books: 3. G. Strang, ***Linear Algebra and Its Applications***, 4^{th} Edition, Academic Press, 2006. ISBN- 978-8131501726.

Course code	**CS 215/ MA 227**
Title of the course	**Mathematics for AI and ML**
Course Category	Department Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Computer Science and Engineering
Pre-requisite, if any	Basic linear algebra and calculus
Objective(s)	This course is designed to provide an introduction to mathematical foundations, concepts, and constructs for artificial intelligence and machine learning algorithm design.
Course Outcomes	Students will develop a foundation such that advanced courses in this area could be taken (Artificial Intelligence, Machine Learning, Soft Computing, and Computational Intelligence).
Course Content	● **Linear Algebra and Matrix Analysis:** Systems of Linear Equations, Vector Spaces, Linear Independence, Basis and Rank, Orthonormal Basis, Orthogonal Complement, Orthogonal Projections, Rotations, Eigenvalue Decomposition and Diagonalization, Singular Value Decomposition, Matrix Approximation. ● **Vector Calculus and Continuous Optimization:** Gradients of Vector-Valued Functions, Gradients of Matrices, Automatic Differentiation, Higher-Order Derivatives, Linearization and Multivariate Taylor Series, Unconstrained Optimization, Constrained Optimization and Lagrange Multipliers. ● **Probability and Distributions:** Probability Space, Discrete and Continuous Probabilities, Sum Rule, Product Rule, and Bayes' Theorem, Summary Statistics and Independence, Gaussian Distribution, Conjugacy and the Exponential Family, Change of Variables/Inverse Transform. ● **Models and Data:** Models Learning and Selection, Empirical Risk Minimization, Parameter Estimation, Probabilistic Modeling and Inference, Directed Graphical Models, Bayesian Linear Regression, Dimensionality Reduction with Principal Component Analysis, Density Estimation with Gaussian Mixture Models, Classification with Support Vector Machines

Suggested Books	Textbooks: 1. M. P. Deisenroth, A. A. Faisal, and C. S. Ong., ***Mathematics of Machine Learning***, Cambridge University Press, 2020. ISBN: 978-1-1084-5514-5. 2. A. Antoniou and W.-S. Liu, ***Practical Optimization: Algorithms and Engineering Applications***, Springer, 2007. ISBN: 978-0-3877-1106-5. Reference Books: 3. C. Meyers, ***Matrix Analysis and Applied Linear Algebra***, SIAM, 2023. ISBN: 978-1-6119-7745-5. 4. J. K. Blitzstein and J. Hwang, ***Introduction to Probability***, Chapman and Hall/CRC Texts in Statistical Science, 2019. ISBN: 978-1-1383-6991-7 5. T. Hastie, R. Tibshirani, and J. Friedman, ***The Elements of Statistical Learning: Data Mining, Inference, and Prediction***, Springer Series in Statistics, 2016. ISBN: 978-0-3878-4857-0.

Course code	MA 228/ CS 212
Title of the course	**Foundation of Algebraic Graph Theory**
Course category	Department elective
Credit Structure	L -T - P - Credits 2-1-0-3
Name of the Concerned Department	Computer Science and Engineering
Pre-requisite, if any	Knowledge of Linear Algebra, Discrete Mathematics
Objective(s)	This course is about ● the analysis of graph properties using matrix theory ● bounds on some intractable graph problems.
Course outcomes	The students will learn analyzing graph properties using matrix theory and bounds on different graph problems
Course Syllabus	● Matrices associated with graphs, adjacency matrix, Laplacian matrix, distance matrix, Seidel Matrix, Spectral Theorem ● Finding number walks, connected components, Counting number of spanning trees, Matrix-Tree Theorem(s) ● Algebraic connectivity, regular graphs, random walks, expanders, Ramanujan Graphs ● Graph Isomorphism problem, graphs determined by the eigenvalues ● Strongly regular graphs, Friendship Theorem, Spectral bounds on NP-hard problems on graphs
Suggested Books	Textbooks: 1. R. B. Bapat, ***Graphs and Matrices***, Hindustan Book Agency, 2014, ISBN: 978-1-4471-6568-2 2. C. Godsil and G. Royle, ***Algebraic Graph Theory***, Springer, 2001, ISBN: 978-0-387-95241-3 Reference books: 3. A. E. Brouwer and W. H. Haemers, ***Spectra of graphs***, Springer, 2011, ISBN: 978-1-4614-1938-9

Course Code	**MA 317**
Title of the Course	**Stochastic Calculus for Finance**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of Calculus and Probability theory
Scope of the course (Objectives)	This course introduces basic knowledge in Stochastic Calculus and highlight some of its applications in Financial Engineering.
Course Outcomes	• Students will learn stochastic modeling and some of its applications in Financial Mathematics.
Course Content	Basic Concept of Probability Theory (Events and probabilities, Events as sets, Definition of random variables and elementary properties), Stochastic Process, Brownian Motion, Conditional Expectations, Martingales, Geometric Brownian Motion and its Quadratic variation and its importance in Financial modeling. Markov Property, Itô's Integral, ltô-Doeblin Formula, Black-Scholes-Merton Equation, Multivariable Stochastic Calculus. Risk-Neutral Measure, Girsanov's Theorem,Martingale Representation Theorem, Fundamental Theorems of Asset Pricing. Stochastic Differential Equations, An Existence and Uniqueness Result, Weak and Strong Solutions. Risk Neutral asset price modeling driven by Brownian Motion. Interest Models: CIR Model, Hull White Model and Vasicek Model, Solution Process of these models described by S.D. Equations.

Suggested Books	**Text Books:** 1. S. E. Shreve: Stochastic Calculus for Finance, Vol. II: Springer-Verlag: New York: 2004: ISBN: 0-387-40101-6 2. T. Mikosch: Elementary stochastic calculus with finance in view: World Scientific Publishing: London: 1998: ISBN: 981-02-3543-7 3. B. Oksendal: Stochastic differential equations: An introduction with applications: Springer-Verlag: Berlin: 2003: ISBN: 3-540-04758-1 **Reference Books:** 4. H.M. Taylor and S. Karlin: Introduction to Stochastic Modeling, Academic Press: USA: ISBN-13:978-0-12-68487-8 5. A. Etheridge: A Course in financial calculus: Cambridge University Press: Cambridge: 2002: ISBN: 0-521-89077-2 6. W. Feller: An Introduction to Probability Theory and Its Applications, Vol I, 3rd Ed., Wiley, 1968: ISBN: 978-0471257080

Course code	**MA 253/ CS 253**
Title of the course	**Data Structures and Algorithms Lab**
Course Category	Department Core
Credit Structure	L - T - P - Credits 0-0-3-1.5
Name of the Concerned Department	Mathematics/Computer Science and Engineering
Pre-requisite, if any	Computer Programming
Objective of the Course	This Course is designed to provide ● an introduction to the theory and practice of different data structures ● familiarity with the algorithms for those data structures
Course Outcomes	Students will learn uses of data structures to make efficient algorithms.
Course Syllabus	● Implementation of array, linked list, stack, and queue ● Implementation of tree and graph data structure ● Implementation of sorting and searching, ● Implementation of Hash and hash tables and order statistics.
Suggested Books	Textbooks: 1. T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, ***Introduction to Algorithms***, (3rd Edition), Prentice Hall, 2009. ISBN: 978-81-203-4007-7 Reference Books: 2. D. E. Knuth, ***The Art of Computer Programming: Fundamental Algorithms***, Vol. 1 (3rd Edition, 1997) and Vol 3, (2nd Edition, 1998), Addison-Wesley Professional. ISBN: 978-0137935109 3. M.T. Goodrich, R. Tamassia, and D. Mount, ***Data Structures and Algorithms in C++***, 2nd Edition, Wiley. ISBN: 978-0-470-38327-8

Course code	**MA 254/CS 254**
Title of the Course	**Design and Analysis of Algorithms Laboratory**
Course Category	Department Core
Credit Structure	L - T - P - Credits: 0-0-3-1.5
Name of the Concerned Discipline	Mathematics/Computer Science and Engineering
Pre-requisite, if any	Knowledge of Data Structures and Algorithms
Objective of the Course	This is an introductory course in the field of computer algorithms.
Course Outcomes	At the end of the course, students will know the basics of ∉ algorithm analysis and design ∉ different problem classes.
Course Syllabus	● Runtime analysis of different sorting algorithms and linked lists in best-case, worst-case, and average-case. ● Implementation and analysis of algorithms based upon the following design techniques: ○ Divide and Conquer Strategy (Closest Pair of Points, Integer Multiplication, Matrix Multiplication, Fast Fourier Transform etc.). ○ Greedy Strategy (Interval Partitioning, Dijkstra's Algorithm, Minimum Spanning Tree etc.). ● Dynamic Programming Strategy (Weighted Interval Scheduling, Sequence Alignment, Bellman-Ford Algorithm etc.).
Suggested Books	Textbooks: 1. T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, ***Introduction to Algorithms*** (Eastern Economy Edition), 3rd Edition, PHI Learning Pvt. Ltd. (Originally MIT Press), 2010. ISBN: 978-8120340077 Reference books: 2. J. Kleinberg and E. Tardos, ***Algorithm Design***, 2nd Edition, Pearson Education, 2022. ISBN: 978-0132131087

Course Code	**MA 301**
Title of the Course	**Matrix Computations**
Course Category	Department Core
Credit Structure	L-T- P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of calculus and linear algebra
Objective of the Course	This course is aimed at understanding the theoretical and computational aspects of important algorithms and techniques of scientific computing.
Course Outcomes	• To solve application problems involving matrix computation algorithms and understanding the relationships between the computational effort and the accuracy of these algorithms. • Knowledge of effect of errors in computations.
Course Syllabus	• Review of basic linear algebra, minimal polynomials, Cayley-Hamilton Theorem, triangulation, diagonalization, Invariant subspace, Rational canonical form, Jordan canonical form. • Linear least-squares problems: Rotation and reflections, QR factorization, Gram-Schmidt orthogonalization, SVD and Moore-Penrose pseudoinverse, low-rank approximation by SVD, solution of least-squares problems by normal equation, QR method. Eigenvalue problems: Eigenvalues and eigenvectors, Schur theorem, Inner product space, spectral theorems for Hermitian and normal matrices, power and inverse power methods, QR algorithm for eigenvalue problems. Iterative methods for linear systems: SOR, and CG methods.

