VISVESVARAYA NATIONAL INSTITUTE OF TECHNOLOGY NAGPUR

DEPARTMENT OF MATHEMATICS

B.Tech. in

Mathematics and Computing

SCHEME OF INSTRUCTION AND SYLLABI

(Effective from 2026-27)

Institute Vision Statement

To contribute effectively to the National and International endeavor of producing quality human resource of world class standard by developing a sustainable technical education system to meet the changing technological needs of the Country and the World incorporating relevant social concerns and to build an environment to create and propagate innovative technologies for the economic development of the Nation.

Institute Mission Statement

The mission of VNIT is to achieve high standards of excellence in generating and propagating knowledge in engineering and allied disciplines. VNIT is committed to providing an education that combines rigorous academics with joy of discovery. The Institute encourages its community to engage in a dialogue with society to be able to effectively contribute for the betterment of humankind.

Department Vision Statement

- To be a leading Mathematics Department in the country.
- To emerge as a global center of learning, academic excellence, and innovative research.

Department Mission Statement

- Imparting quality mathematics education and the inculcating of the spirit of research through innovative teaching and research methodologies.
- To achieve high standards of excellence in generating and propagating knowledge in Mathematics. Department is committed to providing an education that combines rigorous academics with joy of discovery.
- To provide an environment where students can learn, become competent users of mathematics, and understand the use of mathematics in other disciplines.
- Developing linkages with world class organizations to strengthen industry-academia relationships for mutual benefit.

About the Department

The Department of Mathematics VNIT Nagpur grew from its humble beginnings in the year 1960. It has aimed to be a center of excellence in Mathematics and scientific computing. The Department offers several courses in Mathematics to undergraduate and postgraduate students of various science and engineering disciplines. The Department commenced a two-year Master of Science (M.Sc.) program in Mathematics in 2012. The program is fully equipped with the modules that are currently the need of various industries. In addition to the M.Sc. program in Mathematics, the Department also offers doctoral programs in various areas of Mathematics. The Department trains students to international standards, and carries out high-level research in both pure and applied mathematics. Each year faculty members of the department teach over 1500 students from engineering disciplines and about 25 M.Sc. students in Mathematics are trained in the Department. The Department has been working towards placements of its M.Sc. students diligently. The Department is equipped with good computing facilities.

Currently the Department has fifteen full-time regular highly qualified, enthusiastic and energetic faculty members. All faculty members of the Department hold a PhD degree in Mathematics, with some of them having postdoctoral experience, from reputed institutes in India or abroad. The faculty members have collaborative research engagement with reputed national and international institutions. The faculty members of the Department share a commitment to excellence in teaching and research, and have produced a large number of research papers in SCI & refereed journals and conferences.

List of Faculty Members:

S. No.	Name of faculty Member	Designation	Qualification	Area of Specialization
1	Dr. G. P. Singh	Professor (HAG)	Ph.D.	Relativity and Cosmology, Mathematical Modelling
2	Dr. P. P. Chakravarthy	Professor	Ph.D.	Numerical Analysis, Numerical Treatment of Singular Perturbation problems and Singularly Perturbed Differential-Difference equations
3	Dr. Pallavi Mahale	Professor & Head	Ph.D.	Functional Analysis and Operator equations
4	Dr. M. Devakar	Professor	Ph.D.	Fluid Dynamics

5	Dr. G. Naga Raju	Associate Professor	Ph.D.	Numerical Techniques for Partial Differential Equations; Spectral/Finite Element Techniques, Finite Volume Method, Parallel Computing.
6	Dr. Pradip Roul	Assistant Professor	Ph.D.	Numerical methods for fractional differential equations, Singular BVP, Nuclear Reactor dynamics, Computational Finance
7	Dr. Deepesh Kumar Patel	Assistant Professor	Ph.D.	Nonlinear Analysis, Fixed Point Theory
8	Dr. Jyoti Singh	Assistant Professor	Ph.D.	Commutative Algebra
9	Dr. Sourav Pradhan	Assistant Professor	Ph.D.	Queueing Theory; Stochastic Modeling
10	Dr. V. P. Singh	Assistant Professor	Ph.D.	Operation research, Optimization under uncertainty
11	Dr. Purnima Satapathy	Assistant Professor	PhD	Lie Theory and Partial Differential Equations
12	Dr. Sourav Bhattacharya	Assistant Professor	Ph.D.	Planar Topology, Dynamical Systems and Ergodic Theory
13	Dr. Mohan Kumar Mallick	Assistant Professor	Ph.D.	Nonlinear Elliptic PDEs
14	Dr. Neelima Bhengra	Assistant Professor	Ph.D.	Wave propagation Theory; Theoretical Seismology; Solid Mechanics

UG/ PG Programs Offered by Mathematics Department:

The department offers following undergraduate and postgraduate programs

S. No.	Program	Description	Remarks
1	M.Sc. in Mathematics	Intake: 25	
2	Minor in Mathematics	-	For all branches of B.Tech. students

The department proposed the following program:

	Program	**Description**	**Remarks**
UG	B. Tech. in Mathematics and Computing	Intake: 30	NEP provisions for 1. One/Two Semester/s Internship (Semester-VII/VIII) 2. Minor with additional credits of 16-18 (in any specified field chosen by the student, provided she/he meets the required criteria) * (optional in nature) 3. Academic bank of credits* 4. Early exit with certificate/diploma under special circumstances* 5. Honor's* (optional in nature) 6. Students may undertake summer internships of **at least 6 weeks duration** after completion of 2^{nd} semester (1^{st} year and/or 4^{th} semester (2^{nd} year) and/or 6^{th} semester (3^{rd} year). Upon **successful completion and approval**, the student shall earn **1 credit** per summer Internship.

*Please refer to academic rule book for details

Credit System at VNIT

Education at the Institute is organized around the semester-based credit system of study. The prominent features of the credit system are a process of continuous evaluation of a student's performance / progress and flexibility to allow a student to progress at an optimum pace suited to his/her ability or convenience, subject to fulfilling minimum requirements for continuation. A student's performance/progress is measured by the number of credits he/she has earned, i.e., completed satisfactorily. Based on the course credits and grades obtained by the student, grade

point average is calculated. A minimum number of credits and a minimum grade point average must be acquired by a student in order to qualify for the degree.

Course Credits Assignment

Each course, except a few special courses, has a certain number of credits assigned to it depending on lecture, tutorial and laboratory contact hours in a week. For Lectures and Tutorials: One lecture hour per week per semester is assigned one credit and for Practical/ Laboratory/ Studio: One hour per week per semester is assigned half credit. Example: Course XXXXXX with (3-0-2) as (L-T-P) structure, i.e., 3 hr. Lectures + 0 hr. Tutorial + 2 practical per week, will have (3x1 + 0x1 + 2x0.5 =) 4 credits.

Grading System

The grading reflects a student's own proficiency in the course. While the relative standing of the student is clearly indicated by his/her grades, the process of awarding grades is based on fitting performance of the class to some statistical distribution. The course coordinator and associated faculty members for a course 6 formulate appropriate procedures to award grades. These grades are reflective of the student's performance vis-à-vis the instructor's expectation. If a student is declared pass in a subject, then he/she gets the credits associated with that subject. Depending on marks scored in a subject, a student is given a Grade. Each grade has got certain grade points as follows:

Grade	Grade points	Description
AA	10	Outstanding
AB	9	Excellent
BB	8	Very good
BC	7	Good
CC	6	Average
CD	5	Below average
DD	4	Marginal (Pass Grade)
FF	0	Poor (Fail) /Unsatisfactory / Absence from end-sem exam
NP	-	Audit pass
NF	-	Audit fail
SS	-	Satisfactory performance in zero credit core course
ZZ	-	Unsatisfactory performance in zero credit core course
W	-	Insufficient attendance

Performance Evaluation

The performance of a student is evaluated in terms of two indices, viz, the Semester Grade Point Average (SGPA) which is the Grade Point Average for a semester and Cumulative Grade Point Average (CGPA) which is the Grade Point Average for all the completed semesters at any point in time. CGPA is rounded up to second decimal. The Earned Credits (ECR) are defined as the sum of course credits for courses in which students have been awarded grades between AA to DD. Grades obtained in the audit courses are not counted for computation of grade point average.

Earned Grade Points in a semester (EGP) = $\sum$ (Course credits x Grade point) for courses in which AA- DD grade has been obtained

SGPA = EGP / $\sum$ (Course credits) for courses registered in a semester in which AA- FF grades are awarded

CGPA= EGP / $\sum$ (Course credits) for courses passed in all completed semesters in which AA-DD grades are awarded.

Attendance Rules

1. All students must attend every class and 100% attendance is expected from the students. However, in consideration of the constraints/ unavoidable circumstances, the attendance can be relaxed by course coordinator only to the extent of not more than 25%. Every student must attend a minimum of 75% of the classes actually held for that course.
2. A student with less than 75% attendance in a course during the semester, will be awarded W grade. Such a student will not be eligible to appear for the end semester and reexamination of that course. Even if such a student happens to appear for these examinations, then, answer books of such students will not be evaluated.
3. A student with W grade is not eligible to appear for end semester examination, reexamination & summer term.

Program Outcomes (POs)

1. **Engineering Knowledge**

   Apply knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to solve complex engineering problems.

2. **Problem Analysis**

   Identify, formulate, review literature, and analyze complex engineering problems using mathematical and computational principles.

3. **Design/Development of Solutions**

   Design solutions for complex engineering problems and design system components or processes that meet specified needs with appropriate consideration for public health, safety, cultural, societal, and environmental considerations.

4. **Conduct Investigations of Complex Problems**

   Use research-based knowledge and research methods including the design of experiments, analysis, and interpretation of data to provide valid conclusions.

5. **Engineering Tool Usage**

   Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities, with an understanding of the limitations.

6. **The Engineer and The World**

   Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues relevant to professional engineering practice. Understand the impact of engineering solutions in societal and environmental contexts and demonstrate knowledge of sustainable development.

7. **Ethics**

   Apply ethical principles and commit to professional ethics, responsibilities, and norms of engineering practice.

8. **Individual and Collaborative Team Work**

   Function effectively as an individual and as a member or leader in diverse teams and multidisciplinary settings.

9. **Communication**

   Communicate effectively on complex engineering activities with the engineering community and society at large, including writing reports, making presentations, and giving and receiving instructions clearly.

10. **Project Management and Finance**

    Demonstrate knowledge and understanding of engineering and management principles and apply these to one's work as a member or leader of a team to manage projects in multidisciplinary environments.

11. **Life-long Learning**

    Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the context of technological change.

Program Specific Objectives (PSOs)

1. To develop a strong foundation in mathematics and computing techniques to solve real-world problems and drive innovation in technology and science.
2. To demonstrate proficiency in computational tools, programming languages, and algorithmic techniques to model, analyze, and solve problems in Science, engineering and interdisciplinary domains.
3. To apply the mathematical and statistical approaches for analyzing, designing and development of computing systems in interdisciplinary applications.
4. To develop skills and expertise of the students to pursue research in the field of Mathematics and computing.

Program Educational Objectives (PEOs)

1. The graduates will be able to undertake industry careers involving innovation and problem-solving using tools and techniques derived from an understanding of concepts and theories in Mathematics and Computer Science.
2. The graduates will have leadership and lifelong learning qualities required for a professional career along with ethical attitude and teamwork skills.
3. The graduates will be able to formulate, investigate and analyze scientifically real-life problems along with an ethical attitude.
4. The graduates will engage in professional activities to enhance their own stature and simultaneously contribute to the profession and the society at large.
5. To undertake advanced studies for research careers in different areas of Mathematics, Computer Science, and allied areas.

Table 1: Structure for B.Tech. in Mathematics and Computing

Sr. No.	Category of Course	Symbol	Earned Credit Requirement
1	Basic Sciences	BS	16
2	Engineering Sciences	ES	13
3	Humanities	HU	03
4	Institute Core	IC	02
5	Departmental Core	DC	77
6	Mandatory Non-Credit	MNC	At least 4 courses
7	Institute Elective	IE	6-12
8	Departmental Elective	DE	Min 42
9 & 10	Humanities and Management and Open Course	HM/OC	0-3

Semester-wise Credit Structure for B.Tech. in Mathematics and Computing

	PC						PE			Total
	BS	**ES**	**HU**	**IC**	**DC**	**MNC**	**IE**	**OC/HM**	**DE**	
Sem										
I	8	9	0	2	0	0	0	0	0	19
II	8	4	3	0	8	0	0	0	0	23
III	0	0	0	0	20	0	3-4	0	0	23-24
IV	0	0	0	0	17	0	3/4	0-3	4-8	24-25
V	0	0	0	0	15	0	3/4	0-3	6-12	24-27
VI	0	0	0	0	11	0	3/4	0-3	6-12	20-23
VII	0	0	0	0	3	0	0	0-3	9-12	12-15
VIII	0	0	0	0	3	0	0	0-3	9-12	12-15
Total	16	13	3	2	77	Min 4 courses	6-12	0-3	Min 42	Min 160

- While registration of the course's student must ensure that he/she registers for the IE and DE courses in such a way that the minimum requirement of credits for the program as per institute norms fulfills.
- Credits for OC + HM should not exceed 03 credits.

SCHEME OF INSTRUCTION

B.Tech. (Mathematics and Computing) Course Structure

Intake: 30

First Year (Semester I & II)

I Semester

Code	Course	Type	L-T-P	Credits
PHLA1XX	Physics	BS	3-0-0	3
PHPA1XX	Physics Laboratory	BS	0-0-2	1
CSL101	Computer Programming	ES	3-0-2	4
EELA1XX	Electrical Engineering	ES	3-1-0	4
EEPA1XX	Electrical Engineering Laboratory	ES	0-0-2	1
MALA1XX	Calculus	BS	3-1-0	4
ICLA1XX	Environmental Studies	IC	2-0-0	2
SAA101	Health Information and Sports Part I	MNC	0-0-2	0
	Total Credits			**19**

Credits	BS	ES	HU	DC	IC	IE	DE	HM/OC	Total
1st Sem	8	9	0	0	2	0	0	0	19
Cumulative	8	9	0	0	2	0	0	0	19

II Semester				
Code	**Course**	**Type**	**L-T-P**	**Credits**
ECLA101	Basics of Electronic Engineering	ES	3-0-2	4
MALA1XX	Digital Circuit and Computer Architecture	DC	3-1-0	4
MALA1XX	Introduction to Linear Algebra	BS	3-1-0	4
MALA1XX	Data Structures and Applications	DC	3-0-0	3
MALA1XX	Discrete Structures and Graph Theory	BS	3-1-0	4
HULA1XX	English and corporate communications	HU	2-0-2	3
MAPA1XX	Data Structures Laboratory	DC	0-0-2	1
SAA102	Health Information and Sports Part II	MNC	0-0-2	0
	Life skill Management	MNC	0-0-2	0
	Total Credits			**23**

Summer Internship (optional): Students may undertake summer internships of **at least 6 weeks duration** after completion of 2nd semester (1st year and/or 4th semester (2nd year) and/or 6th semester (3rd year). Upon **successful completion and approval**, the student shall earn **1 credit** per summer Internship. These credits will be reflected in the student's transcript under the DE course category.

Credits	**BS**	**ES**	**HU**	**DC**	**IC**	**IE**	**DE**	**HM/OC**	**Total**
2nd Sem	8	4	3	8	0	0	0	0	23
Cumulative	16	13	3	8	2	0	0	0	42

Second Year (Semester III & IV)

III Semester				
Code	**Course**	**Type**	**L-T-P**	**Credits**
MALA2XX	Matrix Computation	DC	3-1-0	4
MALA2XX	Elements of Real Analysis	DC	3-1-0	4
MALA2XX	Abstract Algebra	DC	3-1-0	4
MALA2XX	Design and Analysis of Algorithms	DC	3-1-0	4
MALA2XX	Object Oriented Programming	DC	3-0-0	3
MAPA2XX	Object Oriented Programming laboratory	DC	0-0-2	1
	Institute elective	IE		3/4
		MNC		0
	Minor* (optional in nature)			
	Total Credits			**23-24**

Credits	**BS**	**ES**	**HU**	**DC**	**IC**	**IE**	**DE**	**HM/OC**	**Total**
3rd Sem	0	0	0	20	0	3/4	0	0	23-24
Cumulative	16	13	3	28	2	3/4	0	0	65-66

*Students can choose minor course run by another Science/Engineering department. The provision for Minor is optional in nature.

IV Semester				
Code	**Course**	**Type**	**L-T-P**	**Credits**
MALA2XX	Ordinary Differential Equations	DC	3-1-0	4
MALA2XX	Introduction to Complex Analysis	DC	3-0-0	3
MALA2XX	Applied Numerical Analysis and Scientific Computing	DC	3-0-0	3
MALA2XX	Theory of Computation	DC	3-0-0	3
MALA2XX	Probability Theory	DC	3-0-0	3
	Elective-1	DE		4
	Elective -2	DE/IE/OC/HM		3/4
MAPA2XX	Applied Numerical Analysis and Scientific Computing Laboratory	DC	0-0-2	1
	Minor/ Honors*(optional in nature)			For Honors choose one extra elective from# other than IE/OC/HM
		MNC (if not taken in III semester)		0
	Total Credits			**24-25**

*The provision for Minor / Honors is optional in nature.

Summer Internship(optional): Students may undertake summer internships of **at least 6 weeks duration** after completion of 2nd semester (1st year and/or 4th semester (2nd year) and/or 6th semester (3rd year). Upon **successful completion and approval**, the student shall earn **1 credit** per summer Internship. These credits will be reflected in the student's transcript under the DE course category.

Code	Course# (Electives 1 and 2)	Type	L-T-P	Credits
HULA2XX	Economics for Engineers	DE	3-1-0	3/4
CSL304	Neuro Fuzzy Techniques	DE	3-0-2	
CSL 317	Computer Networks	DE	3-0-2	
CSL309	Operating systems	DE	3-0-2	
MALA3XX	Topics in Measure theory and Integration	DE	3-1-0	
	Institute Elective/ OC/HM			

Credits	BS	ES	HU	DC	IC	IE	DE	HM/OC	Total
4th Sem	0	0	0	17	0	3/4	4-8	0-3	24-25
Cumulative	16	13	3	45	2	6-8	4-8	0-3	89-91

Third Year (Semester V & VI)

V Semester

Code	Course	Type	L-T-P	Credits
MALA3XX	Introduction to Partial Differential Equations	DC	3-1-0	4
CSL315	Database Management Systems	DC	3-0-2	4
MALA3XX	Optimization	DC	3-0-0	3
MALA3XX	Applied Statistics	DC	3-0-0	3

MAPA3XX	Statistics Lab (R Programming)	DC	0-0-2	1
	Elective 3	DE		3/4
	Elective - 4	DE		3/4
	Elective - 5	IE/DE/OC/HM		3/4
	Minor/ Honors (optional in nature)			For Honors choose one extra elective from# other than IE/OC/HM
	Total Credits			**24-27**

Credits	**BS**	**ES**	**HU**	**DC**	**IC**	**IE**	**DE**	**HM/OC**	**Total**
5th Sem	0	0	0	15	0	3-4	6-12	0-3	24-27
Cumulative	16	13	3	60	2	9-12	10-20	0-3	113-118

Code	**Course (Electives 3,4, 5) ##**	**Type**	**L-T-P**	**Credits**
MALA3XX	Numerical Methods for Partial Differential Equations	DE	3-1-0	3/4
MALA3XX	First Course in Topology		3-1-0	
MALA3XX	Integral Equations and Calculus of Variation		3-1-0	
MALA3XX	Number Theory		3-1-0	
MALA3XX	Fourier Transforms and Applications		3-1-0	
ECL211	Signal & Systems Analysis		3-0-2	

EEL305	Control Systems I		3-1-0	
CSL224	Introduction to Web Programming		3-0-2	
	Institute elective/OC/HM			

VI Semester

Code	Course	Type	L-T-P	Credits
MALA3XX	Artificial Intelligence	DC	3-0-2	4
MALA3XX	Machine learning	DC	3-0-0	3
MALA3XX	Topics in Functional Analysis	DC	3-0-0	3
MAPA3XX	Machine Learning laboratory	DC	0-0-2	1
	Elective - 6	DE		3/4
	Elective-7	DE		3/4
	Elective - 8	DE/OC/HM/IE		3-4
	Minor/ Honors (optional in nature)			For Honors choose one extra elective from ### other than IE/OC/HM
	Total Credits			**20-23**

Credits	BS	ES	HU	DC	IC	IE	DE	HM/OC	Total
6th Sem	0	0	0	11	0	3-4	6-12	0	20-23
Cumulative	16	13	3	71	2	12-16	16-32	0-3	133-141

Summer Internship (optional): Students may undertake summer internships of **at least 6 weeks duration** after completion of 2nd semester (1st year and/or 4th semester (2nd year) and/or 6th semester (3rd year). Upon **successful completion and approval**, the student shall earn **1 credit** per summer Internship. These credits will be reflected in the student's transcript under the DE course category.

Code	Course (Electives 6 and 7, 8) ###	Type	L-T-P	Credits
MALA 3XX	Data Science & Visualization in R/Python/SQL	DE	3-1-0	4
MALA 3XX	Fundamentals of Fluid Dynamics		3-1-0	
MALA3XX	Introduction to Finite Element Method		3-0-2	
MALA 3XX	Statistical Inference and Multivariate Analysis		3-1-0	
MALA 3XX	Cryptography		3-1-0	
MALA 3XX	Computational Finance		3-0-2	
MALA 3XX	Numerical methods for Conservation Laws		3-1-0	
CSL316	Language Processor		3-0-2	
CSL444	Image processing and understanding		3-0-2	
CSL 447	Introduction to Parallel computing		3-0-2	
MALA 4XX	Data Mining		3-1-0	
CSL 409	Topics in Distributed System		3-0-2	
CSL 429	Introduction to Internet of Things		3-0-2	
MALA4XX	Network Security		3-0-2	
	Institute Elective /OC/HM			3/4

Fourth Year (Semester VII & VIII)

VII Semester

Code	Course	Type	L-T-P	Credits
	Elective-9	DE		3/4
	Elective-10	DE		3/4
	Elective-11	DE		3/4
MADA4XX	Project Phase - I	DC	0-0-6	**3**
	Minor/ Honors (optional in nature)			For Honors choose extra electives from #### other than IE/OC/HM
	Total Credits			**12-15**

Credits	BS	ES	HU	DC	IC	IE	DE	HM/OC	Total
7th Sem	0	0	0	3	0	0	9-12	0	12-15
Cumulative	16	13	3	74	2	12-16	25-44	0-3	145-156

VIII Semester

Code	Course	Type	L-T-P	Credits
MADA4XX	Project Phase – II	DC	0-0-6	**3**
	*Elective -12 *Elective-13 *Elective-14	DE DE DE		3/4
	Minor/ Honors (optional in nature)			For Honors

				choose extra electives from #### other than IE/OC/HM
	***Number of electives need to be chosen as required to complete 160 credits**			
	Total Credits			**12-15**

Credits	**BS**	**ES**	**HU**	**DC**	**IC**	**IE**	**DE**	**HM/OC**	**Total**
8th Sem	0	0	0	3	0	0	9-12	0	12-15
Cumulative	16	13	3	77	2	6-12	Min 42	0-3	Min 160

Code	**Course (Electives 9, 10, 11, 12, 13, 14) ####**	**Type**	**L-T-P**	**Credits**
	MOOC 1/ NPTEL course (will be identify and approved by BOS in due course)			
	MOOC 2/ NPTEL course (will be identify and approved by BOS in due course)			
	MOOC3 / NPTEL course (will be identify and approved by BOS in due course)			
	MOOC4/NPTEL course (will be identify and approved by BOS in due course)			
	MOOC5/NPTEL course (will be identify and approved by BOS in due course)			
	Internship			6 credits for semester long internship
MALA 4XX	Cluster Computing	DE	3-1-0	4
MALA 4XX	Coding Theory		3-1-0	
MALA 4XX	Advanced Operations Research		3-1-0	

MALA 4XX	Topics in Operator Theory		3-1-0	
MALA 4XX	Introduction to Wavelet Analysis		3-1-0	
MALA 4XX	Computational Fluid Dynamics		3-1-0	
MALA 4XX	Approximation Theory		3-1-0	
MALA 4XX	Non-linear Analysis		3-1-0	
MALA 4XX	Queuing theory and Applications		3-1-0	
MALA 4XX	Stochastic calculus for Finance		3-1-0	
MALA 4XX	Time series Analysis		3-1-0	
MALA 4XX	Fuzzy logic and its applications		3-1-0	
MALA 4XX	Biometrics		3-1-0	
MALA 4XX	High Performance Computation		3-0-2	
MALA 4XX	Topics in Bio-Informatics		3-1-0	
MALA 4XX	Advanced Data Mining		3-1-0	
MALA 4XX	Quantum Computing		3-1-0	
CSL502	Deep Learning		3-0-2	
MALA 4XX	Modules and Fields		3-1-0	
MALA 4XX	Introduction to Game Theory		3-1-0	
MALA 4XX	Basic Algebraic Geometry		3-1-0	
MALA 4XX	Modern theory of Partial differential equations		3-1-0	
	IE/Open course/Humanities	IE/OC/HM	3-0-0	3

Physics

Course Code & Course Title:	PHLA1XX Physics		
Course Type:	BS		
Name of the programme(s):	B Tech		
L – T – P	3-0-0	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

i) To provide a strong foundation in physics in preparation for technical or scientific career.
ii) To develop skills that enables to function as productive, qualified engineering professionals in areas where traditional science and engineering disciplines overlap.
iii) Create awareness about the importance of continued professional development.

2.	**Course Outcomes:** Student will be able to:
CO1	Understand the concepts of quantum mechanics and its application
CO2	Comprehend the primitive crystal systems through packing density and Miller indices.
CO3	Develop an understanding for basics of semiconductors based on band theory applied to electronic devices.
CO4	Learn the basics of LASERs and its applications in optical fibres.

1.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Quantum Mechanics: Origin of quantum mechanics, Compton effect, Concept of matter waves, Davisson and Germer's experiment, Heisenberg's Uncertainty principle, Schrodinger's Wave equation and its application and Quantization of energy.		CO1	2
Applications of Quantum Mechanics: Particle in 1,2 and 3-dimensional infinite potential well, Quantization of energy, Operators, Eigen states and Eigen values, Introduction to quantum computing		CO1	3
Elementary crystal structure: Unit cell and its characteristics in SC, BCC, FCC crystal structure, Miller indices, Bragg's Law, inter-planer spacing.		CO2	2

Semiconductor Physics: Formation of energy bands in solid, classification of solids: intrinsic and extrinsic semiconductor, Fermi level in an intrinsic and extrinsic semiconductor, Hall effect	CO3	2
Device Physics: V-I characteristics of p-n junction diode, Zener diode, photo diode, LED, BJT, FET and MOSFET.	CO3	2
LASER Optics: Introduction to LASER, Spontaneous and Stimulated Emission, Different types of CW & Pulse lasers & their characteristics, Principle & characteristics of optical fibers, Different types of optical fibers	CO4	2

2.	**Text books**

i) M N Avadhanulu, P. Kshirsagar, A Textbook of Engineering Physics, 2017, S Chand Publications ISBN 13: 9789352833993.

3.	**Reference Book(s) and Other Required Material**

i) A.J. Dekker, Solid State Physics, MacMillan, Student Edition (2000), ISBN-13. 9780333918333.

ii) B.B. Laud, Lasers and nonlinear optics, New Age International limited (1991), ISBN-13. 978-9393159670.

iii) B. G. Streetman, Solid State Electronics, Prentice Hall India (2^{nd} Edition) (1986), ISBN-13. 978-0134363790.

iv) B. E. Conway Electrochemical Supercapacitors Scientific Fundamentals and Technological Applications 2013 Springer US, ISBN: 9781475730586.

v) David J. Griffiths, Introduction to Quantum Mechanics, Cambridge India (2016), ISBN-13. 978-1107179868.

vi) Kenneth Krane; Modern Physics, John Wiley Eastern (2^{nd} Edition); (1998), ISBN-13, 978-0471828723.

vii) Resnick, Walker and Halliday, Fundamental of Physics, John Willey and Sons. Inc, 6^{th} Edition (2005), ISBN · 9788126508235.

viii) S.M. Sze Semiconductor devices (Physics and Technology), II Edition, Wiley India Pvt. Ltd., ISBN-13. 978-0470873670.

4.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Mid Sem: 30 Marks, End Sem: 50 Marks, Quiz/Internal assessment: 20 Marks, Total 100 Marks

5.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	2									3	3	2	2
CO2	3	2	2									3	3	2	2
CO3	3	2	2									3	3	2	2
CO4	3	2	2									3	3	2	2

High - 3; Medium – 2; Low – 1;

6.	List of Indicative Laboratory Experiment (if applicable):

Nil

Physics Laboratory

Course Code & Course Title:	PHPA1XX & Physics Lab		
Course Type:	**BS**		
Name of the programme(s):	B Tech		
L – T – P	0-0-2	**No. of Credits**	**1**
Pre-requisites: Course Code(s) & Name(s)	**Nil**		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

i) The Objective of this course is to make the students gain practical knowledge to co-relate with the theoretical studies.

ii) To achieve perfectness in experimental skills and the study of practical applications will bring more confidence and ability to develop and fabricate engineering and technical equipment's.

iii) Design of circuits using new technology and latest components and to develop practical applications of engineering materials and use of principle in the right way to implement the modern technology.