Suggested Books	Text Books: 1. D. S. Watkins, ***Fundamentals of Matrix Computations***, Wiley, 2010, ISBN: 9780470528334. 2. G. Strang, ***Linear Algebra and Its Applications***, Academic Press, 2006, ISBN: 978-8131501726. 3. C. T. Kelley, ***Iterative Methods for Linear and Nonlinear Equations***, SIAM, 1995, ISBN: 9780898713527. Reference Books: 4. G. H. Golub, C. F. Van Loan, ***Matrix Computations***, The Johns Hopkins University Press, 2013, ISBN: 9781421407944. 5. L. N. Trefethen, D. Bau, ***Numerical Linear Algebra***, SIAM, 1997, ISBN: 9780898713619. 6. J. W. Demmel, ***Applied Numerical Linear Algebra***, SIAM, 1997, ISBN: 9780898713893.

Course Code	**MA 302**
Title of the Course	**Statistical Inference**
Course Category	Department Core
Credit Structure	L-T- P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Probability and Statistics
Objective of the Course	This course aims to describe the methods of estimation and testing of hypotheses. The course will help to apply statistical methodologies in data science and other fields of study.
Course Outcomes	After completion of this course, students will be able to: ● understand estimation theory and testing of statistical hypothesis, ● apply these techniques in real life problems.
Course Syllabus	• Review of random variables and associated probability distributions, sampling distributions, order statistics, distribution of order statistics. • **Principles of Data Reduction:** Sufficient statistics, minimal sufficiency, Fisher's factorization theorem, ancillary statistics, completeness. • **Point and Interval Estimation:** Concept of estimation, unbiased estimation, uniformly minimum variance unbiased estimator, Rao-Blackwell and Lehmann-Scheffe theorems and their applications, Cramer-Rao inequality, method of moments, method of maximum likelihood estimation, confidence intervals for mean, difference of means, and proportions, Bayesian estimation. • **Testing of Hypothesis:** Elements of testing of hypothesis, the most powerful test, uniformly most powerful test, tests for one sample and two sample problems for normal populations, tests for proportions.
Suggested Books	Text Books: 1. G. Casella and R. L. Berger, ***Statistical Inference***, Cengage Learning, Delhi. (Duxbury Advanced Series), 2002, ISBN: 9788131503942. 2. V. K. Rohatgi and A. K. Md. E. Saleh, ***An Introduction to***

	Probability and Statistics, Wiley, India, 2001, ISBN: 9788126519262. Reference Books: 3. J. A. Rice, ***Mathematical Statistics and Data Analysis***, Duxbury Press, USA, 2006, ISBN: 0534399428. 4. R. V. Hogg, J. McKean, and A. T. Craig, ***Introduction to Mathematical Statistics***, Pearson Education, USA, 2019, ISBN: 9789332519114. 5. B. L. S. Prakasa Rao, ***A First Course in Probability and Statistics***, World Scientific Publishing Co Pt. Ltd, 2010, ISBN: 9788175967311.

Course Code	**MA 303/ CS 303**
Title of the Course	**Operating Systems**
Course Category	Department Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics / Computer Science and Engineering
Pre-requisite, if any	NIL
Objective of the Course	This course will introduce the basic components of operating systems and functionalities.
Course Outcomes	Understanding basic functionalities of operating system for efficient performance of the processes
Course Syllabus	• **Introduction:** Overview of important features of computer architectures for OS operation; Service and system performance • **Multiprogramming:** Concurrency and parallelism; Processes and threads; Process synchronization; Process deadlocks • **Memory management:** Paging; Segmentation; Virtual memory • **File systems**: File operations. File protection • **Case Studies:** Case studies of contemporary operating systems
Suggested Books	Text books: 1. A. Silberschatz, P.B. Galvin, and G. Gagne, ***Operating System Principles***, 7^{th} edition, John Wiley, 2005, ISBN: 9788126509621. Reference books: 2. A. Silberschatz, P.B. Galvin, and G. Gagne, ***Operating System Concepts***, 9^{th} edition, Wiley, 2018, ISBN: 9781118063330. 3. W. Stallings, ***Operating Systems: Internals and Design Principles***, 5^{th} edition, Pearson Education, 2005, ISBN: 9780134670959.

Course Code	**MA 304/ CS 304N**
Title of the Course	**Computational Intelligence**
Course Category	Department Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics / Computer Science and Engineering
Pre-requisite, if any	Computer Programming, Data structure, and Design and Analysis of Algorithm
Objective of the Course	Basics of machine learning techniques
Course Outcomes	Understanding of machine learning techniques and implementation
Course Syllabus	● **Introduction:** Overview, Basics of Problem solving as an Artificial Intelligence problem, Computational Intelligence, Applications. Intelligent Search techniques, Knowledge representation, ● **Methodologies:** Computational intelligence methodologies; Learning, adaptation: Artificial neural networks: feed-forward, recurrent and multi-layer architectures; Supervised and unsupervised learning; Characteristics: adaptability, fault tolerance, generalization; limitations of neuro-computing. ● **Different learning algorithms:** Perceptron, Back propagation, Hopefield, Kohenen networks. Uncertainty treatment: Fuzzy sets - Basic Definition; Fuzzy-set- theoretic Operations – Member Function Formulation and Parameterization – Fuzzy Rules and Fuzzy Reasoning, Fuzzy If-Then Rules Hybrid computational learning : Fuzzy Neural Networks and Evolutionary Algorithms ● **Detailed Discussion from Example Domains:** Industry, Language, Medicine, Verification, Vision, Knowledge Based Systems etc.
Suggested Books	Textbooks: 1. S. Russell and P. Norvig, ***Artificial Intelligence: A Modern Approach***, Pearson, 2010. ISBN: 978-0136042594 2. E. Rich and K. Knight, ***Artificial Intelligence***, McGraw Hill Education, 2017. ISBN: 978-0070087705 Reference books: 3. J.S.R.J ang, C.T. Sun and E. Mizutani, ***Neuro-Fuzzy and Soft Computing***, Prentice Hall of India and Pearson Education, 2004. ISBN: 978-9332549883 4. D.E. Goldberg, ***Genetic Algorithms: Search, Optimization***

	and Machine Learning, Addison Wesley, 1989. ISBN: 9781584883883 5. S. Rajasekaran and G.A.V. Pai, ***Neural Networks, Fuzzy Logic and Genetic Algorithms***, Prentice Hall, 2003. ISBN: 9788120321861 6. R. Eberhart, P. Simpson and R. Dobbins, ***Computational Intelligence - PC Tools***, AP Professional, 1996. ISBN: 978-0122286308

Course Code	**MA 305**
Title of the Course	**Data Science**
Course Category	Department Core
Credit Structure	L-T- P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Prerequisite, if any	Basics of linear algebra, probability and statistics
Objective of the Course	This is a foundation course on data science for UG students.
Course Outcomes	The students will understand the fundamental concepts of data science, supervised/unsupervised learning and their applications to industrial problems.
Course Syllabus	• Concept of data science, data editing, missing data and logical operators, data management with repeats, sorting, ordering, and lists, statistical functions for handling data through graphics, programming and illustration with examples. • Overview of concepts: Bias/variance, overfitting and train/test splits of data, confusion matrix, accuracy metrics, receiver operator characteristics (ROC) curve, unbalanced datasets, types of machine learning-supervised (regression and classification), unsupervised (clustering), classification and regression algorithms - K-Nearest neighbors, support vector machines (SVM) for classification and regression problems, kernel based SVM and their generalization ability. • Principal component analysis in high dimension - rank and covariance estimation, graph, networks and clustering, k-means and spectral clustering, introduction to diffusion maps of point clouds and relationship to spectral clustering, semi-supervised learning - introduction. • Data science applications such as weather forecasting, stock market prediction, credit card fraud detection, object recognition, real time sentiment analysis, disease diagnosis, etc.
Suggested Books	Text Books: 1. A. Blum, J. Hopcroft, and R. Kannan, ***Foundations of Data Science***, Cambridge University Press, 2020, ISBN:

	9781108485067. 2. J. A. Rice, ***Mathematical Statistics and Data Analysis***, Cengage, Boston, 2013, ISBN: 9788131519547. Reference Books: 3. S. Marsland, ***Machine Learning-An Algorithmic Perspective***, CRC Press, Taylor & Francis, Boca Raton, 2015, ISBN: 9781138583405. 4. M. P. Deisenroth, A. A. Faisal, and C. S. Ong, ***Mathematics for Machine Learning***, Cambridge University Press, 2020, ISBN: 9781108455145. 5. T. T. Soong, ***Fundamentals of Probability and Statistics for Engineers***, John Wiley & Sons, 2004, ISBN: 0470868147. 6. P. Teetor, ***R Cookbook,*** O'Reilly Media, Inc., 2011, ISBN: 9780596809157.

Course Code	**MA 306**
Title of the Course	**Monte-Carlo Simulation**
Course Category	Department Core
Credit Structure	L-T- P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of calculus, probability and statistics
Objective of the Course	This course supply all the basic tools and theory for understanding the Monte-Carlo simulation and demonstrate its applications in mathematics and finance.
Course Outcomes	• The student will learn how to generate random numbers and its usage in Monte-Carlo simulation. • The students will be able to evaluate integrals, finding roots, maximum-likelihood estimation using Monte-Carlo simulation.
Course Content	• Uniform random number generation, apparent randomness of pseudo-random number generators, generating random numbers from nonuniform continuous distributions, generating random numbers from discrete distributions. • Random samples associated with Markov chains, variance reduction for one-dimensional Monte-Carlo integration, errors in numerical integration. • Theory of low-discrepancy sequences, finding a root, maximization of functions, maximum-likelihood estimation, estimating derivatives, the score function estimator.

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Suggested Books	Text Books: 1. G. S. Fishman, ***Monte Carlo Concepts, Algorithms, and Applications***, Springer, 1996, ISBN: 9780387945279. 2. I. T. Dimov, ***Monte Carlo Methods for Applied Scientists***, World Scientific, 2008, ISBN: 9789812779892. Reference Books: 3. C. Robert, G. Casella, ***Monte Carlo Statistical Methods,*** Springer, 2013, ISBN: 9781475730715. 4. W. Wang, ***Monte Carlo Simulation with Applications to Finance***, Chapman and Hall/CRC, 2019, ISBN: 9780367381356. 5. D. L. McLeish, ***Monte Carlo Simulation and Finance***, Wiley, 2005, ISBN: 9780471677789.

Course code	**MA 307 / CS 307**
Title of the Course	**Optimization Algorithms and Techniques**
Course Category	Department Core
Credit Structure	L-T-P-Credits 2–1–0-3
Name of the Concerned Discipline	Mathematics/Computer Science & Engineering
Pre-requisite, if any	Knowledge of Data Structures and Algorithms
Objective of the Course	This is an introductory course in the field of mathematical optimization.
Course Outcomes	At the end of the course, students will know ● The Basics of Optimization, ● Unconstrained and Constrained Optimization, and ● Linear and Quadratic Programming.
Course Syllabus	● **Introduction to Optimization and Math Foundation:** Type of Problems, Examples, Formulations, Applications, Notations, and Convexity. ● **Unconstrained Optimization**: Necessary and Sufficient conditions for a Minima; Linear Search and Trust Region Methods; Multi-dimensional Minimization - Steepest descent, Newton, Gauss Newton, Quasi Newton; One-Dimensional minimization - Dichotomous, Quadratic & Cubic Interpolation. ● **Constrained Optimization:** Conversion to Unconstrained, Lagrange Multipliers, Necessary and Sufficient Conditions for Minima (KKT), and Duality. ● **Linear Programming**: Necessary and Sufficient Conditions for a Minima for a Linear Program, Derivation and Implementation of Simplex, Starting Simplex, and Interior-Point Methods.
Suggested Books	Textbooks: 1. J. Nocedal and S. J. Wright, ***Numerical Optimization***, 1st Edition, Springer, 2006. ISBN: 781493937110 Reference books: 2. A. Antoniou and W.-S.g Lu, ***Practical Optimization: Algorithms and Engineering Applications***, 2nd Edition, Springer, 2021. ISBN: 9781071608432

Course Code	**MA 308**
Title of the Course	**Techniques in Parallel Computing**
Course Category	Department Core
Credit Structure	L-T- P-Credits 1-0-2-2
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of linear algebra
Objective of the Course	To demonstrate the parallel computing techniques to solve mathematical problems.
Course Outcomes	Understanding major benefits and limitations of parallel computing.
Course Content	• Concept of parallelism, scope of parallel computing, sources of overhead in parallel programs. • Performance metrics for parallel systems, scalability of parallel systems, asymptotic analysis of parallel programs, matrix-vector multiplication, matrix-matrix multiplication. • Solving a system of linear equations, sequential search algorithms, search overhead factor, parallel depth-first search, parallel best-first search.
Suggested Books	Text Books: 1. A. Grama, A. Gupta, G. Karypis, and V. Kumar, ***Introduction to Parallel Computing***, Addison Wesley, 2003, ISBN: 0201648652. 2. M. J. Quinn, ***Parallel Computing: Theory and Practice***, Tata McGraw Hill, 2002, ISBN: 9780070512948. Reference Books: 3. W. P. Petersen, and P. Arbenz, ***Introduction to Parallel Computing***, Oxford Texts in Applied and Engineering Mathematics, 2004, ISBN: 019 8515766. 4. P. S. Pacheco, ***An Introduction to Parallel Programming***, Morgan Kaufmann, 2011, ISBN: 9780123742605. 5. D. B. Kirk and W. W. Hwu, ***Programming Massively Parallel Processors: A Hands-on Approach***, Morgan Kaufmann, 2016, ISBN: 9780128119860.

Course Code	**MA 309**
Title of the Course	**Numerical Methods for Partial Differential Equations**
Course Category	Department Elective
Credit Structure	L-T- P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of differential equations
Objective of the Course	The course will introduce some numerical techniques for solving partial differential equations that are used for modelling many practical problems and the theories behind them.
Course Outcomes	Students will be able to choose suitable methods to solve different types of differential equations numerically.
Course Syllabus	• Finite difference method: Explicit and implicit schemes; consistency, stability and convergence, maximum principle, Lax's equivalence theorem; FTCS, ADI methods, Lax-Wendroff method, upwind scheme, CFL conditions. • Finite element method: Variational methods, method of weighted residuals, finite element analysis of one- and two-dimensional problems. • Finite volume schemes, conservation properties, multigrid methods and boundary integral methods. • Recent progresses on numerical PDEs arising in the applicable field will be discussed and demonstrated through computations.
Suggested Books	Text Books: 1. P. Knabner, L. Angermann, ***Numerical Methods for Elliptic and Parabolic Partial Differential Equations***, Springer, 2003, ISBN: 038795449X. 2. G. D. Smith, ***Numerical Solutions of Partial Differential Equations***, Calrendorn Press, 1985, ISBN: 9780198596509. Reference Books: 3. G. F. Pinder, ***Numerical Methods for Solving Partial Differential Equations: A Comprehensive Introduction for Scientists and Engineers***, 2018, John Wiley and Sons, Inc, ISBN: 9781119316114. 4. M. S. Gockenbach, ***Partial Differential Equations Analytical and Numerical Methods***, SIAM, 2002, ISBN: 0898715180. 5. M. M. Hafez, J. J. Chattot, ***Innovative Methods for Numerical***

	Solutions of Partial Differential Equations, World Scientific, 2002, ISBN: 9810248105. 6. R. J. LeVeque, ***Finite Volume Methods for Hyperbolic Problems***, Cambridge University Press, 2002, ISBN: 9780521009249.

Course Code	**MA 310**
Title of the Course	**Algorithmic Techniques and Applications of Data Science**
Course Category	Department Elective
Credit Structure	L-T-P–Credits 2-1-0-3
Name of the Concerned Department	Mathematics / Computer Science and Engineering
Pre-requisite, if any	Linear Algebra, Probability and Statistics, Discrete Mathematics
Objective of the Course	This course will provide fundamentals of algorithmic techniques of data science and presents different applications wherein such techniques are applied.
Course Outcomes	The students will learn the fundamental principles of data science and the mathematical foundations related to high dimensional space, SVD, random walks, etc.
Course Syllabus	• **High Dimensional Space**: Law of large numbers, geometry of high himensions, properties of unit ball, generating points, uniformly at random from a ball, Gaussians in high dimension, random projection and Johnson-Lindenstrauss lemma. • **Singular Value Decomposition (SVD)**: SVD applications to discrete optimization problems. • **Random Walks and Markov Chain**: Stationary distribution, Markov Chain Monte Carlo, Metropolis Hasting algorithm, areas and volumes, convergence of random walks on undirected graphs, random walks in Euclidean space. • **Foundations of Machine Learning**: Perceptron algorithm, kernel functions, generalizing new data, overfitting and uniform convergence, online learning, strong and weak learning, stochastic gradient descent. • **Algorithms for Massive Data Problems**: Streaming, sketching, sampling. • **Advanced Topics in Data Science**: Clustering techniques, linear

	methods for regression and classification, basis expansion and regularization, kernel smoothing methods, model assessment and selection, model inference and averaging, additive models, logistic regression, trees and related methods, boosting and additive trees, decision trees, random forests, neural networks, recurrent neural networks (RNNs).
Suggested Books	Text Books: 1. T. Hastie, R. Tibshirani and J. Friedman, ***Elements of Statistical Learning***, Springer, 2013, ISBN: 9781489905185. 2. A. Blum, J. Hopcroft and R. Kannan**, *Foundations of Data Science*,** Cambridge University Press, 2020, ISBN: 9781108485067. Reference Books: 3. C. C. Aggarwal and C. K. Reddy, ***Data Clustering, Algorithms and Applications.***, Chapman and Hall, CRC Press, 2013, ISBN: 9781466558229. 4. M. J. Kearns and U. Vazirani, ***An Introduction to Computational Learning Theory***, The MIT Press, 1994, ISBN: 9780262111935.

Course Code	**MA 311/ CS 323**
Title of the Course	**Statistical Distribution Theory**
Course Category	Department Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Probability and Statistics
Objective of the Course	This course deals with multivariate distributions and their applications. The concept of copula function will be introduced for measuring the dependence between multivariate random variables.
Course Outcomes	● understanding the multivariate probability distributions. ● apply statistical techniques involving two or more dependent variables using copula functions.
Course Syllabus	● Review of standard univariate distributions, distribution of function of random variable, Jacobians of transformation technique, random sample generation from univariate distributions. ● Bivariate distributions, conditional distributions, conditional expectation and variance, independence of random variables, covariance, Pearson and Spearman correlations, distributions of functions of random variables, including sums, means, products and ratios, convolution technique. ● Bivariate and multivariate normal distributions and their properties, bivariate exponential distribution and their properties, copula function and their applications, and construction of bivariate distributions using copula functions.
Suggested Books	Text Books: 1. V. K. Rohatgi and A. K. Md. E. Saleh, ***An Introduction to Probability and Statistics***, Wiley, 2001, ISBN: 9788126519262. 2. G. Casella and R. L. Berger, ***Statistical Inference***, Cengage Learning, (Duxbury Advanced Series), 2002, ISBN: 9788131503942. Reference Books: 3. J. A. Rice, ***Mathematical Statistics and Data Analysis***. Duxbury Press, 2006, ISBN: 0534399428. 4. R. V. Hogg, J. McKean, and A. T. Craig, ***Introduction to***

	Mathematical Statistics, Pearson Education, 2019, ISBN: 9789332519114. 5. R. B. Nelsen, ***An Introduction to Copulas***, Springer, 2006, ISBN: 9780387286594.

Course Code	**MA 312**
Title of the Course	**Analytical methods in Partial Differential Equations**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Multivariate Calculus and Measure Theory.
Scope of the course (Objectives)	This course will introduce first-order partial differential equations and functional analytic toolboxes for PDEs.
Course Outcomes	Students will learn functional analytic techniques to construct solutions of PDE models arising in Physics and Engineering. They will be introduced with the concept weak solutions whose existence can be proved even when the unknowns involved are not sufficiently regular to infer a classical interpretation of the PDE.
Course Content	● Mathematical models leading to partial differential equations. ● First order partial differential equations and their classification. Introduction to the method of characteristics (a geometric approach), non-characteristic boundary data and the existence of local unique solution, formation of singularity, fully nonlinear equations: Lagrange and Charpit methods. ● Sobolev spaces and variational formulation of elliptic boundary value problems: definition and elementary properties, extension operators, Sobolev inequalities, variational formulation of some boundary value problems, regularity of weak solutions. ● Conservation laws: Shocks, entropy condition, Lax-Oleinik formula, Weak solutions, uniqueness, Riemann's problem, Long time behavior.