2.	**Course Outcomes (Min. 3 & Max. 5):** Student will be able to understand, apply and analyse:
CO1	Demonstrate experimental skills, analyse and interpret the results obtained.
CO2	Acquire written communication skill to write reports of experiments performed in the lab.
CO3	Understand basic concepts of Physics and develop oral communication skills.
CO4	Enhance understanding of concepts in physics by performing practical's.
CO5	Function effectively as an individual and as a member of a team.

3.	**Detailed Description of the Course**		
		CO(s) Addressed	**Duration in weeks**
	1. To study the characteristics of Photocell and to determine the work function of the cathode material. 2. To calibrate an electromagnet and to study the dependence of Hall voltage on magnetic field and current through the sample. 3. To study the I/P, O/P and transfer characteristics and to determine 'α' of transistor in common base mode.		

4. To study I-V characteristics of conventional p-n junction diode and Zener diode. 5. To determine the energy band gap in a semiconductor using reverse biased p-n junction diode. 6. Study of voltage regulation using Zener diode. 7. Study of output characteristics and transfer characteristics of FET. 8. To determine numerical aperture of the optical fibres. 9. To determine wavelength of He-Ne LASER.		

4.	Text books

i) Experiments of Engineering Physics M.N. Avadhanulu, A.A. Dani, P.M. Pokley, S Chand Publishers (2003) ISBN-13- 978-8121912235.

ii) 2. A Textbook of Engineering Physics Practical C. S. Robinson, Ruby Das, Lakshmi Publications Pvt Limited (2016) ISBN-13- 978-9380386867.

5.	Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Continuous evaluation

6.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	2						1	1		3	3	2	2
CO2	3	2	2						1	1		3	3	2	2
CO3	3	2	2						1	1		3	3	2	2
CO4	3	2	2						1	1		3	3	2	2
CO5	3	2	2						1	1		3	3	2	2

High - 3; Medium – 2; Low – 1;

Computer Programming

Course Code & Course Title:	CSL101 Computer Programming		
Course Type:	ES		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-2	**Credits**	4
Pre-requisites: Course Code(s) & Name(s)	None		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

To develop student's proficiency in structured programming using C by teaching them essential constructs (variables, data types, operators, I/O, control flow), foundational problem-solving algorithms, modular and structured data handling (arrays, functions, structures), and basic file operations—empowering them to design, implement, and debug efficient, maintainable programs for real-world computational tasks.

2.	**Course Outcomes:**
CO1	Remember and understand the fundamental programming constructs—such as program structure, data types, operators, expressions, and formatted I/O.
CO2	Implement computational logic using decision structures and loops to solve problem.
CO3	Analyse and modularize solutions using arrays, strings, and user-defined functions (including recursion) to implement algorithms.
CO4	Apply and design structured data and persistent storage solutions by using C structures (including nested and arrays of structs) and basic file-handling operations (text and binary I/O).

3.	**Detailed Description of the Course**		
	Topics	**CO(s) Addressed**	**Duration in weeks**
1	Introduction: Fundamentals of Computer programming, Program development and execution, basics of algorithms and flow charts and the software development lifecycle.	CO1	1.5
2	Basic constructs of C programming: Structure of Programs, Keywords and Identifiers, Variables and Data Types,	CO1	1.5

	Operators and Expressions (Precedence and Associativity, Type Conversions), Formatted Input/Output.		
3	Control Flow: Decision Making and Branching (if, if-else), Loops (while, for). Algorithms such as swapping two variables, reversing digits, character-to-number conversion, generating primes, GCD, smallest divisor, factorial, and Fibonacci generation through loops, nested-loop pattern printing.	CO1, CO2	3
4	Data Organization & Modularity: Arrays and Strings (1-D arrays, 2-D arrays, basic string operations), Functions (user-defined functions, scope and lifetime of variables, recursive functions); Algorithms like array reversal, finding maximum number in a set, factorial computation, Fibonacci sequence generation, reversing the digits of an integer; sorting and searching techniques and comparison.	CO3	3
5	Composite Data Types: structures, defining struct types, declaring instances, accessing members using the dot operator, memory layout and padding. Array of Structures: Declaring arrays whose elements are structures; Nested Structures: Embedding one struct type within another (either defined separately or inline), accessing nested members.	CO4	3
6	File handling: Opening and creating files, Closing files, Text file reading, Text file writing, Binary file reading, Binary file writing.	CO4	2

4.	**Text books (Theory and Practical):**

i) The C Programming Language by Brian Kernighan and Dennis Ritchie. ISBN:9780131101630.

ii) How to Solve It by Computer by R. G. Dromey. ISBN-13. 978-8120303881.

5.	**Reference Book(s) and Other Required Material**

i) Algorithms in C by Robert Sedgewick ISBN-13:9780-0201314526.

ii) Algorithms (4th Edition) by Robert Sedgewick & Kevin Wayne ISBN-13: 978-0321573513.

iii) Introduction to Algorithms (commonly known as *CLRS*) by Cormen, Leiser son, Rivest & Stein ISBN-13: 978-0262033848.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Code	Type	Structure L+T+P	Credits	Evaluation Weightage (%)	
				Method	**Range**
L	Lecture with built-in practical	L:3 T:0 P:4	L+0.5P	Mid Semester Exam.	25
				End Semester Exam.	50
				Quiz	10
				Continuous Evaluation-I (Pr.)	7.5
				Continuous Evaluation-II (Pr.)	7.5

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	1		2		2			1	2			1		2	2
CO2	3	2	3		1		1	2		2	2	3	2	3	3
CO3	2	1	2	2	3	1		3			3	2	1	2	2
CO4	3	3	2	3	3	2	2	3	3	2	3	3	3	2	2

8.	**List of Indicative Laboratory Experiments (If Applicable):**	
Sr. No.	Sample Lab Assignments	CO Addressed
1	Basic Input-Output/Data types/data operators Calculation of simple interest and compound interest. Convert kilometres to miles Compute the area and perimeter of a rectangle or circle; perform temperature conversion between Celsius and Fahrenheit	CO1
2	Conditional Statements/ Loops Input month number and print number of days in a month	CO1, CO2

	Factorial Of a given number. Check the entered no is prime or not. Print patterns using nested loops. Swap using a temporary variable (baseline); swap using arithmetic/logical (without a temporary variable) Calculate compound interest annually or monthly using the iterative approach. Map month number to days; check if a year is a leap year Determine roots of a quadratic equation; use switch-case to build a basic calculator	
3	Arrays: 1-D array, 2-D array, Strings: String functions, strength library Input two sorted arrays and merge to one array. Search element from an array. Reverse an array element. Count vowels/consonants in a string; find string length manually and using strlen() Check palindrome strings, concatenate two strings, compare strings (strum), or count character frequency. Sorting and searching techniques implementation. Merge two sorted arrays into a third array and in-place merging.	CO2, CO3
4	Functions, Recursion and Structures. Call a simple function to find the sum of digits of a number. Recursive function to generate Fibonacci series. Addition of complex numbers using structure. Store multiple records of student details using an array of structures. Determine if an input number is prime. Print all prime numbers up to N, or implement an optimized check via sqrt(n) method Binary search for a sorted array, and discussion on iterative vs. recursive implementation Reduce using recursion; compute factorials in an array or vector. Use a structure to add two complex numbers. Store and process multiple student records using an array of structures (find average, top scorer, etc.).	CO3, CO4
5	File handling. Count the number of words and characters in a given text file. Replace the specific line from a file. Copy the content of source file into destination file	CO4

	Count words and characters in a text file; write content from one file to another. Number and print lines with fgets/fputs; search and replace a specific line in a file	

Electrical Engineering

Course Code & Course Title:	EELA1XX Electrical Engineering		
Course Type:	ES		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	NIL		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

i) To learn basic ideas and principles of Electrical Engineering.

ii) Understanding the details of electrical machines.

2.	**Course Outcomes:** Students will be able to
CO1	Understand the basics of electrical components
CO2	Calculate DC, AC, and magnetic circuits parameters using KCL and KVL
CO3	Determine performance parameters of transformers
CO4	Evaluate performance of rotating electrical machines

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Electrical Circuits: Circuit elements: resistor, inductor, capacitor, and memristor; voltage and current sources, definition, ideal and practical sources, source conversions, Kirchhoff's Laws and star-delta transformation.		CO1	2
Magnetic Circuits: Flux, MMF, reluctance; analogy with electric circuits; simple calculations for composite magnetic circuits.		CO1	2
AC Circuits: Periodic signals, average and R.M.S. values, phasor representation, steady-state analysis of ac circuits with sinusoidal excitation, reactance and impedance, series and parallel AC circuits, power factor, active, reactive and apparent power, series and parallel resonance, principle of generating single-phase and three-phase voltages, balanced three-phase AC systems: Voltages, currents, and powers in star and delta connected load.		CO2	4

Single phase Transformers: Construction, types, basic principles, EMF equation, ideal and practical transformers, phasor diagrams for transformer under no load and load conditions, equivalent circuits, voltage regulation, and efficiency.	CO3	2.5
DC Motors: Construction, types- Shunt and Series, applications, significance of Back EMF, Speed and Torque equations, speed control, and need of starter.	CO4	1.5
Induction Motors: Three-phase induction motor—construction, types, applications, revolving magnetic field, principle of operation, synchronous speed, rotor speed, slip, power flow diagram, equivalent circuit, torque equation, and torque-slip characteristics. Introduction to induction motor drive-block diagram. Single-phase induction motors—principle of operation, types and applications.	CO4	2

4.	**Textbooks**

i) D. C. Kulshreshtha, Basic Electrical Engineering, Second Edition, McGraw-Hill, 2019, ISBN: 9353167213.

ii) S.K. Bhattacharya, Basic Electrical and Electronics Engineering, Second Edition, Pearson Education, 2017, ISBN: 9789332586505.

5.	**Reference Book(s) and Other Required Material**

i) Edward Hughes, Electrical and Electronic Technology, Tenth Edition, Pearson Education, 2010, ISBN: 9788131733660.

ii) Kothari D.P. and Nagrath I.J., Basic Electrical Engineering, Fourth Edition, McGraw-Hill, 2019, ISBN: 9353165725.

iii) Leonard S. Bobrow, Fundamentals of Electrical Engineering, 12th Edition , 2003, ISBN-13: 978-0195667493.

iv) N. K. De, G. D. Roy, T. K. Bhattacharya, IIT Kharagpur, Basic Electrical Technology, Web course of NPTEL. https://share.google/VoalBK3GqjDvGOg7H

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Mid Sem: 20-30 Marks, End Sem: 50-60 Marks, Quiz/Internal assessment: 10-20 Marks, Total 100 Marks

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	2	2	1	1	1			1	2		3	2	2	1	1
CO2	2	2	1	1	1			1	2		3	2	2	1	
CO3	3	2	1	1	1			1	2		3	3	2	2	2
CO4	3	2	1	1	1			1	2		3	3	2	2	2

Electrical Engineering Laboratory

Course Code & Course Title:	EEPA1XX Electrical Engineering		
Course Type:	ES		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	0-0-2	**No. of Credits**	1
Pre-requisites: Course Code(s) & Name(s)	NIL		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

i) To verify basic ideas and principles of various Electrical Circuits.
ii) Understanding the principle and operation of electrical machines.

2.	**Course Outcomes: Students will be able to**
CO1	Understand steady-state behaviour of R, L, C circuit
CO2	Appreciate and analyse magnetic circuits
CO3	Get familiarised with various machines operation
CO4	Verify various parameter/variables of three phase circuits

3.	**Detailed Description of the Course**	
Topics (List of Experiments)	**CO(s) Addressed**	**Duration in Week**
1. Study and verification of Kirchhoff's Laws applied to direct current circuit.	CO1	1
2. Determination of B-H curve of a magnetic material	CO2	1
3. Study of AC series circuits.	CO1	1
4. Study of AC Parallel circuits.	CO1	1
5. To determine Voltage regulation and efficiency of a single-phase transformer by direct loading.	CO3	1
6. Reversal of direction of rotation of a three-phase induction motor.	CO3	1
7. To study balanced three phase circuit- star connection.	CO4	1
8. To study balanced three phase circuit- delta connection.	CO4	1
9. Speed control of a DC motor by varying: - a. Field current with armature voltage kept constant b. Armature voltage with field current kept constant.	CO3	1

Assessment 1 + Assessment 2 + Quiz / Viva	All COs	5

4. Textbooks

i) B.S. Umre and D. P. Kothari, Laboratory Manuals for Electrical Machines, 2nd Edition, I. K. International, 2018, ISBN: 978-93-85909-75-7.

ii) S. G. Tarnekar and P. K. Kharbanda, Laboratory Courses in Electrical Engineering, 3rd Edition, S. Chand, ISBN: 9788121901048.

5. Reference Book(s) and Other Required Material

i) D. C. Kulshreshtha, Basic Electrical Engineering, Second Edition, McGraw-Hill, 2019, ISBN: 9353167213.

ii) P. Tiwari & S. Gairola, Electrical Engineering Laboratory Practice, First Edition, S.K. Kataria & Sons, 2012, ISBN: 978-81-89757-89-2.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Continuous Evaluation, Total 100 Marks

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	1		2	1	2		3	3		2	2	2	1	1
CO2	3	1		2	1	2		3	3		2	2	2	1	
CO3	2		2	2	1	2		3	3		2	3	2	2	2
CO4	2		2	2	1	2		3	3		2	3	2	2	2

Calculus

Course Code & Course Title:	MALA1XX Calculus		
Course Type:	BS		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	NIL		
Course Equivalence: Course Code(s) & Name(s)	NIL		

1.	**Course Objective:**

The objective of this subject is to expose student to understand the basic importance of Differential calculus and Integral calculus in one and several variables in science and engineering.

2.	**Course Outcomes:**
CO1	To deal with differential calculus of functions of single variable and its applications
CO2	To deal with Integral calculus of functions of single variable and its applications
CO3	To deal with differential calculus of functions of several variables and their applications
CO4	Able to understand concepts of multiple integrals and their applications in Science and Engineering problems

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Differential Calculus of function of single variable: Review of limit, continuity, and differentiability. Rolle's theorem Mean value theorems: Lagrange's theorem, Cauchy's theorem, Taylor's theorem with Lagrange's form of remainder, curve tracing.		CO1	3
Integral Calculus of function of single variable: Fundamental theorem of Integral calculus, mean value theorems, evaluation of definite integrals. Beta and Gamma functions (Definition and properties only).		CO2	2
Calculus of function of Several Variables: Limit, continuity, and differentiability of functions of several variables, partial derivatives and their geometrical interpretation, Tangent plane, and normal line. Total differentiation, chain rules, Jacobian, Taylor's formula, maxima and minima, saddle points, Lagrange's method of undetermined multipliers.		CO3	4

Multiple Integrals: Double integrals, change of order of integration, change of variables, application to area, volumes, Mass, Centre of gravity. Triple integrals, change of variables in triple integrals. Application of triple integral to find volume, mass, centre of mass and moments of inertia about the axes of a solid. Gradient of scalar point function, divergence, and curl of vector point function, Line, Surface and volume integrals, Green's theorem, Stoke's theorem and Gauss divergence theorem (without proof)	CO4	4

4. Text books

i) Jain, R.K. and Iyengar, S.R.K., Advanced Engineering Mathematics; Narosa Publishers, 2019, ISBN- 978-8184875607.

ii) James Stewart, Calculus-Early Transcendentals 5e, Thomson™ Brooks/Cole-Indian Edition, 2007, 978-0534274092.

iii) Kreyszig, E, Advanced Engineering Mathematics (Eighth Edition); John Wiley & amp; Sons. 1998, ISBN- 978-0471154969.

iv) Thomas, G.B. and Finney, R.L., Calculus and Analytic Geometry (Ninth Edition); Addison Wesley Longman, Inc. 1998, ISBN – 0-210-40015-4.

5. Reference Book(s) and Other Required Material

i) Michael D. Greenberg: Advanced Engineering Mathematics, Pearson Education Pvt. Ltd. ISBN-: 978-8177585469.

ii) Piskunov N., Differential and Integral calculus, Vol.1, Vol.2 MIR ISBN-: 978-8123904924.

iii) Publishers, Moscow – CBS Publishers and Distributors (India), 1996, ISBN- 978-8123904924.

iv) Sudhir R. Ghorpade, Balmohan V. Limaye, A Course in Calculus and Real Analysis, 2nd Edition, Springer, New York, NY. 2006, ISBN - 978-0387305301.4.

v) Sudhir R. Ghorpade, Balmohan V. Limaye, A Course in Multivariable Calculus and Analysis, Springer, New York, NY, 2010. ISBN 978-1-4419-1620-4 e-ISBN 978-1-4419-1621-1.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO2	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO3	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO4	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2

8. List of Indicative Laboratory Experiment (if applicable):

NA

Environmental Studies

Course Code & Course Title:	ICLA1XX: Environmental Studies		
Course Type:	IC		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	2 – 0 - 0	**No. of Credits**	2
Pre-requisites: Course Code(s) & Name(s)	--		
Course Equivalence: Course Code(s) & Name(s)	--		

1.	**Course Objective:**

i) To introduce various natural resources, their importance and status.
ii) To introduce the concepts of ecosystem, their structure and functions.
iii) To introduce the concept of biodiversity conservation.
iv) To introduce possible causes of various forms of environmental pollution and their consequences, methods of prevention.
v) To introduce various social and climatic changes due to pollution.

2.	**Course Outcomes:**
CO1	Understand about various natural resources, their importance and status
CO2	Understand the concepts of ecosystem and biodiversity, their structure, functions and conservation
CO3	Understand the causes of various forms of environmental pollution and their consequences, and methods of prevention
CO4	About the various changes in social and climate due to pollution and population and the environment

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Natural resources: Forest resources, Water resources, Mineral resources, Food resources, Energy resources, Land resources.		CO1	04
Ecosystem: Concept of an ecosystem, Structure and functions of an ecosystem, Producers, consumers and decomposers, Food chain, food webs and pyramids.		CO2	03

Biodiversity and its conservation: Introduction, definitions: genetics, species and diversity, Value of biodiversity, Biodiversity at global, national and local level, India as a mega-diversity nation, Hot-spot of biodiversity, Threat to biodiversity: habitat loss, poaching of wildlife, man-wildlife conflicts, Conservation of biodiversity: in-situ and ex-situ conservation.		
Environmental pollution: Definition, Causes, effects and control measures of: Air pollution, Water pollution, Soil pollution, Marine pollution, Noise pollution, Thermal pollution, nuclear hazards, Solid waste management: Causes, effects and control measures of urban and industrial wastes.	CO3	06
Social issues and environment: Sustainable development, Water conservation, Rain water harvesting, Watershed management, Climate change, Global warming, Acid rain, Ozone layer depletion, nuclear accident, Environmental rules and regulations. **Human population and environment:** Population growth, Environment and human health, Human rights, Value education, Role of information technology in environment and human health.	CO4	02

4.	**Text books**

i) Rajgopalan R., Environmental Studies, 3rd Edition, Oxford University Press, 2023. ISBN: 13. 9789354978944.

ii) Benny Joseph, Environmental Studies, 3rd Edition, McGraw Hill, 2017. ISBN: 10. 9352605179.

iii) Erach Barucha, Environmental Studies, 3rd Edition, Universities press (India), 2025, ISBN: 9789389211788.

5.	**Reference Book(s) and Other Required Material**

i) Rao M.N. and Rao H.V.N., Air Pollution, 1st Edition, McGraw-Hill Publishing Company Limited, 2007. ISBN: 13, 978-0074518717.

ii) Rao C.S., Environmental Pollution Control Engineering, 3rd Edition, Wiley Eastern Limited, New Age International Limited, 1995. ISBN: 13. 978-9386649898.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Mid Term Examination: 30 Marks Continuous Assessment (Seminars): 10 Marks End Term Examination: 60 Marks, Total Marks: 100

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	1	3	1	3	2	3	2	3	3	3	3	3	3	3
CO2	3	1	3	1	3	2	3	2	3	3	3	3	3	3	3
CO3	3	1	3	1	3	2	3	2	3	3	3	3	3	3	3
CO4	3	1	3	1	3	2	3	2	3	3	3	3	3	3	3

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Health Information and Sports Part 1

Course Code & Course Title:	SAA101- Health Information and Sports-Part I		
Course Type:	MNC		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	0-0-2	**No. of Credits**	0

1.	**Course Objective:**

i) To provide information about physical, physiological & psychological aspects of sports physical.

ii) To create awareness among the students about their health status, by conducting various physical fitness tests and suggest them suitable remedial physical fitness programme.

iii) To make students aware about the rules and regulation of different games & sports.

iv) To provide opportunity to mingle with each other through participating in different physical education & sports activities.

v) To deliver the knowledge of daily calorie requirement to manage the obesity.

2.	**Course Outcomes:**
CO1	Enriched proper knowledge among the students about emerging issues such as health & fitness, wellness etc
CO2	Students will become aware about the sense of discipline & dedication in general life, develop the spirit of team work through various physical education & sports activities
CO3	Development of rational thinking and scientific temper among the students

3.	**Detailed Description of the Course**	
Topics	**CO(s) Addressed**	**Duration in weeks**
Introduction to psychological problem of a sports person	CO1, CO2, CO3	8-12
Warming up, cooling down & full body stretching and its importance	CO1, CO2, CO3	8-12
Obesity & its Management: Daily caloric requirements and daily energy expenditure	CO1, CO2, CO3	8-12
Scientific principles of training	CO1, CO2, CO3	8-12

Health & performance related physical fitness	CO1, CO2, CO3	8-12

4.	Practical	
Topics	**CO(s) Addressed**	**Duration in weeks**
Practice of skills of major games like: Badminton, Table Tennis, Chess, Yoga, Basketball, Football, Handball, Cricket, Kho-Kho, Lawn Tennis, Throw ball, Athletics & Kabaddi	CO1, CO2, CO3	8-12
Screening of health-related physical Fitness	CO1, CO2, CO3	8-12
Participation in Intramural Sports Program	CO1, CO2, CO3	8-12
Preparation for Physical Efficiency Test Level-1	CO1, CO2, CO3	8-12

5.	Reference Books & other required materials

i) Arnold G. Nelson, (2007), "Stretching Anatomy" Human Kinetics: Online available: https://www.therajordanmassage.com/doc/3_%20Stretching%20Anatomy.pdf

ii) Matt Jarvis, Sports Psychology, Taylor & Francis e- library, 2005.

iii) Tudor O Bompa and G Gregory Haff, Periodization theory & methodology of training, 5th Edition, Human Kinetics 2009.

6.	Evaluation Details:

Continuous evaluation Assessment- End Semester 100%

Basics of Electronic Engineering

Course Code & Course Title:	ECLA1XX Basics of Electronics Engineering		
Course Type:	ES		
Name of the programme(s):	B.Tech. in Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)	Nil		

1.	**Course Objective:**

i) To impart fundamental knowledge of semiconductor devices, analog components, and solid-state electronic circuits.
ii) To develop the ability to analyse and design basic digital logic and combinational circuits using standard techniques.
iii) To introduce the working principles of sensors, data converters (ADC/DAC), and microcontroller-based systems.
iv) To provide foundational understanding of communication systems and enable hands-on application development using Arduino platforms.

2.	**Course Outcomes:** Students will be able to
CO1	Demonstrate basics of diodes, BJTs, FET and solid-state devices, ADC, DAC
CO2	Analyse various digital circuits and combinational circuits
CO3	Describe basic working principle of sensors and microcontroller
CO4	Describe various elements of communication systems
CO5	Implement various applications using Arduino microcontroller and sensors

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction to Semiconductor Devices: Diode, Zener circuits, solar cell, photoconductors, PIN photodiode, avalanche photodiode, LED, semiconductor lasers, rectifiers, DC Power supply. Introduction to BJT, MOSFET, OPAMP, Oscillators, 555 based LED blinker and Timer.		CO1	3

Boolean logic, basic gates, truth tables, logic minimization using K maps, Number system (Binary, octal, hexadecimal, excess-3, etc.), 2's complement representation, code converters (BCD to 7 segment and others), universal gates, MUX and DEMUX, overview of Sequential circuits such as Flip-flops and counters.	CO2	3
Introduction to Different types of sensors: Hall effect sensors; Piezoelectric sensors; Micro-sensors. Sensors for displacement, pressure, temperature, flow etc. Optical sensors; chemical and bio-sensors. Sensor parameters: non-ideal ties, Sensitivity, SNR, power/energy, form-factor, Sensor read-out, interfacing of sensors.	CO3	3
Digital-to-analog converters (DAC), Analog-to-digital converters (ADC)- Types of ADC and DAC.	CO1	2
Introduction to Arduino IDE, Arduino - Download and Installation, Syntax, Variables, Data types, Structures- loop, setup, Arithmetic operators, Control Structures, Comparison operators, Bitwise operators, Key Functions – Pin Mode, Analog Read, Analog Write, Digital Read, Digital Write.	CO5	3
Introduction to Communication systems: Introduction to Analog and digital communication, types of modulation, antennas and their types, overview of current wireless standards.	CO4	2

4.	**Text books**

i) Adel S. Sedra and Kenneth C. Smith", "Microelectronics Circuits", Eighth Edition "Oxford University Press ISBN-13*:* 9780190853464.

ii) David Hanes, et.al., IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things, Pearson, 2017. ISBN-13: 9781587144561.

iii) Jacob Freden, Handbook of Modern Sensors – Physics, Designs, and Applications, 4th ed, Springer, 2010 ISBN-13: 9781441964656**.**

iv) Lathi B.P.; Modern Analog & Digital Communication Systems; ISBN-13*:* 9780190686840**.**

v) R.P Jain,"Modern Digital Electronics" fourth edition, Mc Graw hill *ISBN-13:* 9780070669116.

5.	**Reference Book(s) and Other Required Material**

i) D Roy Choudhury, Shail Bala Jain – "Linear Integrated Circuits", 6th edition, new age international publishers.

ii) John Wiley Design - With an Introduction to Verilog HDL, Moris Mano and M. D. Ciletti, Pearson, 5th Edition.

6.	**Evaluation Details:**

Mid Semester Exam. 20-30

Teacher Defined Assessment 20

End Semester Exam. 50-60

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PS01	PSO2	PSO3	PSO4
CO1	3	1	-	-	1	-	-	-	1	-	2	2	1	1	1
CO2	3	1	-	-	-	-	-	-	1	-	1	1	1	1	1
CO3	3	3	3	-	1	-	-	-	1	1	1	1	3	3	2
CO4	3	-	-	-	-	-	-	-	1	-	1	1	1	1	1
CO5	3	3	3	-	1	-	-	1	1	1	1	1	1	2	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

i) Testing of various diodes, their characteristics.

ii) Testing of Bipolar Junction Transistor, Field effect transistor and their characteristics.

iii) Testing of digital oscilloscope & function generator

   i. Probe checking and calibration/adjustment/compensation.
   ii. Study of trigger menu/auto setting.
   iii. Observing waveforms of function generator O/P.

iv) Various applications of 555 timer IC.

v) Experiments on logic gates, flip flop etc.

vi) Arduino microcontroller experiments –

   i. Programs with interfacing of basic I/O devices (LEDs and Switches).
   ii. Programs with Motor control.

vii) Application based Programs with interfacing of Sensors to measure various Parameters- such as temperature, humidity etc.

Digital Circuit and Computer Architecture

Course Code & Course Title:	MALA1XX Digital Circuit and Computer Architecture		
Course Type:	DC		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	NIL		
Course Equivalence: Course Code(s) & Name(s)	NIL		

1.	**Course Objective:**

Understand, analyse and evaluate the performance of various components of digital systems of medium complexity. Understanding the computer architecture and applying the acquired knowledge to interface various programmable devices to the various Computer Architectures.

2.	**Course Outcomes:**
CO1	Ability to understand the basic concepts about the digital circuits and computer architecture
CO2	Ability to apply the acquired knowledge to analyze, design and solve the problems in the concerned area
CO3	The student should be able to build, evaluate, and propose solutions to the problems in the area of digital circuits, of medium complexity, that are based on SSIs, MSIs, and programmable logic devices

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Computer Architecture and Organization: History of the digital computer; Introduction to instruction set architecture, micro architecture and system architecture; Instruction sequencing, flow-of-control, subroutine call and return mechanisms; Structure of machine-level programs; Low-level architectural support for high level languages.		CO1, CO2	2
I/O organization: Program I/O, Interrupt I/O, DMA Hardware and software. Bus timing and design like synchronous/asynchronous etc. Standard I/O interfaces. Memory system: Addressability, Big- and Little-endian assignments. RAM organization and design. ROM and its		CO1, CO2	4

variants. Cache design, mapping and performance of the memory hierarchy. Secondary storage architecture		
Computer Arithmetic: Number Representation, Addition/Subtraction, Fast Adders, Multiplication and Fast Multiplication, Booth's algorithm, FP operations, guard bits and truncation, IEEE 754 and implementing an FP unit	CO2, CO3	3
Processing Unit: Instruction execution concepts, Single bus and multiple bus data paths, Hardwired control, Micro programmed control, Assembly Language Concepts, Macros, Assembly process, linking and loading	CO1, CO2, CO3	4

4.	**Text books**

i) C. Hamacher, Z. Vranesic and S. Zaky, Computer Organization, 5th Ed., McGraw-Hill, 2002 ISBN-13: 978-0072320862.

ii) J.P. Hayes, Computer Architecture and Organization, 3rd Ed ISBN-13: 978-0070273559.

iii) D. A. Patterson and J.L. Hennessy, Computer Organization and Design – The Hardware/Software Interface ISBN-13: 978-0080502571.