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Suggested B	**Text Books:** 1. H. Brezis, **Functional Analysis, Sobolev Spaces and Partial Differential Equations,** 1st ed., Springer New York, NY, 2011. ISBN:978-0-387-70913-0 2. L.C. Evans, **Partial Differential Equations,** 2nd ed., American Mathematical Society, 2010. ISBN:0821849743 **Reference Books:** 3. Y. Pinchover, J. Rubinstein, **An Introduction to Partial Differential Equations,** Cambridge University Press, 2005. ISBN: 978-0521613231. 4. R. Mcowen, **Partial Differential Equations: Methods and Applications**, 2nd ed., Pearson, 2002. ISBN: 0130093351.

Course code	**MA 313 / CS 313**
Title of the course	**Computer Networks**
Course Category	Department Core
Credit Structure	L - T - P - Credits 2-0-2-3
Name of the Concerned Department	Mathematics / Computer Science and Engineering
Pre-requisite if any	Knowledge of data structures and algorithms, programming skills in C/C++/python
Objective of the Course	This course will introduce computer networking protocols and performance analysis of networks.
Course outcome	Understanding the basic functionalities of computer networks
Course Syllabus	● Network Architecture and protocols. History of networking–Circuit switching and packet switching. Network performance metrics–Throughput and delay ● Application layer–HTTP, DNS, CDN, SMTP, P2P etc., ● Transport layer–UDP and TCP, Reliability and congestion control in TCP. ● Socket programming, Introduction to Network Layer. Routing protocols. Interdomain routing–BGP ● Link layer and physical layer, Performance analysis of networks. Router Architecture, Resource allocation, and QoS, Network simulation version 3 (NS3). ● Introduction to next-generation networks. ● Practical components: ○ Experimental study of application protocols such as HTTP, FTP, SMTP, using network packet sniffers and analyzers ○ Socket programming - Small exercises in socket programming in C/C++/Java. ○ Experiments with packet sniffers to study the TCP protocol. ○ Introduction to ns3 (network simulator) and small simulation exercises to study TCP behavior under different scenarios. ○ Setting up a small IP network in ns3 ○ Experiments with ns3 to study Ethernet and 802.11 wireless LAN. ○ Programming with pcap

Suggested Books	Textbooks: 1. J. Kurose and K. Ross, ***Computer Networking, A Top-Down Approach***, Pearson Education, 8th Ed. 2022. ISBN: 978-9356061316 Reference books: 2. L. Peterson and B. Davie, ***Computer Networks, A Systems Approach***, Morgan Kaufmann Publishers Inc, 6th ed. 2021, ISBN: 978-0128182000 3. W. R. Stevens, ***Unix Network Programming: The Sockets Networking API***, Pearson Education, 3rd ed. 2017, ISBN: 978-9332549746 4. Bertsekas and Gallager, ***Data Networks***, Pearson Education 2nd ed., 2015. ISBN:978-9332550476

Course Code	**MA 314**
Title of the Course	**Random Matrices**
Course Category	Department Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre-requisite, if any	Basic knowledge of calculus and linear algebra
Objective of the Course	This course introduces random matrices and their applications.
Course Outcomes	Students will learn how the different ensembles of random matrices are defined and their applications in various fields including data science, mathematical Finance, etc.
Course Syllabus	• **Random matrices in science and applications**: Random matrices in statistics, physics, telecommunications, numerical analysis, community detection in networks • **Norms of random matrices:** Norm of a random symmetric matrix, norms of rectangular matrices, the moment method, Gaussian processes, Sudakov-Fernique inequality • **Sample covariance matrices:** Concentration inequalities and moment inequalities for the sample covariance matrices, spectral projectors, principal component analysis • **Gaussian ensembles of random matrices:** Gaussian Unitary Ensemble (GUE), Gaussian Orthogonal ensemble (GOE), Wishart ensemble, eigenvalues density, eigenvectors, determinantal structure, spectral statistics, Wigner-Dyson-Gaudin-Mehta conjecture • **Random vectors in high dimension:** Multivariate Gaussian distribution, distribution of norm of random vector, dimensionality reduction, Johnson- Lindenstrauss lemma
Suggested Books	Text Books: 1. G. Anderson, A. Guionnet and O. Zeitouni, ***An Introduction to Random Matrices***, Cambridge University Press, 2010, ISBN: 9780521194525. 2. M. L. Mehta, ***Random Matrices***, Academic Press, 2004, ISBN: 9780120884094. Reference Books: 3. T. Tao, ***Topics in Random Matrix Theory***, AMS, 2023, ISBN:

	9781470474591. 4. Z. Bai and J. W. Silverstein, ***Spectral Analysis of Large Dimensional Random Matrices***, Springer, 2010, ISBN: 9781441906601.

Course Code	**MA 315/ CS 325**
Title of the Course	**Mathematical Foundations for Cryptography**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Prerequisite, if any	Elementary Number Theory and Algebra
Scope of the course (Objectives)	The main goal of this course is to introduce important concepts in number theory and give an overview of the applications of number theory to cryptography.
Course Outcomes	● Students will learn basic number theory concepts that are applicable in cryptography. ● Students will learn the theory of elliptic curves and its application to cryptography.
Course Content	● Number System, Prime Numbers, Fundamental Theorem of Arithmetic, Division Algorithm, Congruences, Finite Fields, Fermat's little theorem, Quadratic Residues, Quadratic Reciprocity, Fermat numbers, Mersenne numbers, Primality Testing, Big O notation, examples. ● Some simple cryptosystems, RSA algorithm, Discrete Logarithm Problem, Diffie-Hellman key exchange protocol, AKS algorithm ● Elliptic curves, Mordell-Weil group, Elliptic curves mod n, Torsion points, Weil pairing, Elliptic Curve Cryptography, A Cryptosystem based on Weil pairing.

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Suggested Books	**Text Books:** 1. N. Koblitz, **A course in Number Theory and Cryptography,** Springer, 1994. ISBN: 978-0387942933 2. J. Hoffstein, J. Pipher, J. H. Silverman, **An Introduction to Mathematical Cryptography**, Springer, 2008. ISBN: 978-0387779935 **Reference Books** 3. L. C. Washington, **Elliptic Curves: Number theory and Cryptography**, Chapman, and Hall/CRC, 2008. ISBN: 978-1420071467 4. S. William, **Cryptography and Network Security Principles and Practice**, 6 th Edition, PHI 2014. ISBN: 978-9332585225

Course Code	**MA 316/ CS 316**
Title of the Course	**Spectral Graph Theory**
Course Category	Department Elective
Credit Structure	L-T-P Credits2- 1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of linear algebra
Scope of the course (Objectives)	This introductory course explores the combinatorial properties of graphs through examination of some matrices associated with graphs
Course Outcomes	• Analyse the relationship between graph parameters and the eigenvalues and eigenvectors of associated matrices using matrixtheory.
Course Syllabus	• Basic concepts of Graph Theory, Adjacency matrix and Laplacian matrix of a graph, Laplacian matrix of a weighted graph • Spectra of some special graphs, Spectral Theorem, Rayleigh quotient,Bound on Isoperimetric number of a graph. • Bounds of largest eigenvalue, Perron Frobenius Theorem • Adjacency matrix and Graph Coloring, Wilf's Theorem, Hoffman's bound • Bounding the second smallest Laplacian eigenvalue, path graphs andcomplete binary tree • Normalised Laplacian, Cheeger's inequality
Suggested Books	Text Books: 1. Fan Chung. ***Spectral Graph Theory,*** American Mathematical Society, 1994, ISBN: 1933723130 2. Chris Godsil, Gordon F. Royle. ***Algebraic Graph Theory***, Springer, 2013, ISBN: 1461301637. Reference Books: 3. D. B. West, ***Introduction to graph theory,*** 2nd Edition, PearsonEducation, 2015, ISBN: 0130144002. 4. R. Diestel, ***Graph Theory***, 3rd edition, Springer, 2006, ISBN: 3540261834.

Course Code	**MA 353/ CS 353N**
Title of the Course	**Operating Systems Lab**
Course Category	Department Core
Credit Structure	L-T- P-Credits 0-0-2-1
Name of the Concerned Department	Mathematics / Computer Science and Engineering
Pre-requisite, if any	NIL
Objective of the Course	This course will introduce the basic components of operating systems and functionalities.
Course Outcomes	Understanding basic functionalities of operating system for efficient performance of the processes
Course Syllabus	● **OS Programming prerequisites:** Familiarities with IPC facilities, IPC identifiers, IPC keys, Message queues and their internal and user data structures, System calls related to IPC, Semaphore and Shared memory. ● **CPU scheduling:** Simulation programs for long-term, short-term and medium term schedulers, Simulation for the maintenance of various scheduling queues such as ready, I/O, blocked etc., Implementations of different scheduling algorithms such as FCFS, SJF, Priority scheduling (preemptive and non-preemptive), Round robin, multilevel feedback queue scheduling and their performance evaluations. ● **Concurrent Processing and Concurrency Control:** Simulation of updating processe PCBs with shared memory, Implementation of interprocess communication using simulated semaphore through (i) shared memory, (ii) synchronized producer-consumer problem, (ii) Pipes and message passing (asynchronous and synchronous). Concurrence control with pipes socket for iterative and concurrent servers ● **File Systems Implementation:** creating, removing, accessing, protecting and error handling of EXT2 FS, Registering the virtual file system in Kernel, accessing superblock information.
Suggested Books	Textbooks: 1. A. Silberschatz, P.B. Galvin, and G. Gagne, ***Operating System Principles***, 7th edition, John Wiley, 2005. ISBN: 9788126509621 Reference books: 2. A. Silberschatz, P.B. Galvin, and G. Gagne, ***Operating System Concepts***, 9th edition, Wiley, 2018. ISBN: 978-1-118-06333-0

	3. W. Stallings, ***Operating Systems: Internals and Design Principles***, 5th edition, Pearson Education, 2005. ISBN: 978-0-13-467095-9