5.	**Reference Book(s) and Other Required Material**

i) William Stallings, "Computer Organization & Architecture designing for performance, 7th Ed. ISBN-13: 978-0131856448.

6.	**Evaluation Details:**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PS01	PSO2	PSO3	PSO4
CO1	3	2	-	---	1	---	---	1	---	---	---	2	3	2	3
CO2	3	2	-	---	1	---	---	1	---	---	---	2	3	2	3
CO3	3	2	-	---	1	---	---	1	---	---	---	2	3	2	3

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Introduction to Linear Algebra

Course Code & Course Title:	MALA1XX Introduction to Linear Algebra		
Course Type:	BS		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	NIL		
Course Equivalence: Course Code(s) & Name(s)	NIL		

1.	**Course Objective:**

The objective of this subject is to introduce students to the basic concepts of linear algebra and its applications to science and engineering.

2.	**Course Outcomes:**
CO1	Understand the basic concepts of linear algebra such as matrix algebra vector space, basic vector operations, basis, dimension and linear transformations, and relate matrices and linear transformations.
CO2	Compute Eigenvalues and Eigenvectors of linear transformations and obtain various variants of diagonalization of linear transformations.
CO3	Learn properties of inner product spaces and determine orthogonality in inner product spaces.
CO4	Know properties and related results of unitary, normal and self-adjoint operators.

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Review of Matrix Algebra, Row reduced Echelon form; Rank of matrix, Consistency of the system Equation Ax = b; Gauss elimination method.		CO1	1
Vector spaces over real or Complex field, bases and dimension, subspaces, direct sums.		CO1	2
Linear transformations, representation of linear transformations by matrices, geometry of linear operator on R^2 (Reflection, rotation compression, expansion and shear), rank-nullity theorem (with proof), linear functionals, transpose of linear transformations.		CO1	3

Eigenvalues and eigenvectors, some applications of eigenvalue problem, algebraic and geometric multiplicity, diagonalization, minimal polynomials, Cayley-Hamilton Theorem, invariant subspaces.	CO2	2
Norms, Inner product spaces, Gram Schmidt Theorem, orthogonal projections.	C03	2
Adjoint, self-adjoint, unitary and normal operators over finite dimension spaces, Spectral Theorem for finite dimensional operators (without proof).	CO4	2

4.	**Text books**

i) K. Hoffman and R. Kunze, Linear Algebra, Pearson Education (India), 2003. ISBN-13: 9788131702106.

ii) G. Strang, Linear algebra and its applications (4th Edition), Thomson Publications, 2006 ISBN- 978-8131501726.

iii) D W Lewis, Matrix Theory, World Scientific, 1991. ISBN-978-9810239060.

iv) Kreys. zig, E, Advanced Engineering Mathematics (Eighth Edition); John Wiley & Sons. 1998, ISBN- 978-0471154969.

5.	**Reference Book(s) and Other Required Material**

i) H. Anton, C. Rorres, Elementary Linear Algebra, 11th Edition, Wiley, New York, 2019. ISBN -978-1118434413.

ii) S. Lang, Linear Algebra, 3rd edition, Springer, 2004, ISBN- 978-0387964126.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PS01	PSO2	PSO3	PSO4
CO1	3	2	---	---	---	---	---	---	---	1	---	3	2	3	2
CO2	3	2	---	---	---	---	---	---	---	1	---	3	2	3	2
CO3	3	2	---	---	---	---	---	---	---	1	---	3	2	3	2
CO4	3	2	---	---	---	---	---	---	---	1	---	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Data Structures and Applications

Course Code & Course Title:	MALA1XX Data Structures and Applications		
Course Type:	BS		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-0	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)	NIL		
Course Equivalence: Course Code(s) & Name(s)	NIL		

1.	**Course Objective:**

Students will be able to understand the importance of data structures in computer applications and apply to practical problems.

2.	**Course Outcomes:**
CO1	To identify appropriate data structures to solve problems
CO2	To develop and analyze algorithms for practical implementations
CO3	To understand the limitations and advantages for different algorithms
CO4	To implement sorting and searching algorithms in real world scenario
CO5	To implement linked lists using pointers

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction to Iterative and Recursive Algorithms Abstract Data Types (ADTs), Implementation and Applications of Stacks, Operations and Applications of Queues, Array Implementation of Circular Queues, Implementation of Stacks using Queues, Implementation Queues using Stacks, Linked Lists, Search and Update Operations on Varieties of Linked Lists, Linked List Implementation of Stacks and Queues.		CO1, CO2, CO3, CO5	5
Introduction to Trees, Implementation of Trees, Binary Trees, Tree Traversals with an Application, Binary Search Trees (BSTs), Query and Update Operations on BSTs, AVL Trees, Rotations, Search and Update Operations on Balanced BSTs, Splay Trees, B-trees, Trie, C-Trie.		CO1, CO2, CO3, CO4	3

Hashing: Implementation of Dictionaries, Hash Function, Collisions in Hashing, Separate Chaining, Open Addressing, Analysis of Search Operations.	CO1, CO2, CO3	2
Priority Queues: Priority Queue ADT, Binary Heap Implementation and Applications of Priority Queues, Disjoint Sets.	CO2, CO3 CO4	2
Sorting Algorithms: Stability and In Place Properties, Insertion Sort, Merge Sort, Quick Sort, Heap Sort, Lower Bound for Comparison Based Sorting Algorithms.	CO2, CO3 CO4	3

4.	**Text books**

i) Ellis Horowitz, Sartaj Sahni and Sanguthevar Rajasekaran, Fundamentals of Computer Algorithms, Second Edition, Universities Press, 2011, ISBN: 9788173716126.

ii) Mark Allen Weiss, Data Structures and Algorithm Analysis in C++, Third Edition, Pearson Education, 2006, ISBN: 9780201361223.

iii) Michael T. Goodrich and Roberto Tamassia, Algorithm Design: Foundations, Analysis and Internet Examples, Second Edition, Wiley-India, 2006, ISBN: 978047138023.

v)	**Reference Book(s) and Other Required Material**

i) Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein, Introduction to Algorithms, Second Edition, PHI, 2009, ISBN: 9780262531962.

vi)	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30%, Internal Assessment: 10-20%, End semester: 50-60%

vii)	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PS01	PSO2	PSO3	PSO4
CO1	3	3	3	1	1	1	---	---	---	…	1	3	2	3	2
CO2	3	3	3	2	1	---	---	---	…	…	1	3	2	3	2
CO3	3	3	3	2	1	2	---	---	…	…	1	3	2	3	2
CO4	3	3	3	3	1	2	---	---	…	…	1	3	2	3	2
CO5	3	3	3	1	2	…	---	---	….	…	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

viii)	**List of Indicative Laboratory Experiment (if applicable):**

NA

Discrete Structures and Graph Theory

Course Code & Course Title:	MALA1XX Discrete Structures and Graph Theory		
Course Type:	BS		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	NIL		
Course Equivalence: Course Code(s) & Name(s)	NIL		

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance of Discrete Mathematical Structures in science and engineering.

2.	**Course Outcomes:**
CO1	Apply mathematical logic to solve problems and understand sets, relations, functions and discrete structures
CO2	Understand the notion of mathematical thinking, mathematical proofs, and algorithmic thinking, and be able to apply them in problem solving
CO3	Formulate problems and solve recurrence relations. Use effectively algebraic techniques to analyze basic discrete structures and algorithms
CO4	Understand some basic properties of graphs and related discrete structures and be able to model and solve real world problems using graphs and trees

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Logic: Propositions, Fundamentals of logic, first order logic, Ordered sets.		CO1	1
Graphs and planar graphs: Introduction to graph and graph modelling (Influence graph, Collaboration graph, Precedence Graph, Road map, The Web graph), Graph terminology and Special types of graphs with real life applications (Job assignment problem, interconnection networks for parallel computation), Multigraphs and weighted graphs, Paths and circuits, Shortest paths in weighted graphs (Dijkstra's Algorithm), Eulerian paths and circuits, Hamiltonian paths and circuits, Ore Theorem		CO2, CO4	4

with application. Colourable graphs, Chromatic numbers, Five colour theorem and Four-color problem.		
Trees and cut-sets: trees, rooted trees, Path lengths in rooted trees, Decision Trees, Spanning trees and BFS & DFS algorithms, Application to IP multicasting, Minimum spanning trees and Prims & Kruskal's algorithms with applications	CO4	2
Advanced Counting Techniques: Numeric functions, generating functions, Recurrence relations and recursive algorithms: Recurrence relations, Linear recurrence relations with constant coefficients, Solution by the method of generating functions.	CO3	2
Boolean algebra: Boolean Functions and representing Boolean functions, Partial and total ordering relations, Chains, Lattices and algebraic systems, Principle of duality, Basic properties of algebraic systems, Distributive and complemented lattices, Boolean lattices and algebras, Application of Boolean algebra to switching theory and storage devices (memory chip), Logic Gates, Minimization of Circuits, K-map (Up to three variables).	CO2	4

4.	**Text books**

i) K.D. Joshi: Foundations in Discrete Mathematics, New Age International, 1989. ISBN: 9788122420821.

ii) Keneth H. Rosen: Discrete Mathematics and Its Application with Combinatorics and Graph Theory, McGraw Hill Co., Seventh Edition, 2011. ISBN: 9780073383095.

iii) R. Garnier, J. Taylor: Discrete Mathematics: Proofs, Structures and Applications, CRC Press, Third Edition, 2009. ISBN: 9781439801493.

5.	**Reference Book(s) and Other Required Material**

i) E. G. Goodaire and M. M. Parmenter: *Discrete Mathematics with Graph Theory*, Prentice Hall, 2002. ISBN: 9780130656209.

ii) K. Erciyes: *Discrete Mathematics and Graph Theory: A Concise Study Companion and Guide*, Springer, 2021. ISBN: 9783030611149.

iii) S. S. Epp: *Discrete Mathematics with Applications*, Brooks/Cole, 2004. ISBN: 9780495391326.

6.	**Evaluation Details:**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PS01	PSO2	PSO3	PSO4
CO1	2	2	2	3	---	---	---	---	---	1	1	3	2	3	2
CO2	3	3	2	---	---	---	---	---	1	1	1	3	2	3	2
CO3	3	2	2	2	---	---	---	---	1	1	1	3	2	3	2
CO4	3	3	2	3	---	---	---	---	3	1	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

NA

English and Corporate Communication

Course Code & Course Title:	HULA1XX English and Corporate Communication		
Course Type:	HU		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	2-0-2	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)	HUL101		

1.	**Course Objective:**

To impart the students with the skills they need in their academics and later in their professional pursuit.

2.	**Course Outcomes:**
CO1	Acquaint learners with basic of communication
CO2	Familiarize learners with nuances of corporate communication
CO3	Emphasize the importance of verbal and non-verbal communication
CO4	Discuss key features of corporate communication
CO5	Prepare learners for workplace challenges

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction to Communication • Principles of Communication • Channels of Communication • Inclusive Communication Practices • Speaking and Listening Skills for Communication		CO1	2
Introduction to Corporate Communication • Different Forms of Corporate Communication • Factors Influencing Corporate Communication • Interpersonal Communication • Communication for Effective Leadership		CO2	2

Verbal and Non-verbal Communication • Reading and Writing Skills for Corporate Communication • Nonverbal Communication in Corporate Setting • Interview and Group Discussion • Presentation Skills	CO3	4
Features of Corporate Communication • Levels of Corporate Communication • Barriers to Communication • Organizational Communication • Dos and don'ts of corporate communication	CO4	2
Strategies of Communication • Negotiating Conflict and Management • Crisis Communication • Emotional Intelligence and Stress Management • Ethics in Corporate Communication	CO5	2

4.	**Text books**

i) Joep Cornelissen, Corporate Communication: A Guide to Theory and Practice, 6th Edition, SAGE Publications, 2020, ISBN 1526491982.

ii) Meenakshi Raman and Prakash Singh, Business Communication, 2nd Edition, Oxford University Press, 2012, ISBN 9780198077053.

iii) Shirley Taylor and V. Chandra, Communication for Business: A Practical Approach, 1st Edition, Pearson, 2010, ISBN 9788131727652.

5.	**Reference Book(s) and Other Required Material**

i) Ashraf Rizvi, Effective Technical Communication, 2nd Edition, McGraw Hill Education, 2017, ISBN 9352605780.

ii) Courtland L. Bovee, John V. Thill, et al., Business Communication Today, 14th Edition, Pearson, 2018, ISBN 9789353062682.

iii) Mary Ellen Guffey and Dana Loewy, Business Communication: Process and Product, 10th Edition, South-Western College Publishing, 2021, ISBN 0357129237.

iv) Paul A. Argenti, Corporate Communication, 7th Edition, McGraw-Hill Education, 2016, ISBN 9814636193.

v) Sharon Gerson and Steven Gerson, Technical Communication: Process and Product, 8th Edition, Pearson Education India, 2014, ISBN 9332518599.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Mid Semester Examination – 20 Marks
Teacher Defined Assessment – 20 Marks
End Semester Examination – 60 Marks

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1										3		1			
CO2									3			1			
CO3							3			3	3	1			
CO4								3				1			
CO5											3	1			

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

Week 1.	Ice Breaker	Week 2.	Oral Presentation
Week 3.	Listening Activity	Week 4.	Role Play
Week 5.	Group Discussion	Week 6.	Writing Activities
Week 7.	Peer Interview	Week 8.	PPT Presentation
Week 9.	Debate	Week 10.	Corporate Meeting
Week 11.	Case Study	Week 12.	Interviewing Strangers

Data Structures Laboratory

Course Code & Course Title:	MAPA 1XX Data Structures Laboratory		
Course Type:	DC		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	0-0-2	**No. of Credits**	1
Pre-requisites: Course Code(s) & Name(s)	NIL		
Course Equivalence: Course Code(s) & Name(s)	NIL		

1.	**Course Objective:**

Students will be able to apply data structures in computer applications and practical problems.

2.	**Course Outcomes:**
CO1	Write generic programs using the standard template library
CO2	Formulate a software application and propose an object-oriented design
CO3	Study and use design practical applications for real world scenario

3.	**Detailed Description of the Course**		
List of experiments		**CO(s) Addressed**	**Duration in weeks**
Design an application using data structure concepts for: 1. Arrays and evaluate a given postfix expression. 2. Circular queue using arrays. 3. Double ended queue (de queue) using arrays. 4. Stacks and queues. 5. (a) Single linked list (b) Double linked list 6. Stack and a queue using linked lists. 7. Binary search tree (BST) by considering the keys in given order and perform the following operations on it: (a) Minimum key (b) Maximum key (c) Search for a given key (d) Find predecessor of a node (e) delete a node with given key (f) applications of BST 8. AVL tree for the given set of keys and deleting a key from the given AVL tree.		CO1, CO2, CO3	-

9. Hashing with (a) Separate Chaining and (b) Open addressing methods. 10. Sorting algorithms: (a) Insertion sort (b) Merge sort (c) Quick sort (d) Heap sort (e) Radix sort (f) Shell sort 11. WGraph traversals by applying: (a) BFS (b) DFS 12. Minimum spanning tree of graph by applying: (a) Prim's algorithm (b) Kruskal's algorithm c) any other algorithms 13. Dijkstra's algorithm using priority queue. 14. Euler's path. 15.Biconnected components and strongly Connected components. 16. Creation, insertion, and printing functions of a Treap 17. Creation, insertion, deletion and printing functions of a Bd-Tree. 18. Creation, insertion, deletion and printing functions of Bd+-Tree, B*-Tree. 19. Creation, insertion, deletion and printing functions of a Trie. 20. Creation, insertion, deletion and printing functions of a C-Trie. 21. Mini Project.		

4.	**Text books**

i) Ellis Horowitz, Sartaj Sahni and Sangu Thevar Rajasekaran, Fundamentals of Computer Algorithms, Second Edition, Universities Press, 2011, ISBN: 9788173716126.

ii) Mark Allen Weiss, Data Structures and Algorithm Analysis in C++, Third Edition, Pearson Education, 2006, ISBN: 9780201361223.

iii) Michael T. Goodrich and Roberto Tamassia, Algorithm Design: Foundations, Analysis and Internet Examples, Second Edition, Wiley-India, 2006, ISBN: 9780471380231.

5.	**Reference Book(s) and Other Required Material**

i) Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein, Introduction to Algorithms, Second Edition, PHI, 2009, ISBN: 9780262531962.

6.	**Evaluation Details:**

Continuous Evaluation

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	2	3	2	---	---	---	1	1	3	2	3	2
CO2	3	3	3	2	3	2	---	---	---	1	1	3	2	3	2
CO3	3	3	3	2	3	2	---	---	---	1	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

i) Design a calculator application that evaluates postfix expressions using arrays.
ii) Design a Printer Job Management System using a circular queue.
iii) Develop a Task Scheduler where tasks can be inserted and removed from both ends.
iv) Implement Undo/Redo feature in a Text Editor using stacks and queues.
v) Design a Student Record Management System using singly linked list.
vi) Implement dynamic memory stack and queue using linked lists.
vii) Create a Student Marks Management System using BST.
viii) Develop a Self-balancing Student Ranking System using AVL Tree.
ix) Create a Phone Directory System using hashing.
x) Develop a Student Result Analysis System using multiple sorting algorithms.
xi) Design a Social Network Connection Explorer using graph traversal.
xii) Develop a Network Cabling Optimization System using Prim's or Kruskal Algorithm.
xiii) Create a Shortest Route Finder Application for GPS navigation system.
xiv) Design a City Road Maintenance Route Planner using Euler's path.
xv) Implement a Network Reliability Analyzer using Biconnected Components and Strongly Connected Components.

Health Information and Sports Part II

Course Code & Course Title:	SAA102 Health Information and Sports-Part II		
Course Type:	MNC		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	0-0-2	**No. of Credits**	0
Pre-requisites: Course Code(s) & Name(s)	NIL		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

i) To make the students understand the importance of doing regular physical activities and the effect of exercise on various physiological systems.

ii) To provide information about the scientific principles of training and their implications in various games & sports.

iii) To provide the basic information's about avoiding the injuries and its management.

iv) To make the students understand about the importance of physical activities & sports in managing the stress in day-to-day life.

v) To make students aware about the rules and regulation of different games & sports.

2.	**Course Outcomes:**
CO1	The students will be able to design their own physical fitness training program
CO2	The students will be able understand how to handle their stress by participating in regular physical activities
CO3	The students will follow proper exercise pattern to avoid injuries
CO4	The students will understand how yoga helps to manage stress and improve their academic performance

3.	Detailed Description of the Course		
Topics		**CO(s) Addressed**	**Duration in weeks**
Periodization: Preparatory period, competition period and transitional period.		CO1, CO2, CO3, CO4	8-12
Effects of exercise on various physiological systems.		CO1, CO2, CO3, CO4	8-12
Therapeutic exercises & therapeutic modalities.		CO1, CO2, CO3, CO4	8-12
The science of stress & it's yogic management.		CO1, CO2, CO3, CO4	8-12

4.	Practical		
Topics		**CO(s) Addressed**	**Duration in weeks**
Practice of skills of major games like: Badminton, Table Tennis, Chess, Yoga, Basketball, Football, Handball, Cricket, Kho-Kho, Lawn Tennis, Throw ball, Athletics & Kabaddi.		CO1, CO2, CO3, CO4	8-12
Participation in Intramural Sports Program.		CO1, CO2, CO3, CO4	8-12
Preparation for Physical Efficiency Test Level-2.		CO1, CO2, CO3, CO4	8-12

5.	Reference Books & other required materials

i) Skot K Powers and Edward T Howley, Exercise Physiology Theory & application to fitness and performance, 10th Edition, Mc Graw Hill Education 2015.

ii) Tudor O Bompa and G Gregory Haff, Periodization theory & methodology of training, 5th Edition, Human Kinetics 2009.

iii) William E. Prentice, Therapeutic Modalities for sports medicine & athletic training,6th Edition, Mc Graw Hill Education 2009.

6.	Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Continuous evaluation Assessment- End Semester 100%

Matrix Computations

Course Code & Course Title:	MALA 2XX Matrix Computations		
Course Type:	DC		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-0	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance of Matrix computations and its applications to science and engineering.

2.	**Course Outcomes:** After completion of this course students will be able to (theoretically and/or numerically)
CO1	Understand the vector and matrix norms, exposed to solve large linear systems by using various efficient algorithms
CO2	Deal with conditioning of linear systems and least square solutions for overdetermined and underdetermined systems
CO3	Exposed to learn efficient algorithms for finding eigenvalues of matrices
CO4	Deal with the QR factorization and Singular value decomposition (SVD) and their applications

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Matrix norm, Linear systems, LU decompositions, Gaussian elimination with partial pivoting; Banded systems, positive definite systems, Cholesky decomposition - sensitivity analysis. Gram-Schmidt orthonormal process, Householder transformation, Givens rotations; QR factorization, stability of QR factorization		CO1	3
Solution of linear least squares problems, normal equations, singular value decomposition (SVD), polar decomposition, Moore-Penrose		CO2	4

inverse; Rank deficient least-squares problems; Sensitivity analysis of least-squares problems; Review of canonical forms of matrices		
Sensitivity of eigenvalues and eigenvectors. Reduction to Heisenberg and tridiagonal forms; Power, inverse power and Rayleigh quotient iterations	CO3	3
Explicit and implicit QR algorithms for symmetric and nonsymmetric matrices; Reduction to bidiagonal form; Golub- Kahan algorithm for computing SVD	CO4	3

6.	**Text books**

i) G. H. Golub and C. F. Van Loan: Matrix Computations, 4th Ed., Johns Hopkins University Press, 2013. ISBN: 9781421407944.

ii) B. N. Datta: Numerical Linear Algebra and Applications, 2nd Ed., SIAM, 2010. ISBN: 9780898716856.

iii) L. N. Trefethen and D. Bau: Numerical Linear Algebra, 25th Anniversary Ed., SIAM, 2022. ISBN: 9781611977158.

iv) J. W. Demmel: Applied Numerical Linear Algebra, 1st Ed., SIAM, 1997. ISBN: 9780898713893.

5.	**Reference Book(s) and Other Required Material**

i) D. S. Watkins: Fundamentals of Matrix Computations, 3rd Ed., John Wiley, 2010. ISBN: 9780470528334.

ii) M. L. Overton: Numerical Computing with IEEE Floating Point Arithmetic, 2nd Ed., SIAM, 2025. ISBN: 9781611978407.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	---	1	---	---	---	---	---	---	3	2	3	2
CO2	3	2	1	---	1	---	---	---	---	---	---	3	2	3	2
CO3	3	2	1	---	1	---	---	---	---	---	---	3	2	3	2
CO4	3	2	1	---	1	---	---	---	---	---	---	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Elements of Real Analysis

Course Code & Course Title:	MALA 2XX Elements of Real Analysis		
Course Type:	DC		
Name of the programme(s):	B. Tech. in Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

This course aims to introduce students to the foundational concepts of real analysis, which are essential for the study of advanced mathematics.

2.	**Course Outcomes:**
CO1	Comprehend the essential properties of the real number system, including field and order structures, the Archimedean property, and the completeness axiom
CO2	Able to understand concepts related to sequence and series of real numbers
CO3	Understand limits, continuity and differentiability in metric spaces; learn about complete, compact and connected metric spaces
CO4	Distinguish between pointwise and uniform convergence of sequences and series of functions, and utilize major results including the Weier strass M-test, Ascoli's Theorem, and the Weier strass Approximation Theorem
CO5	Gain a deeper understanding of the Riemann and Riemann-Stieltjes integrals, while recognizing their limitations

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Field properties and order properties of the real number system, Dedekind cuts (without proof), completeness axiom, Archimedean property, infimum and supremum, finite, countable and uncountable sets.		CO1	2
Sequences of real numbers, Monotonic sequence, Bounded Sequences, Convergence of Sequence. Infinite series, tests of convergence		CO2	2

(Comparison test, Ratio test, Root test, Raabe's test, Logarithm test and Integral test statements only), absolute and conditional convergence.		
Metric spaces, open balls, open sets, subspace of a metric space, limits, continuity, uniform continuity and differentiability in metric space, sequences in metric spaces, complete metric spaces, compactness and connectedness.	CO3	3
Sequences and series of functions, pointwise and uniform convergence, Weier strass' M test, equicontinuity, pointwise and uniform boundedness, Ascoli's theorem.	CO4	3
Review of Riemann Integration, The Riemann-Stieltjes integral and its properties, limitations of Riemann Integral.	CO5	2

4.	**Text books**

i) Apostol, T., Mathematical Analysis, 2nd Edition, Narosa / Addison-Wesley, 2002, ISBN-13: 978-0201002889.

ii) Buck, R. C., Advanced Calculus, Waveland Press Incorporated, 2003, ISBN-13: 978-1 577666142.

iii) Kumaresan, S. (2005). Topology of Metric Spaces. Alpha Science International, ISBN: 978-1842652503.

iv) Ross, Kenneth A., Elementary Analysis: Theory of Calculus, 2nd Edition, Springer, 2013, ISBN-13: 978-1461462729.

v) Rudin, W., Principles of Mathematical Analysis, 3rd Edition, McGraw-Hill, 1976, ISBN-13: 978-0070542358.

vi) Simmons, G. F., Topology and Modern Analysis, Krieger Publishing, 2003, ISBN-13: 978-1575242385.

5.	**Reference Book(s) and Other Required Material**

i) Pugh, C. C., Real Mathematical Analysis, 2nd Edition, Springer, 2015, ISBN-13: 978-3319177700 (Hardcover), 978-3319330426.

ii) Stein, Elias M. and Shakarchi, Rami, Real Analysis, Princeton Lectures in Analysis, Princeton University Press, 2005 (reprint 2010), ISBN-13: 978-0691113869.

iii) Tao, Terence, Analysis I, Hindustan Book Agency, 2006. ISBN-13: 978-9386874229; and Analysis II, Hindustan Book Agency, 2006, ISBN-13: 978-9386874236.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30%, Internal Assessment: 10-20%, End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	1	1	1	---	---	---	---	1	3	2	3	2
CO2	3	3	3	2	1	2	---	---	---	---	1	3	2	3	2
CO3	3	3	3	2	1	2	---	---	---	---	1	3	2	3	2
CO4	3	3	3	3	1	2	---	---	---	---	1	3	2	3	2
CO5	3	3	3	3	1	2	---	---	---	---	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Abstract Algebra

Course Code & Course Title:	MALA 2XX: Abstract Algebra		
Course Type:	DC		
Name of the programme(s):	B. Tech Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

This course aims to introduce students to the basic concepts of abstract algebra which are essential for the study of advanced mathematics.

2.	**Course Outcomes:**
CO1	Understand fundamental concepts including groups, subgroups, normal subgroups, direct product of groups, and factor groups.
CO2	Analyze and implement the concepts of homomorphism and isomorphism between groups and rings for solving different types of algebraic problems.
CO3	Understand the basic concepts of group actions and their applications.
CO4	Apply class equations and Sylow's theorems to describe the structure of certain finite groups and to solve different problems.
CO5	Understand rings, fields and their properties.

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Review of basics: Equivalence relations, partitions, division algorithm for integers, primes, unique factorization, congruences, Euler φ-function. Fundamental Theorem of Algebra.		CO1	1
Binary operation and its properties, Groups, symmetries of a square, Dihedral group. Subgroups, Coset of a subgroup, Lagrange's theorem. Cyclic groups, generators and relations. Normal subgroups, Quotient group. Homomorphisms, Isomorphism theorems. Permutation groups, application to Rubik's cube and sliding disk puzzle, Cayley's theorems.		CO1, CO2	2-3

Group actions and Sylow theorems. Direct and semidirect product of groups, Structure theorem for finite abelian groups.	CO3, CO4	2
Ring, Examples and basic properties. Subrings, ideals, prime and maximal ideals. Quotient rings, Isomorphism theorems, Chinese remainder theorem. Ring of polynomials, factorization of polynomials, integral domain, field.	CO5	2-3
Unique Factorization Domains, Principal Ideal Domains, and Euclidean domains.	CO5	1-2

4.	**Text books**

i) Herstein, I. N.**,** Topics in Algebra, 2nd Edition, Wiley India Pvt. Ltd., 2006. ISBN-13: 978-8126500113.

ii) Gallian, J. A.**,** Contemporary Abstract Algebra, 4th Edition, Narosa Publishing House, 1999. ISBN-13: 978-8173192330.

iii) Jacobson, N.**,** Basic Algebra I, 2nd Edition, Hindustan Publishing Corporation, 1991. ISBN-13: 978-0716710433.

5.	**Reference Book(s) and Other Required Material**

i) Dummit, D. S. and Foote, R. M**.**, Abstract Algebra, 3rd Edition, John Wiley & Sons Inc., 2004. ISBN-13: 978-0471433347.

ii) Artin, M.**,** Algebra, Prentice Hall of India, 1994. ISBN-13: 978-8120305127.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Mid Sem-20%-30%, End Sem 50%-60%, Teacher Assessment Marks 10%-20%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO2	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO3	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO4	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO5	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Design and Analysis of Algorithms

Course Code & Course Title:	MALA2XX Design and Analysis of Algorithms		
Course Type:	DC		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	MAL 1XX, Data Structures and Application		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

Students will be able to understand the importance and application of design analysis and algorithms in Science and engineering.