Course code	**CS 319/ MA 319**
Title of the course	**Foundations of Cryptography**
Course Category	Department Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Computer Science and Engineering
Pre-requisite, if any	Discrete Mathematical Structures, Design and Analysis of Algorithms, Computer Networks
Objective(s)	● To understand the basic foundations of cryptography, understand the encryption and authentication protocols with security proofs. ● The students will study block ciphers, stream ciphers, hash functions and public key cryptography.
Outcome of the course	• The students will learn about different proving models, indistinguishability tests about security of encryption algorithms, authentication algorithms, and hashing algorithms. • Along with gaining knowledge about security bounds, the students will learn some number theory and algebra, wherever required.
Course Syllabus	● **Introduction:** Classical ciphers, Cryptanalysis techniques: linear and differential cryptanalysis. ● **Number Theory:** Euclidean Algorithm, Chinese Remainder Theorem, Primality Testing algorithms, Factoring algorithms, Algebraic Structures: Groups, Rings and Fields. ● **Shannon's theory:** Concept of perfect secrecy, Entropy, Key equivocation, Unicity Distance, Perfect cipher, Ideal Cipher. ● **Symmetric-key Cryptography:** Pseudorandomness, Stream ciphers, Block ciphers, Data Encryption Standards, Advanced Encryption Standards, Modes of operation ● **Hash-functions:** Data Integrity, Merkle-Damgard construction, Message Authentication Codes. ● **Public-key Cryptography:** RSA, Discrete log problem, DiffieHellman key exchange protocol, Signatures schemes, Public key Infrastructure, Digital certificates.
Suggested Books	Textbooks: 1. D. R. Stinson, ***Cryptography: Theory and practices***, 3rd Edition, CRC Press, 2006. ISBN: 978-1584885085 2. J. Katz and Y. Lindell, ***Introduction to Modern Cryptography***, Chapman and Hall/CRC, 2020. ISBN: 978-0815354369 Reference books: 3. A. J. Menezes, P. Oorschot, and S. Vanstone, ***Handbook of Applied Cryptography***, CRC Press, 1997. ISBN:

	9781138385979 4. W. Stalling, ***Cryptography and Network security Principles and Practices***, 5th Edition Pearson Education, 2017. ISBN: 978-9332585225

Course code	MA 321/ CS 315
Title of the course	Introduction to Complexity Theory
Course Category	Department Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Computer Science and Engineering
Pre-requisite, if any	Algorithms, Formal Languages and Automata Theory, Discrete Mathematics
Objective(s)	This Course is designed to provide an overview of Turing machine, the details of the complexity classes and their relationships.
Course Outcomes	Students will be able to understand computational complexity and their significance.
Course Syllabus	● **Introduction to the Turing Machine:** Definition of Turing Machines, Examples, Deterministic and non-deterministic Turing machines, Other variants of Turing machine, The Definition of Algorithm ● **Decidability and undecidability:** Reducibility, Undecidable Problems from Language Theory, Mapping Reducibility ● **P, NP and NP-completeness:** The Class P, Class NP, NP-hard, NP-completeness, Reducibility between problems, Discussions on different NP-complete problems such as satisfiability, clique, vertex cover, independent set, set cover, TSP, etc. ● **Space complexity:** Savitch's Theorem, The Class PSPACE, PSPACE-completeness, Class L and NL, NL-completeness, NL equals coNL
Suggested Books	Textbooks: 1. S. Arora and B. Barak, ***Computational Complexity: A Modern Approach***, Cambridge University Press, 2009. ISBN: 978-0521424264 2. M. Sipser, ***Introduction to the Theory of Computation***, 3rd eds., Cengage Learning, 2012. ISBN: 978-8131525296 Reference Books: 3. S. Rudich and A. Wigderson, ***Computational Complexity Theory***, 1st eds., American Mathematical Society, 2004. ISBN: 978-0821828724

Course Code	**MA 327/ CS 327**
Course Name	**Mathematical Methods in Risk Theory**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of Probability and Statistics
Scope of the course (Objectives)	This course will address fundamental risk models and measurement, and explain risk and security issues from diverse areas such as finance and insurance.
Course Outcomes	● Learn core mathematical principles of risk theory, ● Compute key risk measures such as Value-at-Risk (VaR), Expected Shortfall (ES) ● Assess stop-loss premiums using mathematical and statistical techniques.
Course Content	● **Mathematical modeling of risks**: Review of probability theory. Distribution models for individual damage, Modeling the damage figure, Modeling the number of damages through a number of damages process, The total damage figure, Risk processes or total loss calculation processes; Copulas, Sklar's Theorem, and Distributional Transform; Frechet Classes, Risk Bounds, and Duality Theory ● **Risk indicators and Expected Shortfall**: General risk concept, Stochastic risk indicators, Moment-based Measures, Valued at Risk(VaR); Spectral dimensions, Requirements for a risk measure, Estimating risk measures; Optimal Risk Allocation; Optimal Portfolio Diversification w.r.t. Extreme Risks; examples with

	simulations; ● **Statistical methods for estimating extreme cases:** An approach to extremes via Point processes; Exploratory Data Analysis for Extremes; Parameter Estimation for the Generalised Extreme
Suggested Books (Text Books, Reference Books)	Text Books**:** ● Ludger Rüschendorf **, Mathematical Risk Analysis: Dependence, Risk Bounds, Optimal Allocations and Portfolios,** Springer, 2013. ISBN:978-3-642-33589-1. ● Paul Embrechts, Alexander J. McNeil, R¨udiger Frey, **Quantitative Risk Management: Concepts, Techniques and Tools,** Springer, 2015. ISBN 0-691-12255-5. Reference Books: ● Hanspeter Schmidli, **Risk Theory,** Springer, 2017. ISBN: 978-3-319-72005-0. ● Paul Embrechts, Claudia Klüppelberg, Thomas Mikosch, **Modelling Extremal Events (for Insurance and Finance)**, Springer, 1997. ISBN: 978-3-540-60931-5.

Course code	MA 329/CS 329
Title of the Course	**Algebraic Coding Theory**
Course Category	Elective
Credit Structure	L - T - P – Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Linear Algebra
Objectives of the Course	● To introduce the mathematical foundations and motivations behind error detection and correction in communication systems. ● To develop an understanding of algebraic tools such as finite fields, vector spaces, and polynomials used in the design of efficient codes.
Course Outcome	● Students will understand the fundamental concepts of error detection and correction in communication systems using algebraic methods. ● Students will be able to construct and analyze linear, cyclic, and classical error-correcting codes using finite fields and polynomial techniques.

Course Syllabus	• Code, codeword, code length, rate, minimum distance. Types of codes: block codes, linear codes, cyclic codes. Finite fields (of prime characteristic), groups, and polynomial rings. • Linear codes as vector subspaces of finite fields; generator and parity-check matrices; dual codes and orthogonality; minimum distance and weight distribution. Simple parity-check, repetition, and Hamming codes. • Cyclic codes, polynomial representation of codewords, encoding and decoding cyclic codes, parity-check polynomial and dual cyclic codes, Hamming code as a cyclic code. • Bose-Chaudhuri-Hocquenghem codes, Reed–Solomon codes, quadratic-residue codes, equivalence and automorphisms of codes. Bounds for codes - Hamming, Singleton, Gilbert–Varshamov; perfect codes.
Suggested Books	**Textbooks:** 1. L. R. Vermani, Elements of Algebraic Coding Theory. Chapman and Hall/CRC Press, 2022. ISBN: 9781351452892. 2. J. H. van Lint, Introduction to Coding Theory. Graduate Texts in Mathematics, Springer, 1999 (3rd edition). ISBN: 9783642636530. **Reference books:** 3. W. Cary Huffman and Vera Pless, Fundamentals of Error-Correcting Codes. Cambridge University Press, 2003. ISBN: 9780521782807. 4. S. Ling and C. Xing, Coding Theory: A First Course. Cambridge University Press, 2004. ISBN: 9780521529235. 5. F. J. MacWilliams and N. J. A. Sloane, The Theory of Error-Correcting Codes. North-Holland Mathematical Library, 1977. ISBN: 9780444851932

Course Code	**MA 354/ CS 354N**
Title of the Course	**Computational Intelligence Lab**
Course Category	Department Core
Credit Structure	L-T- P-Credits 0-0-3-1.5
Name of the Concerned Department	Mathematics/ Computer Science and Engineering
Pre-requisite, if any	Computer Programming, Data structure, Discrete Structure, Design and Analysis of Algorithm
Objective of the Course	Basics of machine learning techniques
Course Outcomes	Understanding of machine learning techniques and implementation
Course Syllabus	● **AI programming:** Prolog, LISP, Experiments to support the associated theory course that demonstrate the different applications of Neural, fuzzy, evolutionary and hybrid model; ● **Implementation:** Minor project based on real life applications such as Functional approximation; Time-series prediction; Pattern recognition; Data compression; Control applications, Optimization etc.
Suggested Books	Textbooks: 1. S. Russell and P. Norvig, ***Artificial Intelligence: A Modern Approach***, Prentice Hall Series in AI, 1995. ISBN: 978-9332543515 2. E. Rich and K. Knight, ***Artificial Intelligence***, Tata McGraw Hill, 1992. ISBN: 978-0-07-067816-3 Reference books: 3. J.S.R.J ang, C.T. Sun and E. Mizutani, ***Neuro-Fuzzy and Soft Computing***, Prentice Hall and Pearson Education, 2004. ISBN: 978-9332549883 4. D.E. Goldberg, ***Genetic Algorithms: Search, Optimization and Machine Learning***, Addison Wesley, 1989. ISBN: 9781584883883 5. S. Rajasekaran and G.A.V. Pai, ***Neural Networks, Fuzzy Logic and Genetic Algorithms***, Prentice Hall, 2003. ISBN: 9788120321861 6. R. Eberhart, P. Simpson and R. Dobbins, ***Computational Intelligence - PC Tools***, AP Professional, 1996. ISBN: 978-0122286308