2.	**Course Outcomes**
CO1	Analyze time and space complexities of algorithms
CO2	Identify algorithm design methodology to solve problems
CO3	Distinguish between P and NP classes of problems
CO4	Design and analyse approximation algorithms for NP-hard problems

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction to Algorithm Analysis, Asymptotic Notations, Divide and Conquer – Master Theorem		CO1, CO2	2
Maximum Element in an Unimodal Array, Maximum Subarray Sum Problem, Expected Running Time of Randomized Quick Sort		CO1, CO2	2
Strassen's Matrix Multiplication Algorithm, Karatsuba's Large Integer Multiplication, Selection in Worst Case Linear Time, Dynamic Programming - Matrix Chain Multiplication Problem, Optimal Binary Search Tree, Rod-Cutting Problem, 0-1 Knapsack Problem, Travelling Salesman Problem, All-Pairs Shortest Paths Problem,		CO1, CO2	3
Optimal Vertex Cover of a Tree, Greedy Method - Activity Selection Problem, Fractional Knapsack Problem, Correctness and Running Time		CO1, CO2	3

Analysis of Prim's and Kruskal's Algorithms for Finding Minimum Spanning Tree,		
Complexity Classes - P, NP, NP-hard, NP-complete, Example NP-complete Problems – Clique, Independent Set, Vertex Cover, Approximation Algorithms - Vertex Cover Problem	CO3, CO4	4

4.	**Text books**

i) Horowitz, Ellis; Sahni, Sartaj; and Rajasekaran, Sangu Thevar, Fundamentals of Computer Algorithms, Second Edition, Universities Press, 2011. ISBN-13: 978-8173716123.

ii) Wilf, Herbert S., Algorithms and Complexity, AK Peters Ltd., 2003. ISBN-13: 978-1568811849.

iii) Garey, Michael R. and Johnson, David S., Computers and Intractability: A Guide to the Theory of NP-Completeness, W. H. Freeman & Co., 1979. ISBN-13: 978-0716710457.

iv) Cormen, Thomas H.; Leiserson, Charles E.; Rivest, Ronald L.; and Stein, Clifford, Introduction to Algorithms, Third Edition, PHI, 2009. ISBN-13: 978-8120340074.

5.	**Reference Book(s) and Other Required Material**

https://www.algorist.com/

6.	**Evaluation Details:**

Mid Sem-20%-30%, End Sem 50%-60%, Teacher Assessment Marks 10%-20%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	---	---	1	---	---	1	---	---	---	3	2	3	2
CO2	3	2	---	---	1	---	---	1	---	---	---	3	2	3	2
CO3	3	2	---	---	1	---	---	1	---	---	---	3	2	3	2
CO4	3	2	---	---	1	---	---	1	---	---	---	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Object-Oriented Programming

Course Code & Course Title:	MALA 2XX: Object-Oriented Programming		
Course Type:	DC		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-0-0	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

Given the knowledge of procedural programming and data structure, student will be able to study the basic concepts and techniques which form the object-oriented programming paradigm, such as, encapsulation, abstraction, composition, polymorphism, inheritance, file I/O, templates, reflection, exception handling, etc. Student will be able to design software applications using object-oriented techniques and implement the applications using any of the object-oriented programming languages like C++ or Java.

2.	**Course Outcomes:**
CO1	Understand the necessity of encapsulation, data hiding, inheritance, and exception handling
CO2	Formulate a software application and propose an object-oriented design
CO3	Write generic programs using the standard template library
CO4	Study and use design tools like UML, design patterns etc

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Features of object-oriented programming languages like data encapsulation, inheritance, polymorphism and late binding. Concept of a class, Access control of members of a class, instantiating a class, static and non-static members, overloading a method.		CO1, CO2	3
Deriving a class from another class, access control of members under derivation, different ways of class derivation, overriding of a method, runtime polymorphism. Concept of an abstract class. Concept of an		CO1, CO2, CO3	5

interface. Implementation of an interface. Exception and exception handling mechanisms. Study of exception handling mechanisms in object-oriented languages.		
Introduction to streams, use of stream classes. Serialization and deserialization of objects. Templates, Implementation of data structures like linked lists, stacks, queues, trees, graphs, and hash tables etc. using object-oriented programming languages.	CO1, CO2, CO3	4
Introduction to the concept of refactoring, modelling techniques like UML, Design patterns.	CO4	2

4.	**Text books**

i) Arnold, Ken and Gosling, James, The Java Programming Language, Addison-Wesley, 2000. ISBN-13: 978-0201704332.

ii) Stroustrup, Bjarne, The C++ Programming Language, Addison-Wesley, 2013 (4th Edition). ISBN-13: 978-0321563842.

iii) Cox, Brad, Object-Oriented Programming: An Evolutionary Approach, Addison-Wesley, 1986. ISBN-13: 978-0201113714.

iv) Schildt, Herbert, C++: The Complete Reference, 4th Edition, McGraw-Hill, 2003. ISBN-13: 978-0072226805.

5.	**Reference Book(s) and Other Required Material**

i) Weisfeld, Matt, The Object-Oriented Thought Process, Pearson Education, 2008 (3rd Edition). ISBN-13: 978-0321543721.

6.	**Evaluation Details:**

Mid Sem-20%-30%, End Sem 50%-60%, Teacher Assessment Marks 10%-20%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3	PSO 4
CO 1	3	---	---	3	3	---	---	---	2	2	1	2	3	2	3
CO 2	3	---	---		3	---	---	---	2	2	1	2	3	2	3
CO 3	3	---	---	2	3	---	---	---	2	2	1	2	3	2	3
CO 4	3	---	---	3	3	---	---	---	2	2	1	2	3	2	3

8	**List of Indicative Laboratory Experiment (if applicable):**

NA

Object Oriented Programming laboratory

Course Code & Course Title:	MAPA 2XX Object Oriented Programming laboratory		
Course Type:	DC		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	0-0-2	**No. of Credits**	1
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

Students will be able to design software applications using object-oriented techniques and implement the applications using any of the object-oriented programming languages like C++ or Java.

2.	**Course Outcomes:**
CO1	To understand and apply object-oriented programming concepts such as classes, packages, and inheritance in application development
CO2	Develop programs using objects and inheritance in Java Language
CO3	Design and implement GUI programs using components in Java Language

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Design or implement an application using: 1. Classes 2. Packages 3. Inheritance 4. Stack ADT Implementation using Multiple Inheritance (Interface) 5. Array List for String Operations 6. Abstract Class 7. User Defined Exception Handling 8. File Handling 9. Multithreading		CO1, CO2, CO3	

10. Generic Function 11. User interface dialogs 12. I/O processing 13. Event Driven Programming 14. Mini Project		

4.	Text books

i) Schildt, Herbert, Java 2: The Complete Reference, Tata McGraw-Hill (TMH), 2010, ISBN-13: 978-0070701403.

ii) Budd, Timothy, Object-Oriented Programming with Java, Updated Edition, Pearson Education, 2009, ISBN-13: 978-8131720245.

5.	Reference Book(s) and Other Required Material

i) Weisfeld, Matt, The Object-Oriented Thought Process, Pearson Education, 2008 (3rd Edition), ISBN-13: 978-0321543721.

6.	Evaluation Details:

Continuous Evaluation

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3	PSO 4
CO 1	2	---	2	3	3	---	---	---	---	1	1	2	3	2	3
CO 2	2	---	2	3	3	---	---	---	---	1	1	2	3	2	3
CO 3		---	---	---	---	---	---	---	---	---	---	2	3	2	3

8.	List of Indicative Laboratory Experiment (if applicable):

i) Write a Java program to create a class Student with data members and member functions to display student details.

ii) Write a Java program to create and use packages for performing arithmetic operations.

iii) Write a Java program to demonstrate inheritance by creating a base class Person and derived classes Student and Employee.

iv) Write a Java program to implement Stack ADT using interface demonstrating multiple inheritance.
v) Write a Java program using Array List to perform String operations such as insertion, deletion, searching, and displaying elements.
vi) Write a Java program demonstrating abstract class and abstract methods to calculate the area of different shapes.
vii) Write a Java program to implement user defined exception handling for invalid input.
viii) Write a Java program to demonstrate file handling operations (create, read, write, and append data to a file).
ix) Write a Java program to implement multithreading using Thread class or Runnable interface.
x) Write a Java program to demonstrate generic function / generic class.
xi) Write a Java program to create user interface dialogs using JOptionPane (Message dialog, Input dialog, Confirm dialog).
xii) Write a Java program to perform input and output processing using streams.
xiii) Write a Java program to demonstrate event driven programming using GUI components such as button click events.

Ordinary Differential Equations

Course Code & Course Title:	MALA 2XX Ordinary Differential Equations		
Course Type:	DC		
Name of the programme(s):	B.Tech. in Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance of ordinary differential equations in science and engineering.

2.	**Course Outcomes:** After completing this course students will be able to
CO1	Solve the first order differential equations with applications in science and engineering.
CO2	Solve the higher order constant co-efficient linear differential equations along with the applications.
CO3	Find power series solutions to ordinary differential equations, analyze types of singularities and solutions at a singular point.
CO4	Solve two-point BVPs using Green's functions technique and Sturm-Liouville boundary value problems.

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
First order differential equations: Exact equation, Integrating factors, Reducible to exact differential equations, Linear equations, Bernoulli's form, Riccati equation, Clairaut's equation, orthogonal trajectories, Applications: Law of natural growth, natural decay, Newton's law of cooling, simple electric circuits. Existence and Uniqueness of solutions. Picard's theorem, Picard's iteration method of solution.		CO1	3
Solutions of second and higher order linear equations with constant coefficients, Linear independence and dependence and Wronskian, Method of variation of parameters, Solution of Cauchy's equation, Method of reduction of order, simultaneous linear equations. Applications		CO2	4

of linear differential equations: Simple harmonic motion, RLC circuit, simple pendulum, Mass Spring mechanical systems.		
Series solutions for ODEs: Regular and singular points, Frobenius method, Legendre polynomials, Chebyshev polynomials, Bessel functions (generating functions, orthogonal properties and recurrence relations).	CO3	4
Boundary value problems: Sturm-Liouville problems, Green's functions approach.	CO4	2

4.	**Text books**

i) Coddington, E. A. An Introduction to Ordinary Differential Equations — Prentice-Hall, 1974, ISBN: 9780486659428.

ii) Jain, R. K.; Iyengar, S. R. K. Advanced Engineering Mathematics (5th Edition) — Narosa Publishers, 2022, ISBN: 9788184875607.

iii) Ross, S. L. Differential Equations, 3rd Edition — Wiley, 1984, ISBN: 9788126515370.

iv) Simmons, G. F. Differential Equations with Applications and Historical Notes — McGraw Hill, 1991 (3rd ed. 2016), ISBN: 9781315371825.

5.	**Reference Book(s) and Other Required Material**

i) Deo, S. G.; Raghavendra, V.; Kar, R.; Lakshmikantham, V. Textbook of Ordinary Differential Equations (3rd Edition) — Tata McGraw Hill, 2017, ISBN: 9789339219307.

ii) Nandakumaran, A. K.; Datti, P. S.; George, Raju K. Ordinary Differential Equations: Principles and Applications — Cambridge University Press, 2017, ISBN: 9781107196633.

iii) Somasundaram, D. Ordinary Differential Equations: A First Course — Narosa Publishers, 2002, ISBN: 9781842650691.

6.	**Evaluation Details:**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3	PSO 4
CO 1	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO 2	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO 3	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO 4	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Introduction to Complex Analysis

Course Code & Course Title:	MALA 2XX Introduction to Complex Analysis		
Course Type:	DC		
Name of the programme(s):	B. Tech. in Mathematics and Computing		
L – T – P	3-0-0	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The course is designed to introduce students to the core principles of complex analysis.

2.	**Course Outcomes:**
CO1	Comprehend the topology of the complex plane and understand stereographic projection; grasp the concepts of limits, continuity of complex functions, & be introduced to complex exponential, logarithmic and trigonometric functions
CO2	Understand differentiability of complex functions, get introduced to holomorphic functions, study Möbius transformations as special examples of holomorphic functions & study branches of logarithms
CO3	Learn about complex integration and study various notions and results related to it
CO4	Analyse singularities, Cauchy's Residue theorem, Rouche's theorem, open mapping theorem, and the maximum modulus principle

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Topology of the complex plane, stereographic projection, limits and continuity of complex functions, complex exponential, logarithmic and trigonometric functions.		CO1	2 -3
Differentiability, Cauchy-Riemann equations, sufficient conditions for differentiability, holomorphic functions, Möbius transformations as special examples of holomorphic functions, properties of Möbius transformations, conformal mappings. harmonic functions, branches of the logarithm.		CO1, CO2	3-4

The complex integral, Cauchy's theorem, Cauchy integral formula, Morera's theorem, Liouville's theorem, maximum modulus principle, Schwarz lemma, open mapping theorem,	CO3, CO4	3-4
Convergence of series of complex numbers, Taylor's Series, Laurent's Series, singularities, classification of singularities, Cauchy's Residue theorem, behaviour of a function near singularities including the Casorati Weier strass theorem, evaluation of real integrals, argument principle, Rouche's theorem.	CO3, CO4	3-4

4.	**Text books**

i) Sarason, D., Complex Function Theory, Hindustan Book Agency, 2008. ISBN-13: 978-8185931986.

ii) Stein, E. M. and Shakarchi, R., Complex Analysis, Princeton University Press, 2003. ISBN-13: 978-0691113852.

iii) Conway, J. B., Functions of One Complex Variable, Springer-Verlag, 1978. ISBN-13: 978-0387903286.

iv) Brown, J. W. and Churchill, R. V., Complex Variables and Applications, McGraw-Hill, 2008. ISBN-13: 978-0073318707.

5.	**Reference Book(s) and Other Required Material**

i) Ahlfors, L. V., Complex Analysis, McGraw-Hill, 1966 (3rd Edition). ISBN-13: 978-0070006577.

ii) Greene, R. E. and Krantz, S. G., Function Theory of One Complex Variable, American Mathematical Society, 2006. ISBN-13: 978-0821839624.

iii) Ponnusamy, S. and Silverman, H., Complex Variables with Applications, Birkhäuser, 2006. ISBN-13: 978-0817643718.

iv) Gamelin, T. W., Complex Analysis, Springer-Verlag, 2001. ISBN-13: 978-0387950693.

v) Rudin, Walter, Real and Complex Analysis, McGraw-Hill, 1987 (3rd Edition). ISBN-13: 978-0070542341.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	1	…	2	1	1	…	…	1	3	2	3	2
CO2	3	1	1	1	…	1	2	1	…	…	1	3	2	3	2
CO3	2	1	2	2	1	1	2	1	1	…	1	3	2	3	2
CO4	3	3	1	2	…	1	1	1	1	1	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Applied Numerical Analysis and Scientific Computing

Course Code & Course Title:	MALA 2XX Applied Numerical Analysis and Scientific Computing		
Course Type:	DC		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-0	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)	MAL 203		

1.	**Course Objective:**

The objective of this subject is to make the students aware of the numerical methods for the solution of scientific problems which cannot be solved analytically.

2.	**Course Outcomes (Min. 3 & Max. 5):** Upon completion of the course, students would be able to:
CO1	Apply various numerical techniques to solve algebraic and transcendental equations
CO2	Solve systems of linear and nonlinear equations
CO3	Know the interpolation and approximation techniques
CO4	Exploit numerical integration techniques
CO5	Design and implement numerical methods to approximate the solutions of initial value problems and boundary value problems

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Overview of Numerical Analysis: Role of numerical methods in computing, Error analysis: absolute, relative, truncation, and round-off errors. Computer Arithmetic and Error Propagation: Floating-point representation, Error propagation in computations. Root-Finding for Nonlinear Equations: Bisection method, Secant method, Regula-Falsie method, Newton-Raphson method and its variants, Convergence analysis of methods.		CO1	3
Systems of Nonlinear Equations: Newton's method.		CO2	2

Direct Methods for Solving Linear Systems: Gaussian elimination, LU decomposition, Pivoting strategies and error analysis. Iterative Methods for Linear Systems: Jacobi, Gauss-Seidel, Convergence of iterative methods.		
Polynomial Interpolation: Lagrange interpolation, Newton's divided difference, Error analysis in polynomial interpolation Spline Interpolation: Piecewise linear and Cubic splines. Approximation of Functions: Least squares approximation, Chebyshev approximation	CO3	3
Numerical Differentiation: Finite difference approximations, Higher-order derivatives and error estimation Numerical Integration: Trapezoidal rule, Simpson's rule, Romberg integration, Gaussian quadrature.	CO4	2
Numerical Solutions to Initial Value Problems (IVPs) and Boundary value problems (BVPs): IVPs: Euler's method, Improved Euler, and Runge-Kutta methods, predictor and corrector scheme, stability and convergence analysis. BVPs: finite difference methods with convergence results.	CO4	3

4.	**Text books**

i) Atkinson, D. Numerical Analysis, 2nd Edition, John Wiley & Sons, 2009, ISBN: 978-0471624899.

ii) Burden, Richard L. and Faires, J. Douglas Numerical Analysis, 9th Edition, Cengage Learning, 2012, ISBN: 978-0538733519.

iii) Conte, S.D. and De Boor, C. Elementary Numerical Analysis*: An Algorithmic Approach*, 3rd Edition, McGraw-Hill, 1981, ISBN: 978-0070124479.

iv) Gerald, C.F. and Wheatley, P.O. Applied Numerical Analysis, 7th Edition, Addison-Wesley, 1994, ISBN: 978-0201545540.

v) Jain, M.K., Iyengar, S.R.K., and Jain, R.K. Numerical Methods for Engineers and Scientists, 5th Edition, New Age International, 2008, ISBN: 978-8122427074.

vi) Stoer, Josef and Bulirsch, Roland Introduction to Numerical Analysis, 2nd Edition, Springer-Verlag, 1993, ISBN: 978-0387977080.

vii) David Kincoid and Ward Cheney, Numerical Analysis Mathematics of Scientific Computing, American Mathematical Society, 2009**,** ISBN 978-0821847886**.**

5.	**Reference Book(s) and Other Required Material**

i) Chapra, Steven C. and Canale, Raymond P. *Numerical Methods for Engineers*, 7th Edition, McGraw-Hill Education, 2015, ISBN: 978-0073397924.

ii) Eriksson, K., Estep, D., Hansbo, P., and Johnson, C. Computational Differential Equations, Cambridge University Press, 1996, ISBN: 978-0521623501.

iii) Golub, G.H. and Ortega, J.M. Scientific Computing and Differential Equations: An Introduction to Numerical Methods, Academic Press, 1992, ISBN: 978-0122892557.

iv) Rajaraman, V. Computer Oriented Numerical Methods, 3rd Edition, Prentice Hall of India, 1993, ISBN: 978-8122404341.

6.	**Evaluation Details:**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3	PSO 4
CO 1	3	3	2	3	3	---	---	---	---	---	1	3	2	3	2
CO 2	3	3	2	3	3	---	---	---	---	---	1	3	2	3	2
CO 3	3	3	2	3	3	---	---	---	---	---	1	3	2	3	2
CO 4	3	3	2	3	3	---	---	---	---	---	1	3	2	3	2
CO 5	3	3	2	3	3	---	---	---	---	---	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Theory of Computation

Course Code & Course Title:	MALA2XX, Theory of Computation		
Course Type:	DC		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-0	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

Objective of the course is to develop among students' ability to model computation, understand the limitations of each model of computation and also to know the applicability of the model of computation to different problems.

2.	**Course Outcomes:**
CO1	Given a language the student can find the appropriate machine for recognition of that language. The student is able to convert machines to grammar and vice versa
CO2	The student gains knowledge about the hierarchy of languages
CO3	The student develops analytical thinking and intuition for problem solving
CO4	The student is able to show whether a given problem is solvable or unsolvable

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Preliminaries - Sets, operations, relations, transitive closure, countability and diagonalization, induction and proof methods- pigeon-hole principle and simple applications - concept of language - grammars and production rules - Chomsky hierarchy.		CO1	2
Regular grammars, deterministic finite automata - non determinism, conversion to deterministic automata- e-closures, regular expressions, finite automata, regular sets.		CO1, CO2	3
Pump lemma for regular sets- closure properties of regular sets, decision properties for regular sets, minimization of automata.		CO1, CO2	2

Context - free languages, parse trees and ambiguity, reduction of CFGS, Chomsky and Griesbach normal forms, push - down Automata (PDA), non-determinism, acceptance by two methods and their equivalence, CFLs and PDAs – Pumping lemma for context free languages, Closure and decision properties of CFLs.	CO1, CO2, CO3	3
Timing machines – variants, recursively enumerable (R.E.) sets, recursive sets, TM as computer of function, decidability and solvability, Halting Problem, reductions, Post correspondence Problem (PCP) and insolvability of ambiguity problem of CFGs.	CO2, CO3CO4	2
Introduction to recursive function theory - primitive recursive and partial recursive functions Church Turing thesis - convergence of viewpoints of what "compatibility" is: Semi formal treatment.	CO2, CO3CO4	2

4.	**Text books**

i) Martin, John C., Introduction to Languages and the Theory of Computation, Tata McGraw-Hill (TMH), 2003, ISBN-13: 978-0070660489.

ii) Hopcroft, John E.; Motwani, Rajeev; and Ullman, Jeffrey D., Introduction to Automata Theory, Languages, and Computation, Pearson Education, 2006 (3rd Edition), ISBN-13: 978-0321455369.

5.	**Reference Book(s) and Other Required Material**

i) Dexter C. Kozen Theory of Computation Springer 2006, ISBN 9781846282973.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3	PSO 4
CO 1	3	2	0	3	1	0	0	2	0	0	0	2	3	2	3
CO 2	3	3	0	3	1	0	0	2	0	0	0	2	3	2	3
CO 3	3	3	0	0	0	0	0	0	3	0	0	2	3	2	3
CO 4	3	2	0	0	0	0	3	2	3	0	0	2	3	2	3

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Probability Theory

Course Code & Course Title:	MALA2XX Probability Theory		
Course Type:	DC		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-0	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this course is to expose students to understand the importance of probability theory along with real life applicability.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Understand the concept of probability and their applications in real life, engineering and industrial problems
CO2	Understand various significant concepts of probability such as moments, joint distributions etc
CO3	Be able to use the concept of special discrete and continuous probability distributions
CO4	Understand the concept of transformations of random variables and the notion of central limit theorem

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Basic concept: Classical definition and its restriction, Axiomatic definition, Conditional probability, Pairwise and mutual independence of events, Theorem of total probability, Baye's theorem and applications		CO1	2
Random variables and moments (one & two dimensional): Random variables, Probability mass and density function, Cumulative distribution function, Joint mass and density functions, Expectation, Variance, Other moments, Joint moments, Marginal distributions, Covariance, Correlation, Moment generating function, Characteristic function, Chebyshev inequality, Markov inequality		CO2	3

Discrete probability distributions: Discrete uniform, Bernoulli, Binomial, Multinomial probability law, Asymptotic behaviour of Binomial, Poisson, Geometric, Negative binomial, Hypergeometric, Asymptotic behaviour of hypergeometric, Real-life applications of those distributions		
Continuous probability distribution: Uniform, Exponential, Gamma, Hyper-exponential, Beta, Laplace, Triangular, Normal, Log-normal, Rayleigh, Weibull, Real-life applications of those distributions	CO3	3
Transformation of random variables: Sum, product and division of random variables, Transformation for single and multi-dimensional cases, Distribution of order statistics, Expectation vectors and covariance matrices and its properties, Application in image processing	CO4	3
Convergences: Convergence in probability, Convergence in distribution, Mean square convergence, almost sure convergence, Weak and strong law of large numbers, Central limit theorem and its practical applicability	CO4	2

4.	**Text books**

i) Miller, I. and Freund, J., Probability and Statistics for Engineers, Pearson Education, 2005. ISBN-13: 978-0134179678.

ii) Rohatgi, V. K. and Ehsanes Saleh, A. K. M., An Introduction to Probability and Statistics, John Wiley & Sons, 2004. ISBN-13: 978-0471457947.

iii) Soong, T. T., Fundamentals of Probability and Statistics for Engineers, John Wiley & Sons Ltd., New York, 2004. ISBN-13: 978-0470868133.

iv) Stark, H. and Woods, J., Probability and Random Processes with Applications to Signal Processing, Prentice Hall, New Jersey, 2002. ISBN-13: 978-0130488313.

5.	**Reference Book(s) and Other Required Material**

i) Papoulis, A. and Pillai, S. U., *Probability, Random Variables, and Stochastic Processes*, McGraw-Hill, 2002. ISBN-13: 978-0071226613.

6.	**Evaluation Details:**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3	PSO 4
CO 1	3	3	2	2	---	1	---	---	---	---	---	3	2	3	2
CO 2	3	3	2	2	---	1	---	---	---	---	---	3	2	3	2
CO 3	3	3	2	2	---	1	---	---	---	---	---	3	2	3	2
CO 4	3	3	2	2	---	1	---	---	---	---	---	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Applied Numerical Analysis and Scientific Computing Laboratory

Course Code & Course Title:	MAPA2XX Applied Numerical Analysis and Scientific Computing Laboratory		
Course Type:	DC		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	0-0-2	**No. of Credits**	1
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to introduce students to use MATLAB programming for numerical computation of approximate solutions and also exposure to public domain packages like LINPACK and ODEPACK.

2.	**Course Outcomes:** Upon completion of the course, students would be able to write the MATLAB program to:
CO1	Apply various numerical techniques to solve algebraic and transcendental equations
CO2	Solve systems of linear and nonlinear equations
CO3	Know the interpolation and approximation techniques
CO4	Exploit numerical integration techniques
CO5	Find approximate the solutions of initial value problems and boundary value problems

3.	**Detailed Description of the Course**		
	Topics	**CO(s) Addressed**	**Duration in weeks**
	1. Solution of algebraic and transcendental equations (i) Regula-falsi method when interval is given (ii) Regula-falsi method when interval is not given (iii) Newton-Raphson method when initial approximation is given (iv) Newton-Raphson method when initial approximation is not given	CO1	3
	2. Solution of system of linear equations by Gaussian elimination method 3. Solution of system of linear equations by Gauss-Seidel iteration method	CO2	2

4. Solution of Tridiagonal system by Thomas algorithm		
5. Finding the value of a function using Lagrange interpolation, Cubic Spline interpolation	CO3	2
6. Numerical integration (i) Trapezoidal rule (ii) Simpson's 1/3 rule (iii) Simpson's 3/8 rule (iv) Gauss Legendre quadrature	CO4	2
7. Euler's and modified Euler's methods, Runge-Kutta methods, predictor and corrector scheme 8. Finite difference methods	CO4	2

4.	Text books

i) Chapra, Steven C. and Canale, Raymond P. Numerical Methods for Engineers, 7th Edition, McGraw-Hill Education, 2015, ISBN: 978-0073397924.

ii) Eriksson, K., Estep, D., Hansbo, P., and Johnson, C. Computational Differential Equations, Cambridge University Press, 1996, ISBN: 978-0521623501.

iii) Golub, G.H. and Ortega, J.M. Scientific Computing and Differential Equations: An Introduction to Numerical Methods, Academic Press, 1992, ISBN: 978-0122892557.

iv) Burden, Richard L. and Faires, J. Douglas Numerical Analysis, 9th Edition, Cengage Learning, 2012, ISBN: 978-0538733519.

v) David Kincoid and Ward Cheney, Numerical Analysis Mathematics of Scientific Computing, American Mathematical Society, 2009**,** ISBN 978-0821847886**.**

vi) Gerald, C.F. and Wheatley, P.O. Applied Numerical Analysis, 7th Edition, Addison-Wesley, 1994, ISBN: 978-0201545540.

vii) Rajaraman, V. Computer Oriented Numerical Methods, 3rd Edition, Prentice Hall of India, 1993, ISBN: 978-8122404341.

5.	Reference Book(s) and Other Required Material

i) Atkinson, D. Numerical Analysis, 2nd Edition, John Wiley & Sons, 2009, ISBN: 978-0471624899.

ii) Conte, S.D. and De Boor, C. Elementary Numerical Analysis*:* An Algorithmic Approach, 3rd Edition, McGraw-Hill, 1981, ISBN: 978-0070124479.

iii) Stoer, Josef and Bulirsch, Roland Introduction to Numerical Analysis, 2nd Edition, Springer-Verlag, 1993, ISBN: 978-0387977080.

iv) Jain, M.K., Iyengar, S.R.K., and Jain, R.K. Numerical Methods for Engineers and Scientists, 5th Edition, New Age International, 2008, ISBN: 978-8122427074.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3	PSO 4
CO 1	3	3	2	3	3	---	---	---	---	---	1	3	2	3	2
CO 2	3	3	2	3	3	---	---	---	---	---	1	3	2	3	2
CO 3	3	3	2	3	3	---	---	---	---	---	1	3	2	3	2
CO 4	3	3	2	3	3	---	---	---	---	---	1	3	2	3	2
CO 5	3	3	2	3	3	---	---	---	---	---	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

i) Solution of algebraic and transcendental equations:
ii) Bisection method, Secant method, Regula-Falsi method, Newton-Raphson method
iii) System of linear equations:
iv) Gauss-Seidel method, Inverse of a matrix/Gaussian elimination etc.
v) Interpolation:
vi) Lagrange interpolation, Cubic splines.
vii) Numerical integration:
viii) Trapezoidal rule, Simpson's rule, Romberg integration, Gaussian quadrature.
ix) Numerical solution of IVPs:
x) Euler's and modified Euler's methods, Runge-Kutta methods, predictor and corrector scheme
xi) Numerical solution of BVPs:
xii) Finite difference methods

Economics for Engineers

Course Code & Course Title:	HULA- 2XX **Economics for Engineers**		
Course Type:	DE		
Name of the programme(s):	B Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

Students will be able to understand the importance and application of Economics in evaluating costs and benefits associated with projects related to engineering field.

2.	**Course Outcomes:** On successful completion of the course, students will be able to:
CO1	Understand basic tools of Economics that determines equilibrium output and price
CO2	Learn about the concept of revenue, cost and profit maximization
CO3	Comprehend the macroeconomic environment with concepts like inflation and growth
CO4	Evaluate projects based on time value of money
CO5	Estimate depreciation using standard methods

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Engineering Economics- Nature, Scope, Basic problems of an economy, Micro Economics and Macro Economics. Demand, Supply and Markets- Meaning of demand, Demand function, Law of Demand and its exceptions, Determinants of demand, Supply- Meaning of supply, Law of supply and its exception, Determinants of supply, Determination of market equilibrium, Measurements of Elasticity of Demand & Supply.		CO1	3
Theory of Production and Cost- Production function, Laws of returns: Law of variable proportion, Law of returns to scale, Cost and revenue concepts, Basic understanding of different market structures,		CO2	3

Determination of equilibrium price under perfect competition, Break Even Analysis-linear approach.		
Circular flow model of the economy; National Income- Definition, Concepts of national income, Methods of measuring national income. Inflation-Meaning of inflation, types, causes, measures to control inflation. The Balance of payments and exchange rate.	CO3	3
Time value of money- Interest - Simple and compound, nominal and effective rate of interest, Cash flow diagrams, Principles of economic equivalence. Evaluation of engineering projects-Present worth method, Future worth method, Annual worth method, Internal rate of return method, Cost benefit analysis for public projects.	CO4	3
Depreciation- Depreciation of capital asset, causes of depreciation, Methods of calculating depreciation (Straight line method, Declining balance method), After tax comparison of project.	CO5	2

4.	**Text books**

i) D N Dwivedi, "Managerial Economics", Vikas Publishing House Private Limited, 2018.
ii) McEachern W.A. and Kaur Simrit, "Principle of Microeconomics", Cengage Publication.
iii) R. Panneerselvam, "Engineering Economics", PHI Learning Pvt. Ltd., 2020.
iv) R.K Sharma and Sashi K Gupta, "Financial Management", Kalyani Publications.
v) William G. Sullivan, Elin M.Wicks, C. Patric Koelling, "Engineering Economy", Pearson.

5.	**Reference Book(s) and Other Required Material**

i) Capitaline Plus Database – http://www.capitaline.com/
ii) Database of Indian Economy - http://dbie.rbi.org.in
iii) Ministry of Finance – http:/finmin.nic.in/

6.	**Evaluation Details:**

Mid Sem. Exam: 20-30, Teacher Defined Assessment: 20, End Sem. Exam: 50-60

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental of Mathematics)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3	PSO 4

CO 1	2	2	---	---	---	---	---	---	---	---	---	2	3	2	3
CO 2	2	3	---	---	---	---	---	---	---	---	---	2	3	2	3
CO 3	1	2	---	---	---	---	---	---	---	---	---	2	3	2	3
CO 4	2	3	---	---	---	---	---	---	---	---	---	2	3	2	3
CO 5	2	3	---	---	---	---	---	---	---	---	---	2	3	2	3

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Neuro Fuzzy Techniques

Course Code & Course Title:	CSL304: Neuro Fuzzy Techniques (NFT)		
Course Type:	DE		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	CSL213 & CSL214: Data Structure & Program Design I & II		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

Introduce students to soft computing concepts and techniques and foster their abilities in designing and implementing soft computing-based solutions for real-world problems.

2.	**Course Outcomes:**
	Understand the concepts and architecture of neuro fuzzy techniques (Comprehension - Level 2) • Explain the fundamental principles of fuzzy logic and neural networks. • Describe how membership functions, fuzzy rules, and inference mechanisms work. • Illustrate the architecture of neuro-fuzzy models, including Adaptive Neuro-Fuzzy Inference System (ANFIS). • Summarize the advantages and limitations of neuro-fuzzy systems compared to standalone neural networks or fuzzy logic systems.
	Apply neural network and fuzzy concepts to real problems (Application - Level 3) • Implement fuzzy inference systems and neural networks in Python or MATLAB. • Develop simple neuro-fuzzy models for classification, regression, and decision-making tasks. Train ANFIS models on real-world datasets and interpret the results. Apply neuro-fuzzy techniques to solve practical problems in domains such as healthcare, automation, finance, and robotics.
	Design and analyze different methods using neural network and fuzzy inference system (Analysis - Level 4) • Compare different neuro-fuzzy architectures, such as hybrid vs. cooperative models. • Examine the effect of various learning algorithms on neuro-fuzzy model performance.

	• Differentiate between membership function types and their impact on system accuracy.

3.	Detailed Description of the Course		
Topics		**CO(s) Addressed**	**Duration in weeks**
Neural Networks: History, overview of biological neuro-system, mathematical models of neurons, ANN architecture		CO1	1
Learning rules, Learning Paradigms-Supervised, Unsupervised and reinforcement Learning		CO1, CO2	1
Learning Tasks, ANN training Algorithms-Single layer perceptron		CO1, CO2	1
Multi-layer perceptron , Learning Rules		CO1, CO2	2
Self-organizing Map		CO1, CO2	1
Applications of Artificial Neural Networks.		CO2, CO3	1
Introduction to fuzzy set,		CO2, CO3	1
Operations on fuzzy sets,		CO2, CO3	1
Fuzzy relation		CO2, CO3	1
Fuzzy implication,		CO2, CO3	1
Approximate reasoning, Fuzzy rule-based systems,		CO2, CO3	1
Fuzzy reasoning schemes		CO2, CO3	1/2
Fuzzy logic controller.		CO3	1/2
Implementing fuzzy IF-THEN rules by trainable neural nets.		CO3	1/2
Fuzzy neurons, Hybrid neural networks,		CO3	1/2
Neuro-fuzzy classifier		CO3	1/2

4.	Text books

i) Timothy Ross, Fuzzy Logic with Engineering Applications; McGraw-Hill.

ii) Simon Haykin, Neural Network: A Comprehensive Foundation; PHI Learning.

5.	Reference Book(s) and Other Required Material

i) Bar Kosko, Neural Networks and Fuzzy Systems: PHI Learning.

ii) Kishan Mehtrotra, S. Ranka, Penram, Elements of artificial Neural Networks: International Publishing (India).

iii) Roger Jang, Tsai Sun, Neuro-Fuzzy and Soft Computing: A computational Approach to Learning & Machine Intelligence, PHI Learning.

iv) R.A. Aliev, R.R. Aliev, Soft Computing and Its Applications: World Scientific Publishing.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

The instructor uses the following methods: One mid semester, one end-semester examination and assignments.

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3	PSO 4
CO 1	3	3	---	---	---	---	---	---	---	---	---	1	1	1	1
CO 2	2	3	---	---	2	---	---	---	---	---	---	1	1	1	1
CO 3	2	3	---	---	2	---	---	---	---	---	---	1	1	1	1

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

i) Design an application using a back propagation algorithm to recognize handwritten characters from A to Z and digits 0 to 9.

ii) Design an application for binary classification using perceptron learning algorithm.

iii) Design an application for binary classification using Adaline learning algorithm.

iv) Implement a neural network to generate solutions for the 8-Queens problem.

v) Implement a neural network program to play 5× 5 Tic tac toe games. The program should use the least squares learning rule.

vi) Design a neural network for handwritten character recognition problems for A to Z and 0 to 9 digits.

vii)Design an application using self-organizing map.

viii) Design an application using neural network concepts for time series data.

ix) Design an application using Error back propagation Algorithm.

x) Design a Convolutional network for image recognition problems.

Computer Networks

Course Code & Course Title:	CSL317 Computer Networks		
Course Type:	DC		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

To provide students with a clear understanding of modern computer networking—from real-world application protocols down through transport, routing and link layers—using a top-down methodology that balances conceptual foundations with practical hands-on experience.

2.	**Course Outcomes:**
CO1	Build an understanding of the fundamental concepts of computer networking
CO2	Familiarity with the basic protocols of computer networks, and how they can be used to assist in network design and implementation
CO3	To understand internals of main protocols such as TCP, UDP, IP, HTTP, DNS, DHCP, SMTP
CO4	To determine proper usage of the IP address, subnet mask and default gateway in a routed network
CO5	Routing protocols such as distance vector, RIP, Link state, BGP

3. Detailed Description of the Course		
Topics	**CO(s) Addressed**	**Duration in weeks**
Introduction to Computer Networks, Internet	CO1	1
OSI/ISO, TCP/IP Models, Types of Delays	CO1	1
Application Layer Protocols (HTTP, DNS, SMTP, POP, FTP)	CO1, CO2, CO3	3
Transport Layer (TCP/UDP)	CO2, CO3	3

Network Layer (IP Addressing, Routing Protocols, BGP)	CO2, CO3, CO4	3
Link Layer (Sliding Window Protocols, LAN Technologies, Access Control protocols)	CO1, CO2, CO5	3

4.	Text books:

i) James F. Kurose and Keith W. Ross: Computer Networking a Top-Down Approach Featuring the Internet, 3rd Edition.

ii) Peterson, Simon, "Computer Networks: A Systems Approach", Pearson Education, Asia.

5.	Reference Book(s) and Other Required Material

i) Douglas Comer, "Computer Networks and Internets", Addison Wesley 2nd Edition.

ii) Peterson, Davie, "Computers Networks", Elsevier 3rd EditionC.

iii) Simon Haykin, "Communication Systems", John Wiley 4th Edition.

iv) Tanenbaum A. S, "Computer Networks", PHI 4th Edition.

v) William Stallings, "Data and Computer Communications", PHI 6th Edition.

6.	Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Lab Evaluation -30%, Mid Sem Evaluation -20%, End Sem Evaluation -50%

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	1	1	3	3	---	3	1	---	2	---	---	2	2	3	3
CO2	3	2	1	3	1	---	2	---	1	2	---	2	3	3	3
CO3	---	2	---	---	2	---	---	---	1	---	1	2	2	2	3
CO4	3	3	2	1	3	---	3	---	2	---	---	2	3	3	3
CO5	---	3	1	---	3	1	3	---	---	2	3	2	3	3	3

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

i) Understand the workings of wire shark and using it to capture packets while communicating to different sites. This capture should then be analysed to observe protocol data packets and answer related queries.

ii) Implementing different types of client-server systems: the client will be a calculator server; there will be four versions of server a) single processor server b) multi-threaded server c) single process server that uses the "select" method and d) echo server

iii) Implementing the Distance Vector Routing protocol: Since it follows a decentralized approach, this algorithm will be implemented via multithreading in Python. Each thread will represent a router instance. The threads (routers) will communicate through a shared queue. The output should initially display the routing tables of each router. The routing tables should be updated periodically and should be displayed on the terminal.

iv) Understanding the various mechanisms of TCP using simulations. Simulations of TCP transfers will be done in the ns-3 network simulator. The output of the simulations will be analysed to answer various questions about TCP behaviour.

Operating Systems

Course Code & Course Title:	CSL309 Operating Systems		
Course Type:	DC		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	CSL 2xx: Data Structures and Program Design, CSL 2xx Computer Architecture and Organization		
Course Equivalence: Course Code(s) & Name(s)	NIL		

1.	**Course Objective:**

Given the knowledge of digital circuits, computer organization and data structures, a student will be able to study and apply concepts relating to operating systems, such as CPU and memory virtualization, concurrency issues and synchronization primitives, processes, deadlocks, disk scheduling and file system implementation and organization.

2.	**Course Outcomes:**
CO1	Understand basics of operating systems - its structure, roles, design goals etc
CO2	Demonstrate understanding of CPU virtualization and Memory virtualization and implement related concepts
CO3	Demonstrate understanding of concurrency issues, relevant synchronization primitives and apply them to solve such issues in relevant problems
CO4	Demonstrate knowledge and understanding of how operating systems manages persistent data storage

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction and overview to the Course: OS as resource manager and standard library, Services provided by OS, brief discussions on three themes of Virtualization, Concurrency and Persistence along with a small demo, evolution of OS etc.		CO1	1
CPU Virtualization: Introduction to CPU Virtualization, Mechanism for CPU virtualization (system calls etc.), Context Switching and Process API, Shell Program, Scheduling Policies (Metrics, basic ones		CO2	2.5

like FCFS, SJF, STCF, Round robin etc.), advanced policies (like Priority Scheduling, MLFQ, fair scheduling)		
Memory Virtualization: Introduction to Memory Virtualization, Virtual Address space abstraction and dynamic relocation mechanism, Segmentation, free space management, Paging mechanism, TLB, Smaller Page Tables (multi-level page tables), Beyond Physical Memory: Mechanism & policies.	CO2	2.5
Concurrency: Introduction to Concurrency, Threads and Data race, Critical section, Locks and Software based method, Hardware Primitives, Ticket lock and concurrent data structures, Advance locks (queue lock), Condition variable, Producer Consumer using CV, Semaphore, classical problems using semaphore, Deadlocks	CO3	4
Persistence: Communication with IO Devices, Hard disk and Flash based SSDs internals, Disk scheduling, File system abstraction, File system interface/ API,File system implementation (Allocation strategies), File system organization and access methods, Locality and Fast file system, crash consistency: FSCK and journalling etc.	CO4	3

4.	**Text books**

i) Remzi H. Arpaci-Dusseau and Andrea C. Arpaci-Dusseau, Operating Systems: Three Easy Pieces University of Wisconsin-Madison. Published (Online, free for download).

5.	**Reference Book(s) and Other Required Material**

i) Silberchatz & Galvin, “Operating System Concepts”, Addison Wesley.

ii) Tanenbaum A, “Modern Operating Systems”, PHI 2nd Ed.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Exams to Course Outcomes

Assessment Type	CO1	CO2	CO3	CO4
Mid Exam	30%	70%	0	0
Quizzes	25%	25%	25%	25%
Lab assignments	0	60%	30%	10%
Final Exam	10%	30%	30%	30%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	0	0	0	0	1	0	1	0	0	2	2	1	3
CO2	3	2	0	0	0	0	1	0	1	0	0	3	2	1	3
CO3	3	2	0	0	0	0	1	0	1	1	0	3	2	1	3
CO4	3	2	0	0	0	0	1	0	0	0	0	2	1	1	3

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment:**
1	Warm-up exercises: Review of Linux commands, exercises related to /proc filesystem in Linux to get information about the HW configurations and how to monitor the state of a running process in Linux.
2	Getting Prepared for implementing OS related system and kernel exercise/projects: Running C/CPP Programs and using Makefiles to build complex program, Debugging using GDB, Installing Xv6 (teaching operating system in MIT which will be used in this course for doing kernel projects).
3	Understanding and implementing various concepts of process management using process API system calls (like fork, wait, exec etc.) in Linux Assignment 1: Implementing your own command shell using OS system calls to execute built-in Linux commands with support for handling signaling, executing multiple commands in sequential and parallel mode, output redirection etc.
4	Getting overview of XV6 and adding new user programs, system calls and debugging code with gdb. Modifying process management functionalities of XV6 like adding system call to get PID of the parent process, adopting the orphan child by the grandfather process, adding system calls for signaling (IPC) between process. Assignment 2: on memory management in Xv6 – adding new system calls to get number of virtual and physical pages in the user part of the address space of the process and implementing demand paging or lazy allocation of heap memory.
5	To understand the pthread API and the concept of mutex and condition variables, and implement various problems like parallel matrix multiplication, array addition using multiple threads, Producer/Consumer problem using pthread library.
6	Implement solutions (efficient and without any deadlock) for various concurrency problems using semaphores. Assignment 3: Develop a basic multithreaded webserver (where multiple threads process multiple client requests simultaneously) with support for different scheduling policies for the client requests.
7	Understand the concepts of file descriptors and implement basic I/O system calls.

Topics in Measure theory and Integration

Course Code & Course Title:	MALA3XX Topics in Measure theory and Integration		
Course Type:	DE		
Name of the programme(s):	B Tech in Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance of measure theory and Integration.

2.	**Course Outcomes:** Student will be able to
CO1	The students will be able to understand the importance of extending the concept of length function from interval to any abstract set and know about the measurable sets
CO2	The student will be able to distinguish between measurable sets and non-measurable sets, likewise measurable functions
CO3	The student will be able to use a more general theory of integration in an abstract space which will help in solving various physical as well as research problems
CO4	The students will be able to understand the measurability as a condition which is stable under limits, and is therefore a natural framework to study properties of integration under limits

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Limitations of Riemann integral, Outer measure induced by the length, Lebesgue measurable sets in R, Non-measurable sets in R, Abstract Measurable space, Borel σalgebra, Measure, Continuity properties of a measure, Monotone class theorem, Uniqueness of the extension, Completion of a measure space, Completeness of Lebesgue σ-algebra.		CO1	3

Measurable functions, Convergence of measurable functions (almost everywhere, in measure, in mean, almost uniform), theorem, Integral of nonnegative measurable function, Monotone convergence theorem, Fatou's lemma, Lebesgue Integrable functions, Dominated convergence theorem,	CO2, CO3	5
Completeness of L^p(μ), Bounded variation, Absolute continuity, Fundamental theorem for Lebesgue integrable functions. Product measure, Fubini's theorem.	C04	4

4.	**Text books**

i) G. de Barra, Measure and Integration, Wiley Eastern, 1981. ISBN: 9780852264161.

ii) I. K. Rana, An Introduction to Measure and Integration, Second Edition, Narosa, 2005. ISBN: 9788173195617.

iii) H. L. Royden, Real Analysis, Third Edition, Prentice-Hall of India, 1995. ISBN: 9788120305106.

5.	**Reference Book(s) and Other Required Material**

i) G. Folland, Real Analysis: Modern Techniques and Their Applications, Wiley. ISBN: 9780471317169.

ii) Terence Tao, An Introduction to Measure Theory, Graduate Studies in Mathematics, AMS, 2011. ISBN: 9780821869192.

iii) W. Rudin, Real and Complex Analysis, Third Edition, McGraw-Hill, International Editions, 1987. ISBN: 9780070542341.

6.	**Evaluation Details**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	1	1	1	---	---	---	---	1	---	3	2	3
CO2	3	3	3	2	1	---	---	---	---	---	1	---	3	2	3
CO3	3	3	3	2	1	2	---	---	---	---	1	---	3	2	3
CO4	3	3	3	3	1	2	---	---	---	---	1	---	3	2	3
CO5	3	3	3	1	2	---	---	---	---	---	1	---	3	2	3

High - 3; Medium – 2; Low –1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Introduction to Partial Differential Equations

Course Code & Course Title:	MALA3XX Introduction to Partial Differential Equations		
Course Type:	DC		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Ordinary Differential Equations		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to provide an introduction to the basic properties of PDEs and to the basic analytical techniques to solve them.

2.	**Course Outcomes:**
CO1	Formulate and solve certain classes of linear and non-linear PDEs of first order using classical methods mentioned in the course content
CO2	Solve non-homogeneous higher-order partial differential equations with constant and variable coefficients and write canonical forms of second order PDEs
CO3	Apply Fourier's method for solving the wave equation, heat equation and Laplace equation
CO4	Understand the domain of dependence and influence, solve the Cauchy problem in the heat equation using D'Alembert formula
CO5	Analyse the qualitative properties of the solutions of Laplace and heat equations

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Formulation of linear and quasi-linear first order partial differential equations - Pfaffian equation -condition for integrability, Linear partial differential equations of first order, Lagrange's method, Charpit's method, Method of characteristics, Cauchy problem, Monge's method		CO1	3
Non-homogeneous higher-order partial differential equations with constant coefficients, Equations with variable coefficients reducible to linear PDEs with constant coefficients. Classification and canonical		CO2	3

forms of second order partial differential equations in two independents variables.		
Cauchy problem and D'Alembert formula, domains of dependence and influence, non-homogeneous wave equation; Heat equation: Cauchy problem.	CO3, CO4	4
Fourier series, convergence of Fourier series (statement), method of separation of variables for Laplace, heat and wave equations in one space variable; Harnak inequality, maximum principle, and uniqueness results for Laplace and heat equations.	CO3, CO4, CO5	4

4.	**Text books**

i) T. Amaranath, An elementary course in Partial differential equations, 2nd Edition, Narosa Pub., New Delhi, 2003, ISBN: 9788173195198.

i) L.C. Evans, Partial Differential Equations, Graduate Studies in Mathematics, 1st Edition, Vol. 19, American Mathematical Society, 1998, ISBN: 9780821807729.

ii) Qing Hang, A basic course in Partial Differential Equations, 1st Edition, AMS Publications, Vol. 120, 2010, ISBN: 9780821852552.

iii) R. McOwen, Partial Differential Equations: Methods and Applications, 2nd Edition, Pearson, 2002, ISBN: 9780130093356.

iv) Tyn Myint-U, Loknath Debnath, Partial Differential Equations for Scientists and Engineers, 4th Edition Springer, 2007, ISBN: 978081764395.

v) P. Prasad, Partial Differential Equations, 2nd Edition, Wiley Eastern, 1985, ISBN: 9780852267226.

vi) I.N. Sneddon, Elements of Partial Differential Equations, McGraw Hill, New York, 1957, ISBN:9780070594258.

vii) I P Stavroulakis, S A Tersian, Partial Differential Equations: An Introduction with Mathematics and MAPLE, 2nd Edition, World scientific, Singapore, 2004, ISBN: 9810238916.

5.	**Reference Book(s) and Other Required Material**

i) L.C. Evans, Partial Differential Equations, Graduate Studies in Mathematics, 1st Edition, Vol. 19, American Mathematical Society, 1998. ISBN: 9780821807729.

ii) S. Salsa, G Verzini, Partial Differential Equations in Action from modelling to Theory, Fourth edition, Vol 147, Springer, 2022, ISBN: 9783031218521.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO2	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO3	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO4	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO5	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

NA

Database Management Systems

Course Code & Course Title:	CSL315 Database Management Systems		
Course Type:	DC		
Name of the programme(s):	B. Tech Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Data Structures and Program Design, Algorithms		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

To enable the students to design efficient databases to real world problems and understand the complexity of their solution in terms and also use databases efficiently.

2.	**Course Outcomes:**
CO1	• Understand the need for Databases. (Understanding) • Understand various architectures, design techniques and apply appropriate techniques to a given problem. • Understand the theory of ER model, Relational Model, SQL, Relational Algebra, Physical design, Transactions and concurrency. • Understand tools to model databases
CO2	Analyze techniques for querying, modelling and transactions. (Applying, Analyzing, Evaluating) • Analyze Database designs. • Analyze Functional Dependencies and Normalization. • Analyze and evaluate ER model, Relational Model, SQL, Relational Algebra, Physical design, Transactions and concurrency. • Apply designing tools for modelling, querying etc.
CO3	Design and create efficient databases for real problems. (Analyzing, Creating) • Create ER model, Relational Model, SQL, Relational Algebra, Physical design, Indexing, Transactions and concurrency, Query Optimization techniques. • Create databases using tools to model real life problems.

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction		CO1	1
ER, EER, Relational models and their mappings		CO1, CO2, CO3	3
SQL		CO1, CO2, CO3	2

Relational Algebra and Relational Calculus	CO1, CO2, CO3	2
Functional Dependencies and Normalization	CO1, CO2, CO3	2
Storage and Indexing	CO1, CO2, CO3	2
Transactions and Concurrency	CO1, CO2, CO3	2
Query Processing and Optimization	CO1, CO2, CO3	1

4.	**Text books:**

i) Ramez Elmasri, Shamkant B. Navathe, Fundamentals of Database Systems, 7th Edition, Pearson Education India, 2017, ISBN: 9789332582705.

5.	**Reference Book(s) and Other Required Material**

i) Abraham Silberschatz, Henry F. Korth, S. Sudarshan, Database System Concepts, McGraw-Hill, 2020 (7th Edition), ISBN: 9780078022159.

ii) Hector Garcia-Molina, Jeffrey D. Ullman, Jennifer Widom, Database Systems: The Complete Book, 2nd Edition, Pearson Education, 2008, ISBN: 9780131873254.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Exam-Type	Weightage of Marks (in %)
Laboratory	20%
Mid-Sem Exam	24%
Assignments (TA)	16%
End-SEM Exam	40%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	0	3	3	3	2	3	1	3	1	3	2	3
CO2	3	3	3	1	2	0	0	1	3	0	1	1	3	2	3
CO3	3	3	3	3	2	0	0	0	3	0	2	1	3	2	3

High - 3; Medium – 2; Low – 1;

Assessment to Course Outcomes mapping

Assessment Type	Course Outcome		
	CO-1	CO-2	CO-3
Laboratory	40%	30%	30%
Mid-Sem Exam	40%	30%	30%
Assignments (TA)	40%	30%	30%
End-SEM Exam	40%	30%	30%

8.	List of Indicative Laboratory Experiment (if applicable):

i) Implement a relational algebra query to perform the following:
   - Select all employees earning more than 50,000 from a relation Employee
   - Perform a natural join between Employee and Department and project only Employee_Name and Department_Name

ii) Write SQL queries to:
   - Retrieve the second-highest salary from the Employee table.
   - Display the total number of employees in each department, including departments with no employees.

iii) Write a recursive query to display the hierarchy of employees in an organization. The Employee table has columns EmployeeID, Name, and ManagerID.
   - Output should show the hierarchy from the CEO (no ManagerID) to the lowest-level employees.

iv) Create a dynamic pivot table to display sales data.
   - Input: Sales table with ProductID, Region, and Amount.
   - Output: Regions as columns and total sales per product per region.

5. Design an ER diagram for a university database and convert it into a relational schema. Implement the schema using SQL. Extend the university database to include inheritance (e.g., Under graduate Student and Graduate Student). Create appropriate tables and write queries to retrieve records from both base and derived tables.
6. Create a B-tree index on a table Orders with attributes Order ID and Customer ID. Measure the query performance with and without the index for queries like SELECT $*$ FROM Orders WHERE Customer ID=123.
7. For a sales database with a relation
   - Sales (OrderID, CustomerID, ProductID, Quantity, Price)
   - Normalize the relation to 3NF and implement the resulting schema.
8. A table EMPLOYEE has 1,000,000 rows. Each row is 200 bytes. If the database uses a block size of 8 KB:
   - Calculate the number of blocks required to store the table.
   - Estimate the query execution time for SELECT $*$FROM EMPLOYEE, assuming sequential access with a disk read speed of 100 MB/s.
9. Create a composite index on Orders table for columns CustomerID and OrderDate.

- Write queries to retrieve orders for a specific customer within a date range and compare performance with and without the index.

10. Given a relation R (A, B, C, D) with functional dependencies A→A→B and C→D:
    - Check if the relation is in BCNF.
    - If not, decompose it into BCNF and calculate the total number of tuples in the decomposed relations, assuming RRR initially has 10,000 tuples.
11. Write a program to simulate the following interleaved transactions and analyze their final states:
    - T1: Read A, Subtract 100, Write A, Read B, Add 50, Write B
    - T2: Read A, Add 200, Write A, Read C, Subtract 100, Write C
    - Include crash scenarios at different points. Implement recovery strategies and verify if ACID properties are preserved.
12. Design a logging mechanism where each operation (INSERT, UPDATE, DELETE) requires the following:
    - INSERT:2×row size+20bytes
    - UPDATE:2×row size+40bytes
    - DELETE:1×row size+30bytes
    - Calculate the total log size for 100,000 operations, given 60% are inserts, 30% updates, and 10% deletes.
13. Develop a multi-threaded program that runs transactions at different isolation levels:
    - **Scenario**: Transactions T1, T2, and T3 access shared resources (A, B, C).
    - Compare the outcomes for READ UNCOMMITTED, READ COMMITTED, REPEATABLE READ, and SERIALIZABLE isolation levels.
    - Measure execution time and consistency for each level and explain trade-offs.
14. Design a timestamp-based concurrency control system and simulate a scenario where:
    - T1: R(A), W(B)
    - T2: W(A), R(B)
    - Introduce conflicts, and show how timestamps resolve them. Measure and compare system performance for different timestamp assignment strategies.
15. Build a transaction manager that supports:
    - Two-phase locking,
    - Timestamp-based protocols,
    - Deadlock detection,
    - MVCC. Test it on a workload of:
    - 1,000 concurrent transactions
    - 500 read and write operations. Measure system performance under different configurations.
16. For the following schedule, determine whether it is conflict-serializable or view-serializable:
    - T1: R(A), W(B)
    - T2: W(A), R(B)
    - T3: R(A), W(A). Write a program to automate the creation of precedence graphs for conflict-serializability and matrix-based checks for view-serializability.
17. Implement an algorithm to classify a given schedule into one of the following:

- Recoverable,
- Cascadeless,
- Strict. Test the algorithm with 10 complex schedules, and validate its results with precedence graph analysis.