Course Code	**MA 357/ CS 357N**
Title of the Course	**Optimization Algorithms and Techniques Lab**
Course Category	Department Core
Credit Structure	L-T- P-Credits 0-0-2-1
Name of the Concerned Department	Mathematics/Computer Science and Engineering
Pre-requisite, if any	Knowledge of Data Structures and Algorithms
Objective of the Course	This is an introductory course in the field of mathematical optimization.
Course Outcomes	At the end of the course, students will know ● The Basics of Optimization, ● Unconstrained and Constrained Optimization, and ● Linear and Quadratic Programming.
Course Syllabus	• Understanding of Matlab/ Scilab via implementation of Newton's method for solving non-linear system of equations as well as numerical integration. • Analyzing convexity of functions numerically. • Implementation and analysis of Multi-dimensional Unconstrained Optimization algorithms (Steepest Descent, Newton, Gauss-Newton, Quasi-Newton, Conjugate Gradients etc.). • Implementation and analysis of One-dimensional Unconstrained Optimization algorithms (Dichotomous, Quadratic Interpolation, Cubic Interpolation etc.). • Implementation and analysis of Simplex and Interior Point Methods for Linear Program. • Implementation and analysis of Sequential Quadratic Program for solving general Constrained Optimization problem.
Suggested Books	Textbooks: 1. J. Nocedal and S. J. Wright, ***Numerical Optimization***, 1st Edition, Springer, 2006. ISBN: 78-1-4939-3711-0 Reference books: 2. A. Antoniou and W.-S.g Lu, ***Practical Optimization: Algorithms and Engineering Applications***, 2nd Edition,

	Springer, 2021. ISBN: 978-1-0716-0843-2

Course Code	**MA 402/ 602**
Title of the Course	**Industrial Statistics**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Probability and Statistics
Objective of the Course	Understanding the concepts of quality control and system reliability techniques.
Course Outcomes	Techniques to apply these concepts in industrial problems such as pharma, automotive industry, etc.
Course Syllabus	• **Statistical Quality Control:** Product quality, need for quality control, the basic concept of process control, process capability and product control, theory of control charts, operation and uses of control charts, probability limits, specification limits, tolerance limits, 3-sigma limits, and warning limits, control charts for variables and attributes, modified control charts, acceptance sampling plans for attributes inspection, single and double sampling plans and their properties, and plans for inspection by variables for one-sided and two-sided specification. • **Reliability Theory:** Reliability concepts and measures, components and systems, coherent systems, reliability of coherent systems, life distributions, reliability function, hazard rate, mean residual life and mean time to failure, notions of ageing: IFR, IFRA, DMRL, NBU, and NBUE classes and their duals, reliability modellings in series/parallel systems and k-out-of-n systems.

Suggested Books	Text Books: 1. D. C. Montgomery, ***Introduction to Statistical Quality Control***, Seventh edition, Wiley, 2019, ISBN: 9781119399308. 2. J. Navarro, ***Introduction to System Reliability Theory***, Springer, 2022, ISBN: 9783030869526. Reference Books: 3. A. J. Duncan, ***Quality Control and Industrial Statistics***, Irwin, Homewood, 1986, ISBN: 9780256035353. 4. C. D. Lai, and M. Xie, ***Stochastic Ageing and Dependence for Reliability***. Springer, 2006, ISBN: 0387297421.

Course Code	**MA 404/604**
Title of the Course	**Foundation of Approximation Theory**
Course Category	Department Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite if any	Basic knowledge of calculus, linear algebra
Objective of the Course	This course introduces the basic terms and techniques of approximation theory.
Course Outcomes	Students would be able to understand the concept of approximations of functions by polynomials and trigonometric functions.
Course Syllabus	• **Density theorems:** Approximation of periodic function, Weierstrass Theorem, Stone-Weierstrass Theorem. • **Linear Chebyshev approximation:** Approximation in normed linear space, linear Chebyshev approximation of vector-valued functions, Chebyshev polynomials, strong uniqueness and continuity of metric projection, discrete best approximation, approximation by algebraic polynomials. • **Best approximation in normed linear spaces:** Approximative properties of sets, characterization and duality, continuity of metric projections.
Suggested Books	Text Books: 1. H. N. Mhaskar and D. V. Pai, ***Fundamentals of Approximation Theory***, *CRC Press*, 2007, ISBN: 0849309395. 2. M. J. D. Powell, ***Approximation Theory and Methods***, Cambridge University Press, 1981, ISBN: 0521224721. Reference Books: 3. K. G. Steffens, ***The History of Approximation Theory: From Euler to Bernstein***, Birkhauser, Boston, 2006, ISBN: 0817643532.

Course Code	**MA 405/ MA 605**
Title of the Course	**Differential Equations in Population Dynamics**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic concepts of differential equations and numerical methods
Objective of the Course	Theory and computational techniques of differential equations will be applied in population dynamics.
Course Outcomes	• To know some well celebrated models in population dynamics. • exploring some ecological phenomenon such as the paradox of enrichment, ecological resilience, hydra effects, etc.
Course Syllabus	• **Introduction**: Mathematical models: necessity, advantages and limitations; brief history of population models, different tools and modeling frameworks, birth and death processes in population models. • **Ordinary differential equations**: The Multhus, Verhulst, Lotka-Volterra, Rosenzweiz-MacArthur and Hestings-Powell models, Routh-Hurwitz criteria, mean population density in cyclic and chaotic dynamics, population harvesting, resilience in ecology, hydra effects, population genetic models, FitzHugh-Nagumo model. • **Partial differential equations**: Fisher's equation, Turing instability, pattern formation, spatiotemporal chaos, reaction-diffusion in ecological and chemical systems, diffusion in delayed predator-prey systems. • **Delay differential equations**: Discrete and distributed delays in population dynamics, Hopf-bifurcation and stability switching, delayed harvesting in Nicholson blowflies model, delayed dispersal in patchy environment, Mackey-Glass equation. • **Impulsive differential equations**: Fixed-time and variable-time impulses, impulses in biological control theory and epidemic models. • **Computer simulations**: Several measures will be quantified in all the models using numerical methods, and different software will be implemented to interpret the system dynamics graphically.
Suggested Books	Text Books: 1. J. D. Murray, ***Mathematical Biology: I. An Introduction***, Springer, 2002, ISBN: 9780387952239. 2. R. K. Upadhyay, S. R. K. Iyengar, ***Spatial Dynamics and Pattern Formation in Biological Populations***, Chapman and Hall/CRC, 2021, ISBN: 9780367555504.

	Reference Books: 3. K. Gopalsamy, ***Stability and Oscillations in Delay Differential Equations of Population Dynamics***, Springer, 1992, ISBN: 9780792315940. 4. V. Lakshmikantham, D. D. Bainov, P. S. Simeonov, ***Theory of Impulsive Differential Equations***, World Scientific, 1989, ISBN: 9789971509705.

Course Code	**MA 406/606**
Title of the Course	**Graph Theory**
Course Category	Department Elective
Credit Structure	L-T-P- Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of linear algebra
Objective of the Course	This course explores the theoretical development of graph theory and mathematical models based on it.
Course Outcomes	• Solving problems arising from computer science using graphs and trees. • Adapt and demonstrate state-of-the-art algorithms to real-life situations.
Course Syllabus	• Graphs and graph models, graph terminology and special types of graphs, path problems, incidence matrix, adjacency matrix, degree sequence of graphs, graph isomorphism, trees and its characterizations, spanning trees, algorithms for minimum weighted spanning trees, matching, perfect matching, augmenting path, bipartite matching, Hall marriage theorem, matching in general graphs, Tutte's theorem, Min-Max theorems, Konig-Egervary theorem. • Eulerian tour and seven bridges problem, Hamiltonian cycles and travelling salesman problem, necessary conditions for Hamiltonian graphs, sufficient conditions for Hamiltonian graphs, vertex coloring, edge coloring, Brook's theorem, network flows, max-flow min-cut theorem, Ford-Fulkerson algorithm, planar graphs, Euler's Formula, Kuratowski theorem, four color theorem.
Suggested Books	Text Books: 1. D. B. West, ***Introduction to Graph Theory***, Pearson Education, 2015, ISBN: 0130144002. 2. J. A. Bondy, U. S. R. Murty, ***Graph Theory with Applications***, Elsevier Science Publishing Co., Inc., 1984, ISBN: 0444194517. Reference Books: 3. T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, ***Introduction to Algorithms***, MIT press, 2009, ISBN: 026204630X 4. R. Diestel, ***Graph Theory***, Springer, 2006, ISBN: 3540261834. 5. A. M. Gibbons, ***Algorithmic Graph Theory***, Cambridge University Press, 1985, ISBN: 0521288819.

Course Code	**MA 407/ MA 607**
Title of the Course	**Nonlinear Dynamics and Computations**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Linear Algebra and Ordinary Differential Equations
Objective of the Course	Understand the qualitative behaviours of autonomous systems and discrete maps, and write independent algorithms and coding in exploring complex dynamics numerically.
Course Outcomes	● Learning the idea of global stability with Lyapunov function. ● Generating Arnold tongue and shrimp structures using numerical simulation.
Course Syllabus	● Introduction to dynamical systems, flows, phase space analysis, stable and unstable manifolds, Hartman-Grobman theorem, Lyapunov function and stability. ● Transcritical, saddle-node, pitch-fork, and Hopf-bifurcations, limit cycles, index theory, Poincare-Bendixson theorem, homoclinic and heteroclinic orbits, nonlinear centers. ● Lorenz system, Rössler attractor, Chua's circuit, Kuramoto oscillator. ● Difference equations, periodic orbits, period-doubling, Feigenbaum constant, period-bubbling, quasi-periodic, chaos, Lyapunov exponents, Sharkovskii's theorem, synchronization, shadowing lemma, routes to chaos, Ruelle-Takens embedding theorem, reconstructing an attractor, Smale horseshoe, the renormalization idea, Neimark-Sacker bifurcation, Henon map. ● Bifurcations in 2D parameter plane: Isoperiodic diagram, Arnold tongue, shrimp-shaped structure, spiral structure. ● Numerical simulations: Plotting orbits, phase portrait, bifurcation diagrams, Lyapunov exponents, organized structures, etc. using computer programming.
Suggested Books	Text Books: 1. S. H. Strogatz, ***Nonlinear Dynamics and Chaos***, Westview Press, 2015, ISBN: 9780813349107. 2. K. T. Alligood, T. D. Sauer and J. A. Yorke, ***Chaos: An Introduction to Dynamical Systems***, Springer, 1996, ISBN: 9780387224923. Reference Books: 3. M. W. Hirsch, S. Smale and R. L. Devaney, *Differential* ***Equations, Dynamical Systems, and an Introduction to Chaos***, Academic Press, 2012, ISBN: 9780123820105.

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	4. S. Lynch, ***Dynamical Systems with Applications using MATLAB***, Springer, 2014, ISBN: 9783319068206.

Course Code	**MA 408/608**
Title of the Course	**Mathematical Theory of Waves**
Course Category	Department Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Differential Equations
Objective of the Course	To expose the students to the basic ideas that underline linear/non-linear wave motion. To derive important mathematical tools to deal with problems of wave theory. To consider simple examples of linear waves on strings, sound waves and water waves.
Course Outcomes	Upon completion of this course, students will know some of the most interesting wave phenomena that have physical significance, while at the same time, they will also be introduced to some of the deeper mathematical issues that are pertaining to wave motion.
Course Syllabus	● Introduction to waves: Classification, terminology, mathematical representation of waves. ● One-dimensional waves in solids and fluids: Waves in a string (free and forced vibrations), waves in a rod, steady-state waves, reflection and transmission of waves, water waves: Surface gravity waves, internal waves, sinusoidal waves on deep water, ripples, wave patterns, Fourier analysis of dispersive systems. ● Two-dimensional and three-dimensional waves: Basics of elasticity, waves in finite, infinite and semi-infinite media, waves in inhomogeneous media, motion of wave packets, dispersion and attenuation, phase velocity, group velocity. ● Non-linear waves: General effect of nonlinearity, non-linear Schrodinger equation, Riemann invariants, Piston problem, discontinues solutions and shock waves, wave localization phenomena.

Suggested Books	Text Books: 1. C. A. Coulson and Alan Jeffrey, ***Waves: A Mathematical Approach to the Common Types of Wave Motion,*** Longman Group Limited, 1977, ISBN: 9780582449541. 2. G. B. Whitham, ***Linear and Nonlinear Waves,*** Pure and Applied Mathematics, Wiley-Interscience, 1999, ISBN: 9780471359425. Reference Books: 3. R. Knobel, ***An Introduction to the Mathematical Theory of Waves***, American Mathematical Society, 2000, ISBN: 9780821820391. 4. J. Lighthill, ***Waves in Fluids,*** Cambridge Mathematical Library, Cambridge, 2001, ISBN: 9780521010450.

Course Code	**MA 414/614**
Title of the Course	**Time Series Analysis**
Course Category	Department Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Probability and Statistics
Objective of the Course	To introduce various techniques for modelling and forecasting the time series data.
Course Outcomes	• Understand the concepts of time series models and their applications in various fields, • Apply these models and techniques to real-life problems such as finance and stock analysis, sales and demand forecasting, weather forecasting etc.
Course Syllabus	• Components of time series, tests for randomness, trend and seasonality, estimation/elimination of trend and seasonality, mathematical formulation of time series, weak stationary, stationary up to order m. • Auto-covariance and auto-correlation functions of stationary time series and its properties, linear stationary processes and their time-domain properties-AR, MA, ARMA, seasonal, non-seasonal and mixed models, ARIMA models, invertibility of linear stationary processes. • Parameter estimation of AR, MA, and ARMA models-least square approach, estimation based on Yule-Walker for AR, ML approach for AR, MA and ARMA models, asymptotic distribution of MLE, best linear predictor and partial auto-correlation function (PACF), model-identification with ACF and PACF, model order estimation techniques-AIC, AICC, BIC, etc.

Suggested Books	Text Books: 1. P. J. Brockwell and R. A. Davis, ***Introduction to Time Series and Forecasting***, Springer, 2002, ISBN: 9781493970865. 2. C. Chatfield and H. Xing, ***The Analysis of Time Series -An Introduction with R***, Chapman and Hall/CRC Press, 2019, ISBN: 9781138066137. Reference Books: 3. R. H. Shumway, D. S. Stoffer, ***Time Series Analysis and Its Applications with R Examples***, Springer, 2016, ISBN: 9783319524511. 4. G. E. P. Box, G. Jenkins, and G. Reinsel, ***Time Series Analysis-Forecasting and Control***, Prentice-Hall International, Inc., 1994, ISBN: 0130607746.

Course Code	**MA 416/616**
Title of the Course	**Integral Equations**
Course Category	Department Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge in calculus and differential equations
Objective of the Course	The course introduces the classification of integral equations, fundamental mathematical ideas and techniques that lie at the core of the integral equation approach of problem solving.
Course Outcomes	• understand the concepts of Volterra and Fredholm integral equations • apply appropriate integral equation to solve initial and boundary value problems
Course Syllabus	● Basic concepts, Volterra integral equations, relationship between linear differential equations and Volterra equations, resolvent kernel, method of successive approximations, convolution type equations, Volterra equation of the first kind, Abel's integral equation. ● Fredholm integral equations, Fredholm equations of the second kind, the method of Fredholm determinants, iterated kernels, integral equations with degenerate kernels, eigenvalues and eigen functions of a Fredholm alternative, construction of Green's function for BVP. ● Weakly singular integral equations, Cauchy singular integral equations, hypersingular integral equations. ● Bernstein polynomials, properties and its use in solving integral equations.

Suggested Books	Text Books: 1. F. G. Tricomi, ***Integral Equations***, Dover Publications Inc, 1985, ISBN: 9780486648286. 2. N. I. Muskhelishvili, ***Singular Integral Equations: Boundary Problems of Functions Theory and Their Applications to Mathematical Physics***, Springer, 2011, ISBN: 9789400999961. Reference Books: 3. D. Porter and D. S. G. Stirling, ***Integral Equations: A Practical Treatment, from Spectral Theory to Applications***, Cambridge University Press, 2012, ISBN: 9781139172028. 4. R. P. Kanwal, ***Linear Integral Equations: Theory & Technique***, Birkhäuser, 2013, ISBN: 9781461460121.

Course Code	**MA 422 / MA 622**
Title of the Course	**Hyperbolic Geometry**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Knowledge of Complex Analysis and Topology
Scope of the course (Objectives)	This course provides basic information about hyperbolic geometry from two dimensions to higher dimensions in order to start research on hyperbolic geometry.
Course Outcomes	At the end of the course, students should have some fundamental knowledge about hyperbolic geometry through Complex Analysis and topology of non-Euclidean metric geometry.
Course Content	**Mobius transformations:** Stereographic projections. Review of Mobius transformations in the complex plane, Mobius Transformations in higher dimensions. **Schwarz lemma and the hyperbolic metric:** Schwarz lemma, Characterization of conformal maps of the unit disk, Schwarz-pick lemma, Hyperbolic metric of the unit disk and the upper half plane, Schwarz-pick theorems (non-Euclidean), hyperbolic geodesics, Hyperbolic metric in higher dimensions, Topology of the metric balls. **Mapping theorems and the hyperbolic metric:** Riemann mapping theorem (without proof), hyperbolic metric in a simply connected domain, covering spaces, uniformization theorem, hyperbolic metric in hyperbolic regions, Topology of metric balls. **Generalizations of the hyperbolic metric in higher dimensions:** The quasi-hyperbolic metric, Mobius invariant metrics, geodesics, comparison of metrics and their applications, geometry and topology of metric balls.

Suggested Books	**Text Books:** 1. L. Keen and N. Lakic, Hyperbolic Geometry from a Local Viewpoint, Cambridge University Press, 2007. ISBN: 9780521682244 2. A.F. Beardon, The Geometry of Discrete Groups, Springer, 1983. ISBN: 9780387907888 **Reference Books** 3. J.W. Anderson, Hyperbolic Geometry, Springer, 2005. ISBN: 9781852339340 4. M. Vuorinen, Conformal Geometry and Quasiregular Mappings, Springer-Verlag, 1988. ISBN: 9783540193425 5. P. Hariri, R. Klen and M. Vuorinen, Conformally Invariant Metrics and Quasiconformal Mappings, Springer, 2020. ISBN: 9783030320676 6. L.V. Ahlfors, Complex Analysis, McGraw Hill Education, 2013. ISBN: 9781259064821

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Course code	**MA 424/624**
Title of the course	**Algebraic Number Theory**
Course Category	**Elective**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre-requisite, if any	Basic knowledge of number theory and algebra.
Objective of the course	The primary aim of this course is to introduce the key concepts of algebraic number theory and provide an overview of its various applications like solving Diophantine equations.
Course Outcomes	At the end of the course, students will have basic understanding of algebraic number theory and its applications to solve different types of problems in number theory.
Course Syllabus	Motivation via Fermat's Last Theorem, Algebraic Numbers and Integers, Number Fields, Real and Complex Embeddings, Norms, Traces, Discriminant, Ramification, Norms of Ideals. Ring of Integers, Integral Basis, Dedekind Domain, Fractional Ideals, Ideal Class Group, Class Number, Computation of Class Group of Number Fields, Finiteness of Class Group. Dirichlet Unit Theorem and its Applications, Fundamental Units, Units in Quadratic Fields, Cyclotomic Fields, Dedekind Zeta Function, Applications to Diophantine Equations.
Suggested Books	**Text Books:** 1. J. Esmonde and M. R. Murty, Problems in Algebraic Number Theory, Springer, New York, 2004, ISBN: 9780387221823 2. R. A. Mollin, Algebraic Number Theory, CRC Press, 1999. ISBN: 9781138627857 **Reference Book:** 3. J. Neukirch, Algebraic Number Theory, Springer Berlin, Heidelberg, 1999. ISBN: 3540653996

Suggested Course code	**MA 426/626**
Title of the course	**Theory of Modular Forms**
Course Category	**Elective**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre-requisite, if any	Basic knowledge of Complex analysis, Group theory, and Linear Algebra.
Objective of the course	The theory of modular forms is developed as a tool to use in number theory, but it accommodates itself in many branches of mathematics as well as in physics.
Course Outcomes	At the end of this course, students will have a brief idea of the basic techniques and applications of modular forms and their relationship with the theory of elliptic curves.
Course Syllabus	Full Modular Group and its Subgroups, Hecke Subgroups, Action of $\mathbf{SL_2(Z)}$ on the Upper-half Plane**,** Fundamental Domain. Modular Functions, Modular Forms, Cusp Forms, Fourier Expansions, Space of Modular Forms, The Valence Formula and the Dimension Formula, Examples of Modular Forms: Eisenstein series and Ramanujan's Delta function, Ramanujan Tau Function. The Hecke Operators T_n, Multiplicative Property of the Hecke Operators, Eigenfunctions of Hecke Operators. Dirichlet Series, ***L***-functions attached to Modular Forms, Analytic Continuation and Functional Equation. Atkin-Lenner Theory, Newforms, Relation between Modular Forms and Elliptic Curves.
Suggested Books	**Text Books:** 1. J. P. Serre, A Course in Arithmetic, Springer, 1978, ISBN: 9780387900407. 2. M. R. Murty, M. Dewar, H. Graves, Problems in the Theory of Modular

	Forms, Springer, 2015, ISBN: 9789380250724. **Reference Books:** 3. T. M. Apostol, Modular Functions and Dirichlet Series in Number Theory, Springer, 2012, ISBN:9781468499100. 4. F. Diamond, J. Shurman, A First Course in Modular Forms, Springer, 2005, ISBN: 9780387272269.