18. Implement a deadlock detection system using a wait-for graph. Simulate a scenario with:
    - 10 transactions and 20 shared resources.
    - Introduce a timeout mechanism for deadlock resolution. Analyze the system's performance under varying deadlock probabilities.
19. Simulate a database system using fine-grained locking (row-level) and coarse-grained locking (table-level). Measure performance under high-concurrency conditions with:
    - 100 concurrent transactions,
    - 50 reads and 50 writes per transaction. Compare resource utilization, throughput, and contention for both approaches.
20. Implement a priority-based scheduling algorithm for transactions with given priorities. Calculate the average waiting time for 5 transactions with the following arrival times and priorities:
    - T1: Priority 3, Arrival 0ms
    - T2: Priority 1, Arrival 5ms
    - T3: Priority 2, Arrival 10ms

Optimization

Course Code & Course Title:	MALA3XX Optimization		
Course Type:	DC		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-0	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)			
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this course is to expose students to understand the importance of Optimization along with its applications.

2.	**Course Outcomes:**
CO1	Understand the fundamental concepts of optimization
CO2	Apply optimization techniques to solve real-world problems
CO3	Develop skills in algorithm implementation and analysis
CO4	Appreciate the interdisciplinary nature of optimization and its applications

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Mathematical review of Vector spaces and Matrices, Transformations, Geometry, Calculus		CO1	2
Unconstrained Optimization: Introduction to Optimization problems, Conditions for local minimizers, One Dimensional Search Method: Golden section Method, Fibonacci Method, Bi-section Method Newton's Method, Secant Method,		CO1, CO2	3
Gradient Methods: Method of Steepest Descent, Analysis of Gradient Method, Newton's Method: Analysis of Newton's Method, Levenberg-Marquardt Modification, Newton's Method for Nonlinear Least Squares, Linear Programming, Simplex Method.		CO2, CO3	3
Nonlinear Constrained Optimization: Problem Formulation, Tangent and Normal Spaces, Lagrange Condition, Second-Order Conditions,		CO4, CO5	3

Minimizing Quadratics Subject to Linear Constraints, Karush-Kuhn-Tucker Condition, Second-Order Conditions, Convex Functions, Convex Optimization Problems, Semidefinite Programming.		
Practical Assignments and Projects: ● Implement and test various optimization algorithms using Python or MATLAB ● Solve real-world optimization problems from different domains ● Analyse the performance of different algorithms for specific problems ● Work on group projects to develop optimization-based solutions	CO4, CO5	3

4.	**Text books**

i) Aggarwal, C. C., Aggarwal, L. F., & Lagerstrom-Fife, Linear algebra and optimization for machine learning, 1st Edition, Cham: Springer International Publishing, 2020, ISBN: 9783030403430.

ii) Edwin K. P. Chong & Stainslaw H. Zak, An introduction to Optimization, 4th Edition, Wiley, 2013, ISBN: 9781118279014.

iii) Gill, P. E., Murray, W., & Wright, M. H., Practical optimization. Society for Industrial and Applied Mathematics, 2019, ISBN: 9781611975598.

iv) S.S. Rao: Engineering Optimization: Theory & Practice, 1st Edition, New Age International (p) Limited, 1998. ISBN: 9788122411492.

v) Boyd, S., & Vandenberghe, L, Convex optimization. 1st Edition, Cambridge university press. 2004, ISBN: 9780521833783.

vi) H. M. Wagner: Principles of Operations Research, 1st Edition, Prentice Hall of India, New Delhi, 1982. ISBN: 9788120301627.

5.	**Reference Book(s) and Other Required Material**

i) Aggarwal, C. C., Aggarwal, L. F., & Lagerstrom-Fife, Linear algebra and optimization for machine learning, 1st Edition, Cham: Springer International Publishing, 2020, ISBN: 9783030403430.

ii) H. M. Wagner: Principles of Operations Research, 1st Edition, Prentice Hall of India, New Delhi, 1982, ISBN: 9788120301627.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	1	2	1	---	---	---	1	2	3	2	3	2
CO2	3	3	3	3	3	1	---	---	---	3	3	3	2	3	2
CO3	3	3	3	3	2	1	---	---	---	3	3	3	2	3	2
CO4	3	3	3	3	3	1	---	---	---	3	3	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

NA

Applied Statistics

Course Code & Course Title:	MALA3XX Applied Statistics		
Course Type:	DC		
Name of the programme(s):	B.Tech. in Mathematics and Computing		
L – T – P	3-0-0	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this course is to expose students to understand the importance of descriptive statistics, estimation theory and regression analysis along with real life applicability.

2.	**Course Outcomes:**
CO1	Understand the concept of descriptive statistics, dispersion and graphical representation
CO2	Be able to use the concept of different quality criteria for estimates
CO3	Understand techniques for interval estimation and testing of hypotheses
CO4	Be able to learn curve-fitting techniques using regression analysis

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Overview of Probability Distributions: Revisit of probabilistic concept, Special distributions, Descriptive Statistics: Population and sample notions, Simple random sampling with (and without) replacement, Stratified sampling, Sampling from normal distribution, Central limit theorem, t, F and Chi square distributions.		CO1	2
Types of data: categorical, continuous, ordinal, nominal, Visualizing (univariate and multivariate): box plots, histogram, stem leaf plot, bar graph, scatterplot, side-by-side boxplot, star plot, Measures of Dispersion and Association: Variance, interquartile range, Mean absolute deviation, standard deviation, Skewness, kurtosis, coefficient		CO1	3

of variation, Sample *r*-th moment and raw moments, Correlation, Kendall's τ, Spearman rank correlation		
Point estimation: Quality criteria for estimates using unbiasedness, consistency, sufficiency, efficiency, Maximum likelihood and moments estimation, Bayesian parametric models, Conjugate prior, Bayesian estimators	CO2	3
Interval estimation and hypothesis testing: Confidence interval for different parameters, Simple and composite hypothesis, Critical regions, Type-I and Type-II errors, Neyman-Pearson fundamental lemma and its applications, Inferences based on one and two samples, Testing of equality of proportion, Chi-Squared goodness-of-fit test-I & II with known and estimated parameters, Paired t-test with examples, Testing of independence in r×c contingency table-I, Testing of independence in r×c contingency table-I	CO3	3
Linear models and regression: Simple and multiple linear regression, Least squares method of estimation, Properties of least-square estimators, Confidence intervals for regression coefficients, Normal regression and correlation analysis	CO4	3

4.	**Text books**

i) Miller, I. and Freund, J. Probability and Statistics for Engineers, 7th Edition, Person education, 2005, ISBN: 9780131437456.

ii) Papoulis, A. and Pillai, U. Probability, Random Variables, and Stochastic Processes, 4th Edition, McGraHill, 2002, ISBN: 9780073660110.

iii) V. K. Rohatgi and A.K.M. Ehsanes Saleh: An Introduction to Probability and Statistics, 2nd Edition, John Wiley & Sons, 2004, ISBN: 9788126519262.

5.	**Reference Book(s) and Other Required Material**

i) Casella, G., Berger, R. L. Statistical Inference. 2nd Edition, Cengage Learning, 2021, ISBN: 9780357753132.

ii) Hogg, R. V., McKean, J., Craig, A. T. Introduction to Mathematical Statistics, 6th Edition, Pearson Education, 2005, ISBN: 9780130085078.

iii) Soong, T. T. Fundamentals of Probability and Statistics for Engineers, 1st Edition, John Wilely and Sons Ltd, New York, 2004, ISBN: 9780470868133.

6.	**Evaluation Details:**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	1	1	2	---	---	---	---	1	3	2	3	2
CO2	3	3	3	1	1	2	---	---	---	---	1	3	2	3	2
CO3	3	3	3	1	1	2	---	---	---	---	1	3	2	3	2
CO4	3	3	3	1	1	2	---	---	---	---	1	3	2	3	2
CO5	3	3	3	1	1	2	---	---	---	---	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

NA

Statistics Lab (R Programming)

Course Code & Course Title:	MAP3AXX Statistics Lab (R Programming)		
Course Type:	DC		
Name of the programme(s):	B.Tech. in Mathematics and Computing		
L – T – P	0-0-2	**No. of Credits**	1
Pre-requisites: Course Code(s) & Name(s)	Probability Theory, Applied Statistics		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this course is to expose students to use R software for different aspects of probability distributions and statistical methods.

2.	**Course Outcomes:**
CO1	Use R software for plotting statistical data and probability distributions
CO2	Compute mean, variance, correlation and other sample moments numerically in R software
CO3	Understand the random number generation
CO4	Compute different estimators and curve fitting for linear regression

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Data visualization through plotting such as histogram, pie-chart, box plots, scatter diagram, bar graph etc.		CO1	2
Numerical computations of mean, variances and other moments using R, Computations of sample moments and correlation, Plotting of density functions, mass functions, contour plots in two and higher dimensions for joint distributions.		CO2	3
EM algorithm, Mixture of Gaussians, Pseudorandom number generation, Generating random variables (discrete and continuous) – inverse transform.		CO3	3
Computations of maximum likelihood estimations and Bayesian estimations, Bayesian models and Metropolis-Hastings, Accept-reject		CO4	3

for testing of hypothesis, Implementation of least squares for linear regression.		

4.	Text books

i) Robert, C. P., Casella, G., Casella, G., Monte Carlo Statistical Methods, 2nd Edition, New York, Springer, 2004, ISBN: 9780387212395.

ii) Ross, S. M., Simulation, 5th Edition, Academic Press, 2012, ISBN: 9780124158252.

5.	Reference Book(s) and Other Required Material

i) Athreya, S., Sarkar, D., and Tanner, S. Probability and Statistics with Examples Using R. Online Access: https://www.isibang.ac.in/~athreya/ psweur/.

ii) Baclawski, K., Introduction to Probability with R, 1st Edition, CRC Press, 2008, ISBN: 9781420065213.

6.	Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	2	2	1	---	---	---	1	1	---	3	2	3
CO2	3	3	3	2	2	1	---	---	---	1	1	---	3	2	3
CO3	3	3	3	2	2	1	---	---	---	1	1	---	3	2	3
CO4	3	3	3	2	2	1	---	---	---	1	1	---	3	2	3
CO5	3	3	3	2	2	1	---	---	---	1	1	---	3	2	3

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

i) To visualize data-set through plotting such as histogram, pie-chart, box plots, scatter diagram, bar graph etc.

ii) To compute numerically mean, variances and sample moments and correlation using R.

iii) To plot density/mass function, contour in case of two and higher dimensions for joint distributions.

iv) To utilize EM algorithm, mixture of Gaussians.

v) To generate pseudorandom number, random variables (discrete and continuous) – inverse transform.

vi) To compute maximum likelihood and Bayesian estimators (Bayesian models and Metropolis-Hastings).

vii) To implement the accept-reject concept for testing of hypotheses.

viii) Implementation of least squares for linear regression for real-data.

Numerical Methods for Partial Differential Equations

Course Code & Course Title:	MALA 3XX Numerical Methods for Partial Differential Equations		
Course Type:	DE		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Applied Numerical Analysis and Scientific Computing		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance of finite difference methods for solving ordinary and partial differential equations.

2.	**Course Outcomes:**
CO1	Understand different methods involved in solving linear transport equation and their stability aspects.
CO2	Understand different types of methods for solving Parabolic, Hyperbolic and Elliptic Partial differential equations.
CO3	Will be exposed to understand the methods which are inherent in software packages for solving various engineering problems.
CO4	Will be exposed to apply these finite difference methods for solving various problems in science and engineering.

3.	**Detailed Description of the Course**		
	Topics	**CO(s) Addressed**	**Duration in weeks**
	Finite differences: Grids, Finite-difference approximations to derivatives. Linear Transport Equation: Upwind, Lax-Wendroff and Lax-Friedrich schemes, von-Neumann stability analysis, CFL condition, Lax-Richtmyer equivalence theorem, Modified equations, Dissipation and dispersion.	CO1	3
	Heat Equation: Initial and boundary value problems (Dirichlet and Neumann), Explicit and implicit methods (Backward Euler and Crank-Nicolson schemes) with consistency and stability, Discrete maximum principle, ADI methods for two-dimensional heat equation (including LOD algorithm).	CO2, CO3, CO4	3

Poisson's Equation: Finite difference scheme for initial and boundary value problems, Discrete maximum principle, Iterative methods for linear systems (Jacobi, Gauss-Seidel, SOR methods and Conjugate Gradient method), Peaceman -Rachford algorithm (ADI) for linear systems.	CO2, CO3, CO4	3
Wave Equation: Explicit schemes and their stability analysis, Implementation of boundary conditions.	CO2, CO3, CO4	3

4. Text books

i) G. D. Smith, Numerical Solutions of Partial Differential Equations, 3rd Edition, Calrendorn Press, 1985, ISBN: 9780198596509.

ii) K. W. Morton and D. Mayers, Numerical Solution for Partial Differential Equations, 2nd edition, Cambridge, 2005, ISBN: 9780521607933.

5. Reference Book(s) and Other Required Material

i) J. W. Thomas, Numerical Partial Differential Equations: Finite Difference Methods, Texts in Applied Mathematics, Vol. 22, Springer Verlag, 1999, ISBN: 9780387979991

ii) J. W. Thomas, Numerical Partial Differential Equations: Conservation Laws and Elliptic Equations, Texts in Applied Mathematics, Vol. 33, Springer Verlag, 1999, ISBN: 9781461205692.

iii) M. K. Jain, Numerical Solution of Differential Equations, Wiley Eastern, Delhi, 1983, ISBN: 9780852264324.

iv) R. J. LeVeque, Finite Difference Methods or Ordinary and Partial Differential Equations, 1st Edition, SIAM, Philadeiphia, 2007, ISBN: 9780898716290.

v) R. Mitchell and S. D. F. Griffiths, The Finite Difference Methods in Partial Differential Equations, Wiley and Sons, NY, 1980, ISBN: 9780471276418.

6. Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	3	2	2	--	--	--	--	1	1	3	2	3	2
CO2	3	2	3	2	2	--	--	--	--	1	1	3	2	3	2
CO3	3	2	3	2	2	--	--	--	--	1	1	3	2	3	2
CO4	3	2	3	2	2	--	--	--	--	1	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

Exposure to MATLAB and computational experiments based on the algorithms discussed in the course.

First Course in Topology

Course Code & Course Title:	MALA 3XX, First Course in Topology		
Course Type:	DE		
Name of the programme(s):	B. Tech. in Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	NIL		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

This course aims to introduce students to the fundamental concepts of topology which are essential for the study of advanced mathematics

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Explain the concept of topology and intrinsic properties of topological spaces
CO2	Explain the homeomorphism, connectedness, compactness and related theorems.
CO3	Explain the concept of Countability Axioms, Separability
CO4	Discuss the Metrization Theorem and its applications in topology

3.	**Detailed Description of the Course**		
	Topics	**CO(s) Addressed**	**Duration in weeks**
	Review of Set theory, Functions and relations, Cartesian products, Finite sets, Countable and Uncountable sets. Topological Spaces, Examples of topological spaces, Bases, Sub bases, Subspace topology, Order topology, Product topology, Metric topology, Continuous function, Homeomorphism.	CO1	4
	Connectedness: Connected spaces, Connected Subspaces of real lines, Components, and local connectedness.	CO2	2
	Compactness: Compact spaces, Heine-Borel theorem, Local compactness, One-point compactification, Tychnoff theorem.	CO2	3
	Countability and Seperation Axioms: Countability Axioms, Separability i.e. T0, T1, T2 spaces, Regularity, Completed regularity,	CO3, CO4	3

Normality, Urysohn lemma, Tychnoff embedding and Urysohn metrization theorem, Tietze extension theorem.		

4.	Text books

i) J. R. Munkres, Topology, 2nd Edition, Pearson Education (India), 2001, ISBN: 9780137848669.

ii) K. D. Joshi, Introduction to General Topology, New Age International, New Delhi, 2000, ISBN: 9788122436037.

5.	Reference Book(s) and Other Required Material

i) J. L. Kelley, General Topology, Van Nostrand, Princeton, 1955, ISBN: 9780442043025.

ii) M. A. Armstrong, Basic Topology, Springer (India), 2004, ISBN: 9788181281357.

iii) G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, New York, 1963, ISBN: 9780070573895.

6.	Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	1	---	---	–	---	---	---	---	2	3	2	3	2
CO2	3	3	1	---	---	---	---	---	---	---	2	3	2	3	2
CO3	3	2	---	---	---	---	---	---	---	---	1	3	2	3	2
CO4	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2

High - 3; Medium – 2; Low – 1

8.	List of Indicative Laboratory Experiment (if applicable):

NA

Integral Equations and Calculus of Variations

Course Code & Course Title:	MALA 3XX Integral Equations and Calculus of Variations		
Course Type:	DE		
Name of the programme(s):	B. Tech. in Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

This course aims to introduce to the foundational concepts of integral equations, calculus of variations, and Fourier transforms.

2.	**Course Outcomes:**
CO1	Convert the linear differential equations to the corresponding Volterra integral equations and vice-versa, and hence analyze the uniqueness of the solution of Volterra Integral equations. Solve the different types of Volterra integral equations
CO2	Solve the different types of Fredholm integral equations. Analyze the role of the kernel in solving the Fredholm integral equations
CO3	Obtain extremum of a functional and apply Ritz method to find solution of a variational problem
CO4	Analyze the relation between the Fourier transform and the Fourier series. Find the Fourier transform of the elementary functions and apply the Fourier transform for solving the partial differential equations

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Integral Equations: Volterra Integral Equations: Basic concepts - Relationship between Linear differential equations and Volterra integral equations - Resolvent Kernel of Volterra Integral equation - Solution of Integral equations by Resolvent Kernel - The Method of successive approximations - Convolution type equations, solution of integral differential equations with the aid of Laplace transformation.		CO1	3 weeks

Fredholm Integral equations: Fredholm equations of the second kind, Fundamentals– Iterated Kernels, Constructing the resolvent Kernel with the aid of iterated Kernels -Integral equations with degenerate Kernels - Characteristic numbers and eigen functions, solution of homogeneous integral equations with degenerate Kernel - non-homogeneous symmetric equations - Fredholm alternative.	CO2	4 weeks
Calculus of Variations: Extrema of functionals, Variation of a functional and its properties, Euler's equation, Field of extremals, Sufficient conditions for the Extremum of a Functional, Conditional extrema, Moving boundary problems, Ritz method.	CO3	3 weeks
Fourier transform as a limit of Fourier series, properties of Fourier transforms, Fourier transform of some elementary functions, Convolution theorem, Applications to partial differential equations.	CO4	2 weeks

4.	**Text books**

i) Elsgolc LD, Calculus of Variations, New York: Dover Publications; 2007, ISBN: 978-0486457994.

ii) Hildebrand FB, Methods of Applied Mathematics, 2nd ed. New York: Dover Publications; 1992, ISBN: 978-0486670027.

iii) Kot M., A First Course in the Calculus of Variations. Providence (RI): American Mathematical Society; 2014, ISBN: 978-1470414955.

iv) Krasnov ML, Kiselev AI, Makarenko GI, Problems and Exercises in Integral Equations, Moscow: Mir Publishers; 1971, ISBN: 978-0714704050.

v) Sneddon IN, The Use of Integral Transforms, New Delhi: Tata McGraw-Hill; 1974, ISBN: 978-0070594364.

5.	**Reference Book(s) and Other Required Material**

i) Mesterton-Gibbons M, A Primer on the Calculus of Variations and Optimal Control Theory, Providence (RI): American Mathematical Society; 2009, ISBN: 978-0821847725.

ii) Tricomi FG, Integral Equations, New York: Dover Publications; 1985, ISBN: 978-0486648286.

iii) M.R. Spiegel, Laplace Transforms (Schaum's Series), McGraw-Hill, 1965, ISBN : **-978 .0070602311**

iv) J.L. Schiff, The Laplace Transform, Springer (1999).

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	3	1	---	–	---	---	---	---	1	3	2	3	2
CO2	3	2	2	1	---	---	---	---	---	---	1	3	2	3	2
CO3	3	2	2	1	---	---	---	---	---	---	1	3	2	3	2
CO4	3	2	3	1	---	---	---	---	---	---	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Number Theory

Course Code & Course Title:	MALA 3XX Number Theory		
Course Type:	DE		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Abstract Algebra		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

This course aims to introduce the foundational concepts of number theory.

2.	**Course Outcomes:**
CO1	Understand the main concepts related to primality, divisibility, congruences, and number-theoretic functions
CO2	Formulate main results, in particular, the Euclidean Algorithm, Euclid's Lemma, the Chinese Remainder Theorem, Fermat's Little Theorem, Euler's Theorem, and the Quadratic Reciprocity Law etc.
CO3	Develop a deeper conceptual understanding of the theoretical basis of number theory and to introduce an important modern application of number theory to RSA cryptosystem
CO4	Understand the concept of binary quadratic forms, partition and Diophantine equations

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Divisibility: basic definition, properties, prime numbers, some results on distribution of primes;		CO1	2
Congruences: basic definitions and properties, complete and reduced residue systems, theorems of Fermat, Euler & Wilson, application to RSA cryptosystem, linear congruences and Chinese Remainder theorem, quadratic congruences, and Quadratic Reciprocity law.		CO2, CO3	2-3
Arithmetical functions: examples, with some properties and their rate of growth; Continued fractions, and their connections with		CO3, CO4	3-4

Diophantine approximations, applications to linear and Pell's equations.		
Binary quadratic forms: equivalence, reduction, Fermat's two square theorem, Lagrange's four-square theorem.	CO4	3-4
Partition: basic properties and results; Diophantine equations: linear and quadratic, some general equations.	CO4	2-3

4.	**Text books**

i) Adams WW, Goldstein LJ, Introduction to the theory of numbers. 3rd ed, Englewood Cliffs (NJ): Prentice-Hall; 1976, ISBN: 9780134912820.

ii) Baker A, A concise introduction to the theory of numbers. Cambridge: Cambridge University Press; 1984, ISBN: 9780521286541.

iii) Burton DM, Elementary number theory. 2nd ed. Dubuque (IA): W.C. Brown Publishers; 1989, ISBN: 9780697059192.

5.	**Reference Book(s) and Other Required Material**

i) Ireland K, Rosen M, A classical introduction to modern number theory. 2nd ed. New York: Springer-Verlag; 1990, ISBN: 9780387973296.

ii) Niven I, Zuckerman HS. An introduction to the theory of numbers. 4th ed. New York: Wiley; 1980, ISBN: 9780471028512.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3	PSO 4
CO 1	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO 2	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO 3	3	2	2	---	---	1	---	---	---	1	2	3	2	3	2
CO 4	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Fourier Transforms and Applications

Course Code & Course Title:	MALA 3XX Fourier Transforms and Applications		
Course Type:	DE		
Name of the programme(s):	B. Tech. in Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

This course aims to introduce the fundamental concepts of Fourier transformers.

2.	**Course Outcomes (Min. 3 & Max. 5):** After completing this course students will be able to understands
CO1	The main concepts related to continuous and discrete Fourier transforms
CO2	The computational accepts of discrete Fourier transform
CO3	Basic concepts of wavelet transforms
CO4	Use of Fourier transforms in applications

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Fourier integral formulas, Definition of Fourier transform and examples, Basic properties of Fourier transforms, Inverse Fourier transform, Convolution, Existence of Fourier transform and inverse Fourier transform, Fourier transform of delta function.		CO1	3
Discrete Fourier transform, discrete inverse Fourier transform, Relationship between discrete and continuous Fourier transform, discrete Fourier transform properties, discrete convolution, relation between discrete and continuous convolution, Discrete cosine and sine transforms and its properties, Fast Fourier transform: matrix formulation and intuitive development.		CO2	4
FFT algorithm, FFT in NumPy and FFT in SciPy with examples.		CO4	2

Multidimensional DCT, DST, DFT and FFT.	CO4	2
Continuous wavelet transforms and discrete wavelet transforms, examples of orthonormal wavelets.	CO3	2

4. Text books

i) Brigham EO. The Fast Fourier Transform and Its Applications. Englewood Cliffs (NJ): Prentice-Hall, Inc.; 1988. ISBN: 978-0133075052.

ii) Debnath L, Bhatta D. Integral Transforms and Their Applications. 2nd ed. Boca Raton: CRC Press; 2015. ISBN: 978-1584885757.

5. Reference Book(s) and Other Required Material

i) Krasnov ML, Kiselev AI, Makarenko GI. Problems and Exercises in Integral Equations. Moscow: Mir Publishers; 1971.

ii) Press WH, Teukolsky SA, Vetterling WT, Flannery BP. Numerical Recipes: The Art of Scientific Computing. 3rd ed. Cambridge: Cambridge University Press; 2007, ISBN: 978-0521880688. https://docs.scipy.org/doc/scipy/reference/fft.html https://numpy.org/doc/stable/reference/routines.fft.html

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	2	---	---	---	---	---	---	2	3	2	3	2
CO2	3	3	2	2	---	---	---	---	---	---	2	3	2	3	2
CO3	3	3	2	2	---	---	---	---	---	---	2	3	2	3	2
CO4	3	3	2	2	2	---	---	---	---	---	3	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Signal and System Analysis

Course Code & Course Title:	ECLA211 Signals and System Analysis		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)	Nil		

1.	**Course Objective:**

i) To impart fundamental knowledge of semiconductor devices, analog components, and solid-state electronic circuits.
ii) To develop the ability to analyze and design basic digital logic and combinational circuits using standard techniques.
iii) To introduce the working principles of sensors, data converters (ADC/DAC), and microcontroller-based systems.
iv) To provide foundational understanding of communication systems and enable hands-on application development using Arduino platforms.

2.	**Course Outcomes:** Students will be able to
CO1	Classify systems using properties and determine the response of the LTI system using convolution.
CO2	Analyse and synthesize spectral characteristics of continuous-time periodic and aperiodic signals.
CO3	Analyse system properties based on impulse response and Fourier analysis.
CO4	Interpret and relate the sampling process and the effects in the time and frequency domain.
CO5	Apply spectral tools to gain insights into continuous/ discrete-time signals and systems.

3.	**Detailed Description of the Course**		
	Topics	**CO(s) Addressed**	**Duration in weeks**
	Continuous-time, and Discrete-time signals and Systems Signals, Signal Energy and Power, Transformations of the Independent Variable, Periodic Signals, Even and Odd Signals, Exponential and	CO1, CO2	3

Sinusoidal Signals, Complex Exponential and Sinusoidal Signals, Unit Impulse and Unit Step Functions, Systems and Properties		
Linear Time-invariant Systems LTI Systems: The Convolution Integral/ Sum, The Unit Impulse, The Representation of Signals in Terms of Impulses, The Unit Impulse Response, Representation of LTI Systems, Properties of LTI Systems.	CO1	3
Time and Frequency Characterization of Signals and Systems The Magnitude-Phase Representation of the Fourier Transform, Frequency Response of LTI Systems, Linear and Nonlinear Phase, Group Delay.	CO2, CO3	3
SAMPLING Introduction, Representation of a Continuous-Time Signal by Its Samples: The Sampling Theorem, Impulse-Train Sampling, Reconstruction of a Signal from Its Samples Using Interpolation, The Effect of Undersampling: Aliasing, Discrete-Time Processing of Continuous-Time Signals, Sampling of Discrete-Time Signals, Impulse-Train Sampling, Discrete-Time Decimation, and Interpolation.	CO4	3
THE LAPLACE AND Z-TRANSFORM Region of Convergence, Inverse Laplace Transform, Geometric Evaluation of the Fourier Transform from the Pole-Zero Plot, Properties, Analysis, and Characterization of LTI Systems, Interconnections.	CO5	3

4.	**Text books**

i) Ashok Ambardar, Introduction to Analog and Digital Signal Processing, PWS Publishing Company, New York, 2002. ISBN: 9780534950976.

ii) John G. Proakis, Digital Signal Processing: Principles, Algorithms and Applications, Prentice Hall, New Delhi, 2006. ISBN: 9788120324589.

iii) Sanjit K. Mitra, Digital Signal Processing: A Computer-Based Approach, Tata McGraw-Hill Edition, New Delhi, 2001. ISBN: 9780074635292.

iv) S. Haykin and Barry Van Veen, Signals & Systems, John Wiley & Sons Inc., New Delhi. ISBN: 9780471378511.

v) Rodger E. Ziemer and William H. Tranter, Signals & Systems – Continuous and Discrete, Macmillan Publishing Company, Bangalore, 2005. ISBN: 9780024312112.

5.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Mid Semester Exam. 20-30

Teacher Defined Assessment 20

End Semester Exam. 50-60

6.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	2	---	---	---	---	---	---	1	3	3	1	1
CO2	3	3	2	2	---	---	---	---	---	---	1	2	2	2	2
CO3	3	3	2	2	---	---	---	---	---	---	1	2	2	2	2
CO4	3	2	3	3	---	---	---	---	---	---	1	2	2	2	1
CO5	3	3	2	2	---	---	---	---	---	---	1	2	2	2	1

High - 3; Medium – 2; Low – 1;

7.	List of Indicative Laboratory Experiment (if applicable):

i) To demonstrate generation of some simple signals such as the complex exponential signal and real sinusoids.

ii) To explore the commutation of even and odd symmetries in a signal with algebraic operations.

iii) To explore the effect of transformation of signal parameters (amplitude-scaling, and time-shifting).

iv) To explore the various properties of the impulse signals.

v) To verify different properties of a given system as linear or non-linear, causal or non-causal, stable or unstable etc.

vi) To compute discrete Fourier transform of a signal.

vii) Verification of Perceval's theorem associated with Fourier series analysis for a periodic square wave sampled using appropriate sampling frequency.

viii) Verification of Multiplication property associated with Fourier series analysis for a periodic triangular wave sampled using appropriate sampling frequency.

ix) Verification of shifting property associated with Fourier series analysis for a periodic square wave sampled using appropriate sampling frequency.

x) Verification of symmetry properties associated with Fourier series analysis for a real valued and complex valued periodic square wave sampled using appropriate sampling frequency.

xi) Verification of Fourier series properties associated with down sampling of a periodic square wave sampled using appropriate sampling frequency.

xii) To compute Z transform of a sequence.

EEL305 Control Systems - I

Course Code & Course Title:	EELA305 Control Systems - I		
Course Type:	DE		
Name of the programme(s):	B.Tech, Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	NIL		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

i) The lessons in basics of control systems will familiarize with the mathematical frame work of the system modeling and analysis.
ii) Introduction to various techniques used in analysis of the dynamical system.

2.	**Course Outcomes: Students will be able to**
CO1	Do mathematical modelling and derivation of transfer function of various systems
CO2	Determine the stability of system and analyse the system in time domain
CO3	Analyse the systems in frequency domain
CO4	Do state space modelling of system and its analysis

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction: Introduction to automation and automatic control, Broad spectrum of the control system applications. Block-diagram and signal-flow-graph algebra		CO1	1.5
Mathematical modeling of dynamical systems: Differential equations, Transfer functions. Input-output description of Electrical, electromechanical and other control system components. Servomechanisms and regulators. Loading effect. Concept of feedback and its effect on system parameter variation and disturbances acting on the system.		CO1	1.5
Time response analysis: Standard inputs used for analysis. First order and second order system time response. Concept of system type and time constants. Time response characteristics. Correlation of the root location		CO2	3

to the time response. Dominant poles and approximate time response for higher order system		
Stability analysis: Characteristic equation of a system. Condition for stability. Routh-Hurwitz criterion, special cases for determining relative stability.	CO2	2
Root-locus technique: Relation between open-loop and close-loop system characteristic equations. Need and basic idea of root-locus technique. Construction of root-locus. Assessing close-loop system stability from root-locus. Effect of adding poles and zeros on the root-locus of a system.	CO2	1
Frequency response analysis: Concept of frequency response of a dynamical system. Construction of Bode plot and polar plot for a system. Conformal mapping, Nyquist contour and construction of Nyquist plot for a system. Nyquist stability criterion and stability margins. Reading the stability margin on Bode plot and assessing close-loop stability. Effect of gain variation and addition of poles and zeros on the frequency response plots.	CO3	3
State space technique: Concept of system state and state variable. Writing system math model in state variable form. Derivation of transfer function from state variable model. Introduction to concept of controllability and observability	CO4	2

4.	Textbooks

i) Benjamin C Kuo, "Automatic Control Systems", Prentice Hall of India.

ii) M. Gopal, "Control Systems- Principle of Design", Fourth Edition, 2012, McGraw Hill.

iii) I.J. Nagrath, "Control Systems Engineering", New Age International Ltd., 2000.

5.	Reference Book(s) and Other Required Material

i) Richard C. Dorf and Robert H. Bishop, "Modern Control Systems", Pearson Education Inc.

ii) Norman S Nise, "Control System Engineering", John Wiley & Sons.

iii) Katsuhiko Ogata, "Modern Control Engineering", Prentice Hall of India.

iv) D'AzzoHoupis, Logakusha, Huelsoman, "Linear System Analysis", McGraw Hill.

6.	Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Mid Sem: 20-30 Marks, End Sem: 50-60 Marks, Quiz/Internal assessment: 10-20 Marks, Total 100 Marks

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	1	2	3	2	2	2	-	3	2	2	1	1	2	1	2
CO2	2	2	2	2	3	2	3	3	2	3	1	1	2	2	2
CO3	3	3	2	2	3	2	3	3	2	3	1	1	3	2	2
CO4	2	2	3	3	3	2	3	3	2	3	1	1	2	1	2

High - 3; Medium – 2; Low – 1;

Introduction to Web Programming

Course Code & Course Title:	**CSL224:** Introduction to Web Programming		
Course Type:	**DE**		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	**3-0-2**	**No. of Credits**	**4**
Pre-requisites: Course Code(s) & Name(s)	**None**		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

i) Awareness about different tools for Web Programming.
ii) Background of working on the web.
iii) Construct efficient web pages with CSS and JavaScript.
iv) Demonstrate competency in the use of common HTML code.
v) Ability to design efficient client as well as server-side scripts.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	To learn about fundamental web development components and HTML tags.
CO2	To design responsive web pages using HTML and CSS.
CO3	To understand JavaScript concepts, including classes and functions.
CO4	To design interactive web pages using JavaScript, DOM manipulation, and event handling.
CO5	To understand server-side programming and backend connectivity.

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Internet fundamentals, LAN, WAN, Introduction to common Internet terms, www History of Web.		CO1	1
Basics of networking, DNS, URL, Web protocols – http and https. Introduction to search engines, web crawlers, social networks.		CO1	1
Designing web pages: HTML syntax, headings, linking, images, special characters and horizontal rules, lists, navigation tags, tables, forms, internal linking, Meta elements.		CO1	1
Introduction to CSS, stylesheets linking, selectors, box model, Margin, Keyframes Flexbox		CO2	2

Introduction to Javascript, DOM, Event Handling, Event Loop	CO3	2
Advanced Javascript Concepts: Closure and Currying, synch, await,async, JSON.	CO4	2
Introduction to Node Js, installation, server side scripting.	CO5	1-2
MongoDB (Optional), Website Deployment.	CO5	1

4. Text books

i) Deitel H.M. and P. J. Deitel, Internet & World Wide Web - How to Program, Prentice-Hall.

ii) Goodman D, Morrison M., JavaScript Bible; Wiley India.

iii) Lutz, Mark, Learning Python (4th Ed.). O'Reilly Media.

iv) Garfinkle S., Spafford G; Web Security, Privacy and Commerce; O'Reilly, 2002.

v) N.P.Gopalan, Akilandeswari, Web Technology, Prentice-Hall.

5. Reference Book(s) and Other Required Material

i) Eloquent JavaScript by Marijn Haverbeke – MIT Licence MDN Web Docs.

6. Evaluation Details:

Mid Sem: 20-30 Marks, End Sem: 50-60 Marks, Quiz/Internal assessment: 10-20 Marks, Total 100 Marks

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	0	0	0	0	0	0	0	0	0	2	3	2	3
CO2	2	3	0	0	2	0	0	0	0	0	0	2	3	2	3
CO3	2	3	0	0	2	0	0	0	0	0	0	2	2	2	3
CO4	0	2	0	0	0	0	0	0	0	0	0	2	3	3	2
CO5	0	0	3	3	3	0	3	0	1	2	0	2	3	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

1	Lab Listicle: A listicle is a piece of writing or other content presented wholly or partly in the form of a list. You will create a listicle web page that describes the “3 on-campus labs you should be visiting” at VNIT. You should create the web page in & lt;roll no>_< Name& gt;_listicle.html with styles defined in & lt;roll no& gt;_& lt;Name>_listicle-style.css

	1. Overall appearance Here is a miniature screenshot of the website you need to recreate in this assignment: Note that: • You have to select the images and content from your own side. • The images should be stored in the current directory/images/ folder.
2	Section measurements Note: measurements of some elements that are absent should be chosen by you. 3. Font faces, sizes, and colors • Page Title: • The font face is ' Roboto Slab' and the fallback font is serif. • The font size is 36px. • The font weight is normal (not bold). • The font color is white. • The title is vertical and center aligned to the header image. • Profile Text: • The font face is ' Source Sans Pro' and the fallback font is sans-serif. • The font size is 18px. • The font weight for the author name (“The Instructor”) is bold • The font style for the last updated (“September 2021”) is italic. • The font color is rgb(51, 51, 51). • The line height 24px. • The gray line under the “Last updated” line is 10px under the text, 2px wide, and the color is #e6e6e6. Body Text: • Heading • The font face is ' Roboto Slab' and the fallback font is serif. • The font size is 36px. • The font weight is bold. • The number’s color is rgba(0, 0, 0, 0.25). • The title color is rgb(51, 51, 51).

- Address
  - The address under the heading is a link and is described in the Links Section below.

- Paragraphs
- The font face is ' Source Sans Pro' and the fallback font is sans-serif.
- The font size is 18px.
- The line height 32px.
- The font color is rgb(51, 51, 51).

4. Links

Here is a description of how links should work on your page:

• Each address of the page is a link. The URL for each link is specified by the coder

(Can be the respective lab or the department website).

• The link color is #42b4d6.

• The link is not bold, and the link is not underlined unless you hover over the link.

• When you hover over the link, the link becomes underlined.

• Hint: To remove or add an underline, you can play with CSS property text decoration;

5. Images

- Header image
- The header is a background image and should be referenced from the images folder.
- The background does not repeat.
- The background's size is set to cover.
- The background position is anchored to the top.
- Its height is 500px.
- There is a semi-transparent color overlay on top of the header image,
- which is rgba(0, 0, 0, .3)

▪ Note: You can achieve this using the following CSS rule:

Background-image: linear-gradient (rgba(0, 0, 0, .3),

Rgba (0, 0, 0, .3)), url(../images/header.jpg);

3	Profile image (cartoon of a user using a laptop) • The profile image should be referenced from the images folder. • Its width is 100px. • It has rounded corners with radius 100%. It has a white border that is 1px thick
4	HTML and CSS style requirements following practices will carry weightage: • Use HTML and CSS we've learned in class. You should be able to complete this assignment using HTML and CSS we've learned in class. While you are not strictly forbidden from using HTML/CSS we haven't talked about in class, if you use it incorrectly or if you make poor stylistic choices, you may be marked down.
5	Do not use JavaScript. There's no need to use JavaScript in this assignment. Respect Separation of Concerns. Your HTML should describe the content of your page, and your CSS should describe your page's appearance. This carries significant weightage. • Do not use an ordered list element (ol) to create the list layout. There's nothing wrong with doing this, per se, but it involves some fairly esoteric CSS that we did not cover in class. We recommend you write out the numbers "1.", "2.", etc. in the HTML instead of using ordered list element. • Follow the best practices that were discussed in lecture. • Reduce redundancy in CSS. Try not to have too many redundant styles, if there are ways to use inheritance or special selectors to concisely define style rules. • Match the given appearance as closely as possible. It's fine if your web page is off from our description by a few pixels here and there, but noticeable differences may result in a lower assignment score. • Use descriptive names, consistent spacing, and otherwise follow good code hygiene. • Use flex layout at least once. • The website should be properly viewable on a mobile as well. The images and content text should be selected by you – however, these selections will not decide the marks
6	Classes. This assignment is designed to understand the concept of classes, communication between classes and reading data from a structured format like JSON. You are required to implement and submit two versions of this assignment.

	● The first version must use custom events as the means of communication between the classes. The second version must use callback functions for communication between the classes. ● Using the fetch () API, you are required to obtain a list of entities from the json file (input.json) and populate entity values in the web page. ● When the user clicks on an entity, the corresponding images of the entity (retrieved from the JSON file) should be displayed in the IMAGE Section of the web page.

Artificial Intelligence

Course Code & Course Title:	MALA3XX Artificial Intelligence		
Course Type:	DC		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Data Structures and Applications		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

Given the knowledge of algorithms and data structures, students will be able to design intelligent agents that solve problems using exploratory search techniques, perform reasoning using formal logic, and work in uncertain environments using probabilistic reasoning techniques.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Formulate problems so that exploratory search can be applied.
CO2	Implement optimal, heuristic and memory bounded search techniques.
CO3	Represent knowledge using formal logic and design algorithms to work in a semi-observable environment using logical reasoning.
CO4	Design and develop practical algorithms for solving real-life planning problems and will be implement probabilistic reasoning techniques to work in uncertain environments.

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction: What is AI? History, Overview, Intelligent Agents, Performance Measure, Rationality, Structure of Agents, Problem-solving agents, Problem Formulation, Uninformed Search Strategies Informed (Heuristic) Search and Exploration, Greedy best first search, A* search, Memory bounded heuristic search, Heuristic functions, inventing admissible heuristic functions, Local Search algorithms, Hill-climbing, Simulated Annealing, Genetic Algorithms, Online search		CO1	2

Constraint Satisfaction Problems, Backtracking Search, variable and value ordering, constraint propagation, intelligent backtracking, local search for CSPs, Adversarial Search, Games, The minimax algorithm, Alpha-Beta pruning, Imperfect Real-Time Decisions, Games that include an Element of Chance	CO2	3
Knowledge Based Agents, Logic, Propositional Logic, Inference, Equivalence, Validity and Satisfiability, Resolution, Forward and Backward Chaining, DPLL algorithm, Local search algorithms, First Order Logic, Models for first order logic, Symbols and Interpretations, Terms, Atomic sentences, complex sentences, Quantifiers, Inference in FOL, Unification and Lifting, Forward Chaining, Backward Chaining, Resolution	CO3	3
Planning, Language of planning problems, planning with state-space search, forward and backward state-space search, Heuristics for state-space search, partial order planning, planning graphs, planning with propositional logic	CO3, CO4	3
Uncertainty, handling uncertain knowledge, rational decisions, basics of probability, axioms of probability, inference using full joint distributions, independence, Baye's Rule and conditional independence, Bayesian networks, Semantics of Bayesian networks, Exact and Approximate inference in Bayesian Networks.	CO3, CO4	3

4.	**Text books**

i) Russel and Norvig, Artificial Intelligence a Modern Approach, 2nd Edition, Pearson Education, 2002, ISBN: 9780137903955.

ii) Patterson, D. W, Artificial Intelligence – A Practical Approach, 3rd Edition, Tata McGraw Hill, 2009, ISBN: 9780070490819.

iii) Winston, P. H., Artificial Intelligence, 3rd Edition, Addison-Wesley, 1992, ISBN: 9780201533774.

5.	**Reference Book(s) and Other Required Material**

i) Patterson, D.H., Introduction to Artificial Intelligence and Expert Systems, 1st Edition, Prentice Hall of India, New Delhi, 2001, ISBN: 9788120307773

ii) Charniak, E., and McDermott, D., Introduction to Artificial Intelligence, 1st Edition, Addison-Wesley, 1985. ISBN: 9780201119459.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	1	2	1	---	---	---	1	2	2	3	2	3
CO2	3	3	3	3	3	1	---	---	-	3	3	2	3	2	3
CO3	3	3	3	3	2	1	---	---	-	3	3	2	3	2	3
CO4	3	3	3	3	3	1	---	---	-	3	3	2	3	2	3
CO5	3	2	1	1	2	1	---	---	---	1	2	2	3	2	3

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

i) Formulate simple AI problems and implement basic problem-solving agents using uninformed search strategies.

ii) Design heuristic functions and apply local search algorithms like Hill Climbing, Simulated Annealing, Genetic Algorithms, and Online Search.

iii) Solve CSP problems like the N-Queens problem using Backtracking, variable/value ordering, and constraint propagation. Implement game playing algorithms including Minimax and Alpha-Beta Pruning and analyse games with chance elements.

iv) Implement inference techniques such as resolution, forward and backward chaining, and DPLL. Apply reasoning using First Order Logic including unification and resolution.

v) Implement State Space Planning (Forward Search), Backward State Space Planning, Planning Graph algorithm (Graph Plan), Partial Order Planning and Planning using propositional logic.

Machine Learning

Course Code & Course Title:	MALA3XX Machine Learning		
Course Type:	DC		
Name of the programme(s):	B.Tech. in Mathematics and Computing		
L – T – P	3-0-0	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)	NIL		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this course is to expose students to understand the concept of machine learning algorithms and its applications in real life scenarios.

2.	**Course Outcomes:**
CO1	Understand instance-based learning algorithms
CO2	Design neural network to solve classification and function approximation problems
CO3	Build optimal classifiers using genetic algorithms
CO4	Design convolutional networks to solve classification problems

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction – Well defined learning problems, designing a Learning System, Issues in Machine Learning; - The Concept Learning Task - General-to-specific ordering of hypotheses, Find-S, List then eliminate algorithm, Candidate elimination algorithm, Inductive bias - Decision Tree Learning - Decision tree learning algorithm		CO1	3
Inductive bias- Issues in Decision tree learning; - Artificial Neural Networks – Perceptrons, Gradient descent and the Delta rule, Adaline, Multilayer networks, Derivation of backpropagation rule- Backpropagation Algorithm- Convergence, Generalization; – Evaluating Hypotheses – Estimating Hypotheses Accuracy, Basics of sampling Theory, Comparing Learning Algorithms; - Bayesian Learning – Bayes theorem, Concept learning, Bayes Optimal		CO2	4

Classifier, Naïve Bayes classifier, Bayesian belief networks, EM algorithm; - Computational Learning Theory – Sample Complexity for Finite Hypothesis spaces, Sample Complexity for Infinite Hypothesis spaces, The Mistake Bound Model of Learning; - Instance-Based Learning – k-Nearest Neighbour Learning, Locally Weighted Regression, Radial basis function networks		
Case-based learning - Genetic Algorithms – an illustrative example, Hypothesis space search, Genetic Programming, Models of Evolution and Learning;	CO3	4
Reinforcement Learning - The Learning Task, Q Learning, Support vector Machines, Deep learning networks – Deep Feedforward Networks – Convolutional Network.	CO4	3

4. Text books

i) C Bishop, Pattern Recognition and Machine Learning, 1st Edition, Springer, 2006, ISBN: 9780387310732.

ii) Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, 1st Edition, The MIT Press Cambridge, Massachusetts, London, England, 2016, ISBN: 9780262035613.

5. Reference Book(s) and Other Required Material

i) Tom.M.Mitchell, Machine Learning, 1st Edition, McGraw Hill, 1997, ISBN: 9780071154673.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7		PO8	PO9	PO10	PO11	PSO 1	PSO2	PSO3	PSO4
CO1	3	3	3	0	1	3	0	0	1	3	0	3	2	3	2	3
CO2	3	3	3	0	2	0	0	0	1	3	0	3	2	3	2	3
CO3	3	3	3	0	3	0	0	0	1	3	0	3	2	3	2	3
CO4	3	3	3	0	3	0	2	0	2	3	2	3	2	3	2	3
CO5	3	3	3	0	1	3	0	0	1	3	0	3	2	3	2	3

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Topics in Functional Analysis

Course Code & Course Title:	MALA3XX Topics in Functional Analysis		
Course Type:	DC		
Name of the programme(s):	B.Tech. in Mathematics and Computing		
L – T – P	3-0-0	**No. of Credits**	3
Pre-requisites: Course Code(s) & Name(s)	Introduction to Linear Algebra		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

This course is intended to introduce the student to the basic concepts and theorems of Functional Analysis and its applications.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Understand fundamental properties, theorems of normed linear spaces, Banach space and Hilbert space.
CO2	Understand definitions, properties and theorems related to Bounded linear operators, Linear functionals and closed operators
CO3	Understand concept and theorem related to orthogonal set, orthonormal set and orthogonal basis including Bassel inequality and parseval's Formula, Riesz Fischer theorem
CO4	Understand and apply fundamental theorems from the theory of Normed linear space and Banach spaces, including the Hahn-Banach theorem, the open mapping theorem, the closed graph theorem

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Normed linear spaces. Non-compactness of the unit ball in infinite dimensional normed linear spaces. Product and quotient spaces. Banach spaces, Hilbert spaces, Schauder basis, separability, Heine Borel Theorem, best approximation and projection Theorem		CO1	3
Linear maps. Boundedness and continuity. Linear isometries, linear functionals, Examples of bounded and unbounded operators, The space B(X, Y), Riesz Representation theorem, dual Hilbert space, Lax Milgram Theorem. Convergence of sequence of operators,		CO2	4

completeness of space B(X, Y), convergence of Quadrature formulas, Closed operators		
Orthonormal set and Orthonormal bases, Bessel's inequality, Fourier expansion, Parseval's identity, Riesz-Fisher theorem	CO3	3
Hahn-Banach extension theorem and its consequences, Applications of Hahn-Banach extension theorem (in operator equations, in generalization of Lax-Milgram theorem). Hahn-Banach extension of operators, Uniform boundedness Principle, Banach-Steinhaus theorem and its Applications (on divergence of Lagrange interpolation, on convergence of Quadrature Formula, on divergence of Fourier series), closed graph theorem, bounded inverse theorem, open mapping theorem and applications to operator equations.	CO4	4

4.	**Text books**

i) Conway, J. B., A Course in Functional Analysis, Springer, New York, 1990, ISBN: 9780387972459.

ii) Kreyszig E., Introductory Functional Analysis with Applications. John Wiley & Sons, 1978, ISBN: 9780471037293.

iii) Limaye B. V., Functional Analysis, 2nd Edition, New Age International Publishers, 1996, ISBN: 9788122408492.

iv) Simmons G. F. Introduction to Topology and Modern Analysis, McGraw-Hill Kogakusha, Tokyo, 1963, ISBN: 9780070856950.

v) Thamban Nair M., Functional Analysis: A First Course, 2nd Edition, PHI learning pvt limited, 2021, ISBN: 9789390544004.

5.	**Reference Book(s) and Other Required Material**

i) Yosida, K, Functional Analysis, 4th Edition, Narosa, 1974, ISBN: 9783540068129.

ii) Rudin W, Functional Analysis, 2nd Edition, McGraw-Hill, 2006, ISBN: 9780070542365.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO2	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO3	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO4	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO5	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Machine Learning Laboratory

Course Code & Course Title:	MAPA3XX Machine Learning Laboratory		
Course Type:	DC		
Name of the programme(s):	B.Tech. in Mathematics and Computing		
L – T – P	0-0-2	**No. of Credits**	1
Pre-requisites: Course Code(s) & Name(s)	Data Structures and Algorithms		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

To develop skills of using recent machine learning algorithms for solving practical problems. To understand different machine learning algorithms to use them for solving real-world problems.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Design and implement algorithm using least means square learning rule for practical problems
CO2	Design a classifier using Genetic Algorithm
CO3	Apply supervised learning using perceptron
CO4	Design and implement Convolutional Networks to solve classification problems

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
1. Design and implement machine learning algorithms using least squares learning rules to play checkers games. The training experience should be generated by the system playing the game with itself. 2. Implement a genetic algorithm program to successfully classify examples in the restaurant domain problem. Data for RESTAURANT domain given in this table. Example Friday Patrons Price Rain Res Est Type Will Wait X1 No Some High No Yes 0-10 French Yes X2 No Full Low No No 30-60 Thai No X3 No Some Low No No 0-10 Burger Yes		CO1, CO2, CO3, CO4	

X4 Yes Full Low Yes No 10-30 Thai Yes X5 Yes Full High No Yes >60 French No X6 No Some Med Yes Yes 0-10 Italian Yes X7 No None Low Yes No 0-10 Burger No X8 No Some Med Yes Yes 0-10 Thai Yes X9 Yes Full Low Yes No >60 Burger No X10 Yes Full High No Yes 10-30 Italian No X11 No None Low No No 0-10 Thai No X12 Yes Full Low No No 30-60 Burger Yes Res indicates reservation made and Est means estimated waiting time to get a table, WillWait target attribute indicates whether to wait for table in that restaurant. 3. Design an application using a back propagation algorithm to recognize handwritten characters from A to Z and digits 0 to 9. 4. Design an application for binary classification using perceptron learning algorithm. 5. Design an application for binary classification using Adaline learning algorithm. 6. Implement a Genetic algorithm to generate solutions for the 8-Queens problem. 7. Implement a machine learning program to play 5× 5 Tic tac toe games. The program should use the least squares learning rule. 8. Design a Convolutional network for handwritten character recognition problems for A to Z and 0 to 9 digits. 9. Design a Convolutional network for image recognition problems. 10. Design an application using machine learning concepts for time series data.		

4.	**Text books**

i) C Bishop, Pattern Recognition and Machine Learning, 1st Edition, Springer, 2006, ISBN: 9780387310732.

ii) Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, 1st Edition, The MIT Press Cambridge, Massachusetts, London, England, 2016, ISBN: 9780262035613.

5.	**Reference Book(s) and Other Required Material**

i) Tom.M.Mitchell, Machine Learning, 1st Edition, McGraw Hill, 1997, ISBN: 9780071154673.

6.	**Evaluation Details:**

Continuous Evaluation

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	2	2	1	---	---	---	1	1	2	3	2	3
CO2	3	3	3	2	2	1	---	---	---	1	1	2	3	2	3
CO3	3	3	3	2	2	1	---	---	---	1	1	2	3	2	3
CO4	3	3	3	2	2	1	---	---	---	1	1	2	3	2	3
CO5	3	3	3	2	2	1	---	---	---	1	1	2	3	2	3

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

i) Implement Decision Tree Learning Algorithm for classification of a dataset.
ii) Implement Decision Tree using Information Gain or Entropy for dataset classification
iii) Implement Perceptron Learning Algorithm for binary classification.
iv) Implement Gradient Descent and Delta Rule for training a simple neural network.
v) Implement Multilayer Neural Network using Backpropagation Algorithm.
vi) Implement Naïve Bayes Classifier for classification of a dataset.
vii) Implement Bayesian Belief Network for probabilistic inference.
viii) Implement k-Nearest Neighbour (k-NN) Algorithm for classification.
ix) Implement Radial Basis Function (RBF) Network for classification.
x) Implement Genetic Algorithm to optimize a function or search hypothesis space.
xi) Implement Support Vector Machine (SVM) for classification.
xii) Implement Genetic Programming for evolving simple programs.
xiii) Implement Deep Feedforward Neural Network for classification or regression.
xiv) Implement Convolutional Neural Network (CNN) for image classification.

Data Science & Visualization in R/Python/SQL

Course Code & Course Title:	MALA 3XX Data Science & Visualization in R/Python/SQL		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	No. of Credits	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The course aims to equip students with the knowledge and skills to analyze large datasets, build predictive models, and effectively communicate insights through data visualization techniques. Students will learn to apply statistical and machine learning methods, evaluate model performance, and create informative visualizations using Python and R.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Apply statistical methods to data for inferences.
CO2	Access online resources for R and import new function packages into the R workspace. Import, review, manipulate and summarize data-sets in R
CO3	Perform descriptive analytics over large scale data and apply appropriate statistical tests using R.
CO4	Explore data-sets to create testable hypotheses and identify appropriate statistical tests.

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Importance of analytics and visualization in the era of data abundance, Review of probability, statistics and random processes.		CO1	2
Brief introduction to estimation theory, – Introduction to machine learning, supervised and unsupervised learning, gradient descent, overfitting, regularization.		CO1	3
Clustering techniques: K-means, Gaussian mixture models and expectation-maximization, agglomerative clustering. evaluation of		CO1, CO3, CO4	3

clustering - Rand index, mutual information-based scores Data visualization: Basic principles, Fowlkes-Mallows index.		
Regression: Linear models, ordinary least squares, ridge regression, LASSO, Gaussian Processes regression., categorical and continuous variables.	CO3, CO4	2
Exploratory graphical analysis - Creating static graphs, animated visualizations - loops, GIFs and Videos, Data visualization in Python and R, examples.	CO2, CO3, CO4	3

4. Text books

i) Richard O. Duda, Peter E. Hart and David G. Stork, Pattern Classification (2nd Edition). Wiley- Interscience, New York, NY, USA, 2000, ISBN: 9780471056690.

ii) Hastie, T., Tibshirani, R., Friedman, J, The elements of statistical learning: data mining, inference and prediction. Springer, 2009, ISBN: 9780387848570.

5. Reference Book(s) and Other Required Material

i) Christopher M. Bishop. Pattern Recognition and Machine Learning (Information Science and Statistics). Springer-Verlag, Berlin, Heidelberg, 2006, ISBN: 9780387310732.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	2	2	2	1	1	-	-	-	2	2	3	2	3
CO2	3	2	2	2	2	1	1	-	-	-	2	2	3	2	3
CO3	3	2	2	2	2	1	1	-	-	-	2	2	3	2	3
CO4	3	2	2	2	2	1	1	-	-	-	2	2	3	2	3

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Fundamentals of Fluid Dynamics

Course Code & Course Title:	MALA 3XX Fundamentals of Fluid Dynamics		
Course Type:	DE		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance of fluid dynamics in Science and Engineering.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Deal with both Lagrangian and Eulerian description of fluid motion, find streamlines and pathlines for the given fluid flow.
CO2	Understand the theory behind the continuity equation, Euler equations of motion and Bernoulli equations.
CO3	Deal with 2-dimensional potential flows and 3-dimensional axisymmetric flows of an incompressible ideal fluid. Deal with the flows concerning line source/sink, line doublet, 3-dimensional source/sink, doublet.
CO4	Understand the relationship between stress and rate of strain for Newtonian fluids, understand the theory behind the Navier-Stokes equations and solve some simple fluid flow problems concerning the Newtonian fluids.