Course Code	**MA 432/ MA 632**
Title of the Course	**Introduction to Commutative Algebra**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Department	Mathematics
Pre-requisite, if any	Basic knowledge in algebra
Objectives of the course	● Develop a thorough understanding of the structure of commutative rings and modules. ● Build the foundational tools for algebraic geometry and algebraic number theory.
Course Outcomes	● Apply core concepts of commutative rings and ideals to solve algebraic problems and prove basic structural results. ● Work effectively with modules over commutative rings, including homomorphisms, exact sequences, and tensor products.
Course Content	**Module 1:** Commutative rings, ideals, prime and maximal ideals. Noetherian and Artinian rings. **Module 2:** Primary decomposition over Noetherian rings, Modules over commutative rings, Nakayama's lemma, Extension and Contraction. **Module 3:** Exact sequences, Exactness properties of the Tensor product, rings and modules of fractions, Integral dependence. **Module 4:** Valuations and Dedekind domains, Local properties, Going-Up and Going-Down Theorem.

Suggested Books (Text Books , Reference Books)	**Text Books:** 1. M. F. Atiyah and I. G. MacDonald, Introduction to Commutative Algebra, CRC Press, 2019. ISBN-978113832960 2. H. Matsumura, Commutative Ring Theory, Cambridge University Press, 1989. ISBN- 9780521367646 **Reference Books** 3. D. Eisenbud, Commutative Algebra with a View Toward Algebraic Geometry, Graduate Texts in Mathematics, Springer Science & Business Media, 1995. ISBN- 9780387942698 4. R. Y. Sharp, Steps in Commutative Algebra, Issue 51 of London Mathematical Society Student Texts, Cambridge University Press, 2000. ISBN- 9780521646239

Course Code	**MA 434 / MA 634**
Title of the Course	**Introduction to Modal Logic**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	A working knowledge of elementary set theory, relations, and orderings.
Objectives of the course	● To provide a rigorous introduction to the syntax, semantics, and proof theory of modal logic, with particular emphasis on Kripke frames, models, and the principal normal systems **K**, **T**, **S4**, and **S5**. ● To analyze the expressive power of modal languages and explore their applications in computer science, and artificial intelligence.
Course Outcomes	Upon completing the course, students will be able to: ● Comprehend and apply the syntax, semantics, and axiomatic systems of modal logic. ● Analyze various modal logics, including epistemic and temporal logics. ● Develop reasoning techniques for applications such as knowledge representation and distributed reasoning.
Course Content	**Introduction to Modal Logic** ● Syntax and semantics of modal logic ● Kripke models and accessibility relations ● Basic modal axioms and their properties ● The minimal modal system K and extensions (T, S4, S5) **Proof Theory and Expressiveness** ● Hilbert-style axiomatic systems ● Soundness and completeness theorems ● Expressive power of modal languages. **Applications** ● Epistemic logic and reasoning about knowledge and belief, multi-agent reasoning ● Temporal logic for reasoning about time

Suggested Books (Text Books , Reference Books)	**Text Books:** 1. Patrick Blackburn, Maarten de Rijke, and Yde Venema, Modal Logic, Cambridge University Press, ISBN: 9781316101957 2. Ronald Fagin, Joseph Y. Halpern, Yoram Moses, and Moshe Y. Vardi, Reasoning About Knowledge, MIT Press. ISBN: 9780262562003. **Reference Books:** 3. Brian F. Chellas, Modal Logic: An Introduction, Cambridge University Press. ISBN: 9780521295154 4. Robert Goldblatt, Logics of Time and Computation, CSLI Publications. ISBN: 9780937073993 5. Alexandru Baltag, and Sonja Smets, The Logic of Knowledge, Belief, and Certainty, Cambridge University Press. ISBN: 9781107036639

Course Code	**MA 452/ MA 652**
Title of the Course	**Theory of Transforms**
Course Category	Department Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of calculus, complex variable, differential equations
Objective of the Course	This course explores properties of integral transforms, applying them to solve initial and boundary value problems arise from mathematical modelling.
Course Outcomes	Understanding the concept of various transform techniques and their applications.
Course Syllabus	• Fourier series, Riemann-Lebesgue lemma, Gibbs phenomenon, Fourier sine and cosine series, Fourier transform, Fourier integral theorem, convolution and Parseval's theorem, applications to partial differential equations. • Laplace transform: Definition and properties, complex inversion, convolution theorem, Heaviside's expansion theorem, Bromwich contour integral, applications to initial and boundary value problems. • Fundamental theorem of the discrete Fourier transform, cyclical convolution, and Parseval's theorem. • Z-transform: Definition and examples, basic operational properties of Z-transforms, inverse Z-transform and examples, applications of Z-transforms to finite difference equations and summation of infinite series.
Suggested Books	Text Books: 1. R. J. Beerends, H. G. ter Morsche, J. C. van den Berg, E. M. van de Vrie, ***Fourier and Laplace Transforms,*** Cambridge University Press, 2003, ISBN: 0521534410. 2. U. Graf, ***Applied Laplace Transforms and Z-Transforms for Scientists and Engineers,*** Birkhauser Verlag, Basel, 2004, ISBN: 3034895933. Reference Books: 3. L. Debnath, D. Bhatta, ***Integral Transforms and their Applications,*** Chapman & Hall/CRC, 2006, ISBN: 1584885750. 4. G. B. Folland, ***Fourier Analysis and its Applications,*** American

	Mathematical Society, Providence, 2009, ISBN: 9780821847909. 5. A. Pinkus, S. Zafrany, ***Fourier Series and Integral Transforms***, Cambridge University Press, 1997, ISBN: 0521597714.

Course Code	**MA 454 / MA 654**
Title of the Course	**Mathematical Modeling and Simulations**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of differential equations and linear algebra
Objective of the Course	The Mathematical model plays a significant role providing a quantitative framework for understanding and solving many real-life problems under certain conditions.
Course Outcomes	• Students should be exposed to fundamental knowledge of implementing the models in real-world situations. • They will get the bright idea about constructing or selecting the appropriate model, identify the problem, analytically or numerically computing the solution and test the validity of models.
Course Syllabus	• **Introduction to mathematical modeling**: Characteristics, classifications, tools, techniques, deterministic and stochastic models, modeling approaches, compartmental models, introduction to discrete models and continuous models, dynamical systems and its mathematical models. • **Models from systems of natural sciences**: Population models for a single species (discrete and continuous-time models), modeling of population dynamics of two interacting species, analytical tool: Kolmogorov Theorem, linear stability snalysis, Lotka-Volterra model, variation of the classical LV model, Leslie-Gower model, prey-predator model, arms race model, Holling-Tanner model, modified HT model, applications of Lyapunov functions. • **Modeling of atmospheric, mining and engineering systems**: Spatial models using partial differential equations, modeling with stochastic differential equations, models of heating and cooling, models for traffic flow, model for detecting land mines, models in mechanical systems, models in electronic systems, models for vehicle dynamics, kicked harmonic oscillator, modeling the ventilation system of a mine. • MATLAB/MATHEMATICA programs to study the dynamics of the developed model systems
Suggested Books	Text Books: 1. B. Barnes, G. R. Fulford, ***Mathematical Modeling with Case Studies***, CRC PRESS, Taylor & Francis, 2009, ISBN: 9781420083484. 2. S. Banerjee, ***Mathematical Modeling, Models, Analysis and Applications***, CRC Press, Taylor & Francis, London, 2014, ISBN: 9781482229165.

	Reference Books: 3. E. A. Bender, ***An Introduction to Mathematical Modeling***, Dover Publications, 2012, ISBN: 9780486137124. 4. R. K. Upadhyay, S. R. K. Iyengar, ***Introduction to Mathematical Modeling and Chaotic Dynamics***, CRC Press Taylor & Francis, London, 2014, ISBN: 9781439898871.

Course Code	**MA 456/ MA 656**
Title of the Course	**Stochastic Approximation**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Theoretical knowledge of probability
Scope of the course (Objectives)	This course provides basic tools and techniques for studying Stochastic Algorithms and their convergence analysis
Course Outcomes	The student is able to use iterative method to find the approximate zeros of class of function whose numerical value is not directly available. The student will expose to theoretical convergence analysis of recursive stochastic algorithms.
Course Content	• Introduction to stochastic approximation. • Conditional Expectation, Independence, Filtration, Martingales, Doob's Maximal inequality, Martingale convergence theorem, Burkholder-Davis-Gundy Inequality. • Robbin-Monro method, Kiefer-Wolfowitz method, Robbins-Siegmund Lemma, stochastic gradient method, the ordinary differential equation method, rate of convergence, asynchronous schemes

Suggested Books	**Text Books:** 1. R. L. Karandikar, B.V. Rao, Introduction to Stochastic Calculus, Springer Nature Singapore, 2018. ISBN: 978981108318 2. H. J. Kushner, G.G. Yin, Stochastic Approximation and Recursive Algorithms and Applications, Springer, New York NY, 2011. ISBN: 9780387891194 3. Vivek S. Borkar, Stochastic Approximation: A dynamical systems viewpoint, Springer, Singapore, 2023. ISBN: 9789819982769 **Reference Books** 4. Gilles Pages, Numerical Probability: An introduction with applications to finance, Springer Nature, Switzerland, 2018. ISBN: 9783319902746 5. M.T. Wasan, Stochastic Approximation, Cambridge University Press, New York NY, 2004. ISBN: 9780521604857