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Kinematics of fluids in motion: Real fluids and ideal fluids, Velocity of a fluid at a point , Stream lines and path lines, Steady and unsteady flows, The velocity potential, The velocity vector, Local and particle rates of change		CO1	2.5

Equation of continuity, Acceleration of fluid, Conditions at a rigid boundary, Equations of motion of fluid: Euler's equations of motion, Bernoulli's equation, Some flows involving axial symmetry,	CO2	2.5
Some special two-dimensional flows, The Milne-Thomson circle theorem, Theorem of Blasius. Some three-dimensional flows: Introduction, Sources, sinks and doublets, Axisymmetric flows, Stokes ` stream function.	CO3	3
Viscous flows: Stress analysis in fluid motion, Relations between stress and rate of strain, Coefficient of viscosity and laminar flow, Navier-Stokes equations of motion of viscous fluid, Steady motion between parallel planes and through tube of uniform cross section. Flow between concentric rotating cylinders. Steady viscous flow in tube having uniform elliptic cross section, Tube having equilateral triangular cross section, Steady flow past a fixed sphere.	CO4	4.5

4.	**Text books**

i) G.K. Batchelor, Introduction to Fluid Dynamics, Cambridge University Press, 1967, ISBN: 9780521663960.

ii) Whitaker, Introduction to Fluid Mechanics, Prentice-Hall, 1968, ISBN: 9780134839097.

iii) P.K. Kundu and I.M. Cohen, Fluid Mechanics (3rd edition) Elsevier Science & Technology, 2002, ISBN: 9780121782535.

iv) M. C. Potter, D. C. Wiggert and B. H. Ramadan, Mechanics of Fluids, Cengage Learning, 2012, ISBN: 9781439062036.

5.	**Reference Book(s) and Other Required Material**

i) N. Curle and H. J. Davies, Modern Fluid Dynamics, Vol. I, 1968, ISBN: 9780442017972.

ii) F. Chorlton, Text book of Dynamics, CBS Publishers and Distributors, Delhi, 1998, ISBN: 9789387964488.

iii) L.M.Milne Thomson, Theoretical Hydrodynamics, Macmillan Company, New York, 1955, ISBN: 0486689700.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	0	0	0	0	0	0	0	0	2	3	2	3	2
CO2	3	2	0	0	0	0	0	0	0	0	2	3	2	3	2
CO3	3	2	1	0	0	1	1	0	0	0	2	3	2	3	2
CO4	3	2	1	0	0	1	1	0	0	0	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Introduction to Finite Element Method

Course Code & Course Title:	MALA 3XX Introduction to Finite Element Method		
Course Type:	DE		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Introduction to Partial differential equations and Topics in Functional Analysis.		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance of finite element methods to tackle the problems of science and engineering.

2.	**Course Outcomes:**
CO1	Explore Galerkin method for elliptic boundary value problems
CO2	Construct finite element spaces and the role and significance of shape functions in finite element formulations
CO3	Develop and analyze the semi-discrete and fully discrete schemes for parabolic problems
CO4	Numerical Algorithms, perform numerical experiments using MATLAB

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Sobolev Spaces: basic elements, Poincare inequality. Abstract variational formulation and elliptic boundary value problem. Galerkin formulation and Cea's Lemma.		CO1	3
Construction of finite element spaces. Polynomial approximations and interpolation errors. Convergence analysis: Aubin-Nitsche duality argument; non-conforming elements and numerical integration; computation of finite element solutions.		CO2	4

Parabolic initial and boundary value problems: semi discrete and completely discrete schemes with convergence analysis.	CO3	4
Lab component: Implementation of algorithms and computational experiments using MATLAB	CO4	2.5

4. Text books

i) C. Johnson, Numerical solutions of Partial Differential Equations by Finite Element Methods, Cambridge University Press, 1987, ISBN: 9780486469003.

ii) K. E. Brenner and R. Scott, The Mathematical Theory of Finite Element Methods, Springer- Verlag, 1994, ISBN: 9780387941936.

5. Reference Book(s) and Other Required Material

i) P.G. Ciarlet, The Finite Element Methods for Elliptic Problems, North Holland, 1978, ISBN: 9780444850287.

ii) C. Mercier, Lectures on Topics in Finite Element Solution of Elliptic Problems, TIFR Lectures on Mathematics and Physics Vol. 63, Narosa, 1979, ISBN: 9783540095439.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	3	3	-	-	-	-	1	1	3	2	3	2
CO2	3	3	2	3	3	-	-	-		1	1	3	2	3	2
CO3	3	3	2	3	3	-	-	-		1	1	3	2	3	2
CO4	3	3	2	3	3	-	-	-		1	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

Implementation of algorithms and computational experiments using MATLAB

Statistical Inference and Multivariate Analysis

Course Code & Course Title:	MALA 3XX Statistical Inference and Multivariate Analysis		
Course Type:	DE		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this course is to expose students to understand the importance of statistics along multivariate analysis with real life applicability.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Understand the concept of estimations and its properties
CO2	Be able to use the concept of different testing of hypothesis using normal distribution
CO3	Understand techniques for sampling from multivariate normal distribution
CO4	Be able to learn principal component analysis

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Inference I: Basic concepts of point estimations, Properties of MLE, Lower bounds of variance, Minimal sufficiency and completeness, Uniformly minimum variance unbiased estimators, Bayes and minimax estimation.		CO1	3
Inference II: Neymann Person fundamental lemma, UMP test, UMP unbiased test, Unbiased test for normal populations, Likelihood ratio test, Invariant test, sequential procedure.		CO2	3
Sampling distributions from multivariate normal: Covariance matrix, Generalized variance, Sample mean, Covariance and correlation as Matrix operations. Multivariate Normal distribution, Sampling from a multivariate Normal Distribution, Maximum Likelihood Estimation, The sampling distribution of and S, Inferences about a Mean Vector, Plausibility of mu_0 as a value for a Normal population Mean,		CO3	4

Hotelling's T^2 and Likelihood Ratio Tests Paired Comparisons and a Repeated Measures Design, Comparing Mean Vectors from two populations, Introduction to One Way MANOVA.		
Principal component and factor analysis: Principal components, Population principal components, Graphing the principal components, The orthogonal factor model, Factor rotation, Factor scores, Perspectives and a strategy for factor analysis.	CO4	3

4. Text books

i) Richard A. Johnson, Applied Multivariate Statistical analysis, Prentice Hall, 2001, ISBN: 9780131877153.

ii) A.M. Mood, F.A. Graybill and D.C. Boes, Introduction to the Theory of Statistics, McGraw-Hill series, 2002, ISBN: 9780070854659.

iii) Cooly WW and PR Lohnes – Multivariate Data Analysis-John Wiley & Sons, 1971, ISBN: 9780898747812.

5. Reference Book(s) and Other Required Material

i) J E Hair, W C Black, B. J. Babin, R E Anderson, Multivariate Data Analysis, Prentice Hall, 2009, ISBN: 978013813263.

ii) G. Casella & R.L. Berger, Statistical Inference, CRC Press, 2002, ISBN: 9780534243128.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	2	1	1	---	---	---	1	1	3	2	3	2
CO2	3	3	3	2	1	1	---	---	---	1	1	3	2	3	2
CO3	3	3	3	2	1	1	---	---	---	1	1	3	2	3	2
CO4	3	3	3	2	1	1	---	---	---	1	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Cryptography

Course Code & Course Title:	MALA 3XX Cryptography		
Course Type:	DE		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The course aims to provide a comprehensive understanding of number theory, cryptography and their applications in secure communication and data protection. Students will learn to analyse cryptographic algorithms, implement secure protocols, and assess the security of cryptographic systems.

2.	**Course Outcomes:**
CO1	Understand the mathematics of the cryptographic algorithms
CO2	Understand the basic concepts of symmetric cryptosystem, public key cryptosystem and digital signature scheme.
CO3	Reason about the security of cryptographic constructions
CO4	Break the cryptosystems that are not secure. To get an insight into the working of different existing cryptographic algorithms
CO5	Learn how to use cryptographic algorithms in security

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Review: Divisibility, GCD, Primes, Congruences, Primitive roots, groups, rings, finite fields. Quadratic Residues, Legendre & Jacobi Symbols, Quadratic Reciprocity Law and proofs.		CO1	2
The Shift Cipher, The Substitution Cipher, The Affine Cipher, The Vigenere Cipher, The Hill Cipher, The Permutation Cipher, Stream & Block ciphers.		CO1, CO2	2
Shannon's Theory of Perfect Secrecy, Vernam One Time Pad, Random Numbers, Mode of operations in block cipher, the Data		CO1, CO2	3

Encryption Standard (DES), Feistel Ciphers, the Advanced Encryption Standard (AES), Prime Number Generation, Fermat Test, Miller Rabin Test.		
Public Key Cryptography, RSA Cryptosystem, Factoring problem, Rabin Cryptosystem, Quadratic Residue Problem, Diffie-Hellman (DH) Key Exchange Protocol, Discrete Logarithm Problem (DLP), ElGamal Cryptosystem, Elliptic Curve, Elliptic Curve Cryptosystem (ECC).	CO2, CO3	3
Hash and Compression Functions, Security of Hash Functions, Iterated Hash Functions, SHA-1, MD-5, Message Authentication Codes. Digital Signature, RSA Signature, ElGamal Signature, Digital Signature Algorithm (DSA), ECDSA. Identification and Authentication, Passwords, Challenge-Response Identification, Zero-Knowledge Proofs, The Schnorr Identification Scheme, The Okamoto Identification Scheme, Identity-based Identification Schemes, Shamir Secret Sharing Protocol.	CO4, CO5	4

4.	**Text books**

i) B Forouzan, Cryptography and Network security, Tata McGraw Hill, 2011, ISBN: 9780073327532.

ii) D R Stinson, Cryptography: Theory and Practice. CRC Press, 2000, ISBN: 9781138197015.

iii) J Buchmann, Introduction to Cryptography, Springer (India) 2004, ISBN: 9780387207568.

iv) Wenbo Mao, Modern Cryptography: Theory and Practice. Pearson Education, 2004, ISBN: 9788131702123.

5.	**Reference Book(s) and Other Required Material**

i) Koblitz, A Course in Number Theory and Cryptography by, Springer, ISBN: 9780387942933.

ii) Oorschot and Vanstone, Handbook of Applied Cryptography by Menezes, CRC, ISBN: 9780849385230.

iii) Christof Paar and Jan Pelzl, Understanding Cryptography, Springer, ISBN: 9783642446498.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	---	---	---	---	---	---	---	1	3	2	3	2
CO2	2	2	2	---	3	1	---	---	---	1	1	3	2	3	2
CO3	1	2	2	---	3	1	---	---	---	1	1	3	2	3	2
CO4	1	2	2	---	3	1	---	1	1	1	1	3	2	3	2
CO5	1	2	2	---	3	1	---	1	---	1	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Computational Finance

Course Code & Course Title:	MALA 3XX Computational Finance		
Course Type:	DE		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The course aims to provide a comprehensive understanding of financial markets, instruments, and risk management techniques. Students will learn to apply computational tools and financial mathematics to analyse and optimize investment portfolios, assess risk exposures, and price derivatives.

2.	**Course Outcomes:**
CO1	Understand the fundamental concepts of financial markets and instruments
CO2	Apply computational techniques to analyze financial data and model financial phenomena
CO3	Develop skills in risk management, portfolio otpimization, and derivatives pricing
CO4	Appreciate the role of computational finance in the financial industry

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Financial Markets: Overview of financial markets (stock, bond, derivatives) Financial instruments and their characteristics.		CO1	1
Computational Tools: Financial data sources and APIs Financial Mathematics: Time value of money, interest rates, present value, future value, Risk and return. Value at Risk (VaR): Historical simulation, parametric methods, Conditional Value at Risk (CVaR). Credit Risk: Credit rating, probability of default, expected loss. Market Risk: Sensitivity analysis, stress testing.		CO2	4
Modern Portfolio Theory (MPT): Efficient frontier, Capital Asset Pricing Model (CAPM), Risk-return trade-off, Portfolio Optimization:		CO3	3

Mean-variance optimization, risk parity, Constraints and objectives. Factor Models: Fama-French factor model, Barra factor model.		
Options: Call and put options, Black-Scholes model, Binomial option pricing model. Futures and Forwards: Pricing and hedging, Interest rate futures and swaps. Monte Carlo Simulation: Applications in option pricing, risk management, and Variance reduction techniques.	CO4	4
Practical Assignments and Projects: Implement financial models and algorithms using programming languages, Analyse financial data using statistical and time series techniques, Develop portfolio optimization strategies, Price and hedge derivatives using various methods.	CO4	2

4. Text books

i) Capiński, M., & Zastawniak, T. Mathematics for finance: an introduction to financial engineering. Springer London (2003), ISBN: 9781852338466.

ii) Y.-l. Zhu, X. Wu, I-L. Chern and Z.-z. Sun, Derivative Securities and Difference Methods, 2nd Ed., Springer, 2013, ISBN: 9781461473053.

iii) D. Higham, Introduction to Financial Option Valuation: Mathematics, Stochastics and Computation, Cambridge University Press, 2004, ISBN: 9780521838849.

5. Reference Book(s) and Other Required Material

i) P. Wilmott, S. Howison and J. Dewynne, The Mathematics of Financial Derivatives: A Student Introduction, Cambridge University Press, 1997, ISBN: 9780521497893.

ii) Y. Lyuu, Financial Engineering and Computation, Cambridge University Press, 2002, ISBN: 9780521781718.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	2	1	1	---	---	---	3	2	3	2	3	2
CO2	3	3	3	3	2	1	---	---	---	3	2	3	2	3	2
CO3	3	3	3	3	2	1	---	---	---	3	2	3	2	3	2
CO4	3	3	3	3	3	1	---	---	1	3	3	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

i) Implement financial models and algorithms using programming languages.

ii) Analyse financial data using statistical and time series techniques.

iii) Develop portfolio optimization strategies.

iv) Price and hedge derivatives using various methods.

Numerical Methods for Conservation Laws

Course Code & Course Title:	MALA 3XX Numerical Methods for Conservation Laws		
Course Type:	DE		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance of conservation laws.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	The nonlinear behaviour in the solution of hyperbolic conservation laws
CO2	Concepts related to weak solution for one dimensional conservation laws
CO3	How to evaluate the discrete solution (finite difference and finite volume) of conservation laws
CO4	Understand the intricacies involved in the formulation of numerical schemes

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Linear hyperbolic equations: Finite differences, Theoretical concepts of stability and consistency, Order of accuracy, Upwind, Lax Fredrichs and Lax-Wendroff schemes.		CO1	2
Nonlinear equations: One dimensional scalar conservation laws, Review of basic theory, weak solutions, Solutions of the Reimann problem and entropy conditions. Introduction to the finite volume methods, First order schemes like Lax Fredrichs, Godunov, Enquist-Osher and Roe's scheme. Convergence results, Entropy consistency and numerical viscosity.		CO2	4
Introduction to the higher order schemes: Second order (high resolution) finite volume schemes: Lax-Wendroff scheme, Upwind schemes of Van Leer, Central schemes, Relaxation methods, ENO/WENO schemes.		CO3, CO4	3

Linear hyperbolic systems in one dimension, examples, hyperbolicity, characteristic decomposition, Reimann problems, Higher order finite volume methods.	CO3, CO4	3

4. Text books

i) R. J. Le Veque: Numerical Methods for Conservation Laws, Birkhauser Verlag, 1992, ISBN: 9783764327231.

ii) E. F. Toro: Reimann Solvers and Numerical Methods for Fluid Dynamics, Springer, 1999, ISBN: 9783540659662.

5. Reference Book(s) and Other Required Material

i) C. B. Laney: Computational Gas Dynamics. Cambridge university press, 1998, ISBN: 9780521625586.

ii) Randall J. Le Veque: Finite Volume Methods for Hyperbolic Problems, Cambridge Texts in Applied Mathematics, 2002, ISBN: 9780511404368.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	1	0	0	0	0	0	0	3	3	2	3	2
CO2	3	3	2	1	0	0	0	0	0	0	2	3	2	3	2
CO3	3	1	2	2	0	0	0	0	1	0	2	3	2	3	2
CO4	3	3	3	1	0	0	0	0	1	0	3	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Language Processors

Course Code & Course Title:	CSL316 Language Processors		
Course Type:	DC		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Theory of Computation		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

Given the knowledge of languages and grammars with tools to process them, a sixth semester B.Tech. Mathematics and Computing students will be able to solve the problem of creating a language processing tool and understand ways of its optimization.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	This course introduces students how a compiler translates the higher-level language into machine language
CO2	The student should be able to analyse issues associated with the implementation of higher-level programming languages
CO3	To inform students about different parsing techniques, techniques to generate intermediate code and different optimization techniques**.** Understanding of compiler optimization techniques would enable students to write reasonably efficient programs
CO4	The students will also appreciate the need of understandable error reports, accurate and reliable object code, and efficient use of in-memory data structures

3.	**Detailed Description of the Course**		
	Topics	**CO(s) Addressed**	**Duration in weeks**
	Introduction to compilers, compilers and translators, phases and passes of a typical compiler, Dealing with ambiguity of the grammar.	CO1	1
	Syntax specification of programming languages, Design of top-down parser, Recursive Decent and Predictive parsing, LL (1) parsing.	CO1, CO2, CO3	2
	Bottom-up parsing technique, Operator Precedence Parsing, LR parsing algorithm, Design of SLR, LALR, CLR parsers.	CO1, CO2, CO3	2

Study of syntax directed definitions and syntax directed translation schemes. Using syntax directed translation schemes for translation of expressions, controls structures, declarations, procedure calls.	CO1, CO3	3
Storage allocation and run time storage administration, symbol table management, Error detection and recovery, error recovery in LR parsing, error recovery in LL parsing, Automatic error recovery in YACC.	CO1, CO4	1
Introduction to Important code optimization techniques, loop optimization, control flow analysis, data flow analysis, setting up data flow equations to compute reaching definitions, available expressions, Live variables for doing constant folding, code hoisting.	CO1, CO2, CO3	3
Problems in code generation, simple code generator code generation from DAG, Peephole optimization.	CO1, CO4	2

4.	**Text books**

i) Aho, Ullman, Lam, and Sethi, Compilers: Principles, Techniques, and Tools (2nd ed.), Addison Wesley, 2006, ISBN:978-0-321-48681-3.

ii) Aho A. V., Ullman J.D, Principles of Compiler Design, Narosa Publishing House, 1998, ISBN: 8185015619.

5.	**Reference Book(s) and Other Required Material**

i) Fischer and LeBlanc, Crafting a compiler, Benjamin-Cummings, 1988, ISBN: 0805332014.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Assessment Type	CO1	CO2	CO3	CO4
Mid Exam	60%	40%	0	0
Assignment	20%	40%	20%	10%
Final Exam	30%	30%	20%	10%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	1	1	2	2	---	---	---	---	---	---	---	3	2	2	3
CO2	1	1	1	1	---	---	---	---	---	1	---	3	2	2	3
CO3	1	1	2	---	---	---	1	---	---	1	---	2	2	2	3
CO4	---	---	1	1	1	2	---	---	---	---	---	1	1	2	3

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

i) Simulate memory management as is done in interpreted languages like Python or Java. (CO2)
ii) Write a lexer to recognise the tokens in a program written in C language. (CO1, CO2)
iii) Write a parser to parse the program written in C language. (CO1, CO2, CO4)
iv) Write a translator to generate IR code in three address code formats. (CO3, CO4)

Image Processing and Understanding

Course Code & Course Title:	CSL444 Image Processing and Understanding		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Probability Theory and Statistical Methods. Linear Algebra & Applications, Design and Analysis of Algorithms		
Course Equivalence: Course Code(s) & Name(s)	NIL		

1.	**Course Objective:**

Beyond the obvious applications in entertainment and scientific visualization, digital images have become a central component of net-centered computing, human/computer interfaces and data analysis for domains such as biometrics, surveillance, health care, remote sensing etc. This course offers introduction to fundamental concepts in image formation, low level image processing techniques, mid-level analysis as well as high level recognition tasks. Students will develop the theoretical and algorithmic basis by which useful information about the world/scene can be automatically extracted and analysed from an observed image or image sequence. It will survey a variety of interesting real-world problems/applications and understand basic approaches to tackle them.

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2.	**Course Outcomes:**
CO1	Describe the fundamentals of image formation and digital image processing
CO2	Develop familiarity with various methods of edge & feature extraction, matching, segmentation, motion analysis, object detection and recognition
CO3	Select and apply appropriate techniques to real world problems in computer vision

3.	**Detailed Description of the Course**		
	Topics	**CO(s) Addressed**	**Duration in weeks**
	Overview: Introduction to Image processing and challenges in Image understanding, Real world applications. Overview of course topics. Basics of image formation, acquisition, digitization (sampling & quantization), representation and resolution (spatial, intensity and temporal)	CO1	1
	Low-Level image processing: Introduction to Image processing environments and tools (Matlab & IPT, Python with numpy and opencv library etc.) Basic operations on images like addition, subtraction, multiplication etc. with their applications. Geometric	CO1	3

transforms and interpolation techniques with applications in image registration. Pixel connectivity, distance measures, connected component labelling methods. Image enhancement techniques – intensity/point transformations, histogram based processing such as histogram equalization/matching, neighborhood processing, Noise removal techniques etc. Color Image processing – color fundamentals and models, pseudocolor image processing, full color image processing and using color for segmentation, image retrieval etc.		
Mid-Level image analysis: Linear Filtering, Correlation & Convolution, Template matching via normalized cross-correlation. Edge and blob detection - LOG, DOG, Canny's method. Binary mathematical morphology - Erosion and Dilation, Opening and Closing, The Hit or Miss Transformations, basic morphological algorithms such as region filling, extraction of connected components, thinning etc. Feature detection and matching: Harris Corners, Scale Space and scale selection - Image Pyramids and Gaussian derivative filter, SIFT - Scale invariant feature point detector and descriptors. Applications like Image stitching and Panaroma creation. Feature matching & Model Fitting - Line, circle & ellipse detectors (Hough Transform), RANSAC for feature point matching.	CO2	5
High-Level visual understanding: Image Segmentation: Region and Edge Based approaches, thresholding-based methods like Otsu's thresholding, clustering based methods like K-means, Mean-Shift etc. Motion based object segmentation (Background Subtraction) with applications to object tracking and activity analysis, basic machine learning and pattern recognition concepts for visual matching and recognition. Case studies like Face detection with sliding window – Haar-features, Viola Jones method and Adaboost. Object representation, descriptors and classification methods such as Bag of Visual words (BoVW). Neural Networks fundamentals, Past issues with deep networks, introduction to Convolutional Neural Networks (CNNs), training and transfer learning in CNNs, CNNs for image classification and recognition task.	CO3	4

4.	**Text books:**

i) R.C. Gonzalez and R.E. Woods: "Digital Image Processing" Pearson Education, 3rded.

ii) M. Sonka, V. Hlavac, and R. Boyle. Cengage Learning. "Image Processing, Analysis, and Machine Vision", 2009.

5.	**Reference Book(s) and Other Required Material:**

i) Reference manuals of Image/Video processing tools/platforms like OpenCV, Matlab etc.

ii) Richard Szeliski: "Computer Vision: Algorithms and Applications", 2nd ed., 2022.

iii) Davies, E. "Computer Vision: Principles, Algorithms, Applications, Learning", Elsevier, 5th ed. (2017).

iv) Computer Vision: A modern approach by Forsyth and Ponce, Pearson Education, 2nd ed.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Assessment Type	CO1	CO2	CO3
Mid Exam	60%	40%	0
Assignment	40%	40%	20%
Final Exam	30%	50%	20%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	0	0	0	3	0	2	1	1	0	1	1	2	3
CO2	3	3	3	0	0	2	0	0	0	0	0	2	3	2	3
CO3	3	3	2	0	3	2	2	0	2	0	0		3	1	3

High - 3; Medium – 2; Low – 1;

Introduction to Parallel Computing

Course Code & Course Title:	CSL4XX Introduction to Parallel Computing		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	None		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:** Students will be able to:

i) Understand the scope, design and model of parallelism
ii) Know the parallel computing architecture.
iii) Know Tiling transformation for Loop Parallelization.
iv) Know the Characteristics, Model and design of parallel algorithms.
v) Knows programming models and methods for basic computer science problems.
vi) Analytical modelling and performance of parallel programs.
vii) Solve a complex problem with message passing model and programming with MPI.
viii) Analyse complex problems with shared memory programming with open MP.

2.	**Course Outcomes:**
CO1	This course introduces critical methods and techniques related to parallel computing. Particularly, the course focuses on hardware, algorithm, and programming of parallel systems, providing students a complete picture to understand pervasive parallel computing. Through this course, the students will have a deep understanding of how parallel systems are designed and what are the fundamental methods to program and analyze them. By the end of this course, students will be able to: Compute speedup, efficiency, and scaled speedup of parallel computations, given appropriate problem
CO2	Study in depth dependence analysis and then apply Amdahl's Law to predict the maximum speedup achievable from a parallel version of a sequential program
CO3	Explain how large-scale parallel systems are architecture and how massive parallelism are implemented in accelerator architectures
CO4	Write parallel programs for large-scale parallel systems, shared address space platforms, and heterogeneous platforms
CO5	Design efficient parallel algorithms and applications
CO6	Be conversant with performance analyze and modeling of parallel programs;

3.	Detailed Description of the Course		
Topics		**CO(s) Addressed**	**Duration in weeks**
Understand Parallel Programming Platforms. Concepts of implicit parallelism. Trends in parallel Architectures. Need for Parallelization. Limitations of Memory System Performance, Physical Organization of Parallel Platforms, Communication Costs in Parallel Machines, Routing Mechanisms for Interconnection Networks. Process-Processor Mapping and Mapping Techniques, Decomposition Techniques, Characteristics of Tasks and Interactions.		CO1	4
Basic Communication Operations like One-to-All Broadcast and All-to-One Reduction, All-to-All Broadcast and Reduction, All-Reduce and Prefix-Sum Operations, Scatter and Gather, All-to-All Personalized Communication, Circular Shift, Improving the Speed of Some Communication Operations		CO2	4
Analytical Modelling of Parallel Programs: Sources of Overhead in Parallel Programs, Performance Metrics for Parallel Systems. Effect of Granularity and Data Mapping on Performance, Amdahl's law, Scalability of Parallel Systems, Minimum Execution Time and Minimum Cost-Optimal Execution Time, Asymptotic Analysis of Parallel Programs, Other Scalability Metrics		CO3	4
Principles and Programming Using the Message Passing Paradigm, Send and Receive Operations, MPI Interface, Collective Communication and Computation Operations, Groups and Communicators. Applications: Parallel algorithm development for Matrix multiplication, Sorting and Graph. Introduction of Dependence Analysis		CO4	3

4.	Text books:

i) Dependence Analysis by Utpal Banerjee, Kluwer Academic Publishers, Boston / Dordrecht / London.

ii) Introduction to Parallel Computing, Second Edition by AnanthGrama, Anshul Gupta, George Karypis, Vipin Kumar, Publisher: Addison Wesley January 16, 2003, ISBN: 0-201-64865-2.

iii) Loop Tiling for Parallelism by Jingling Xue, Springer Science Business Media, LLC.

5.	Reference Book(s) and Other Required Material

i) Using OpenMP by Barbara Chapman, Gabriele Jost, Ruud Van Der Pas.

6.	Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	1	3	0	0	3	2	0	2	1	1	0	1	1	2	3
CO2	3	0	1	3	3	0	0	0	1	0	3	2	3	2	3
CO3	0	2	0	0	0	0	1	0	0	2	0	2	2	2	3
CO4	3	3	0	3	3	3	0	2	3	0	1	1	3	3	3
CO5	0	0	2	0	0	2	3	0	0	1	0	2	2	2	3
CO6	1	0	0	3	0	1	0	1	3	3	2	3	3	3	3

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

i) Implement Dot product operation of two vectors using OpenMP and Find time complexity and speedup of each with respect to its serial version.

ii) Implement Matrix-Matrix multiplication using OpenMP and Find time complexity and speedup of each with respect to its serial version.

iii) Implement Matrix-Vector multiplication using OpenMP and Find time complexity and speedup of each with respect to its serial version.

iv) Write a program to implement the following algorithms sequentially and then make a parallel version of the same (with 4 threads) using OpenMP. Find the speedup and efficiency with respect to its sequential version.

   a. Prims Algorithm
   b. Floyd's Algorithm
   c. Breadth First Search Algorithm
   d. Depth First Search Algorithm
   e. Johnson's Algorithm
   f. Parallel LU Factorization using Block Cyclic Distribution
   g. Parallel (recursive decomposition) using Quick Sort algorithm
   h. Parallel (recursive decomposition) to find Minimum/Maximum from a large array.
   i. Traveling Salesman Problem.
   j. Longest Common Subsequence
   k. Graph Coloring Problem.
   l. Bellman-Ford Algorithm.

v) Write your own version of MPI_Reduce using functions MPI_Send and MPI_Recv. Compare the performance of your implementation with the 'real' MPI_Reduce in your system's MPI library.

vi) Write your own version of MPI_Bcast using functions MPI_Send and MPI_Recv and global sum to add numbers available with all nodes. Compare the performance of your implementation with the 'real' MPI_AllReduce in your system's MPI library.

vii) The gap between consecutive prime numbers 2 and 3 is only 1, while the gap between consecutive primes 7 and 11 is 4. Write a parallel program (both OpenMP and MPI) to determine, for all integers less than 10 exa, the largest gap between a pair of consecutive prime numbers.

viii) Sometimes two consecutive prime numbers are both prime numbers. For e.g. 3-5, 5-7, 11-13 belongs to it, but 7-9 is not consecutive primes. Write a parallel program (both OpenMP and MPI) to determine, for all integers less than 10 zetta the number of times that two consecutive odd integers are both prime.

ix) Write an MPI program that implements multiplication of a very large vector by a scalar and dot product. The user should enter two very large vectors and a scalar, all of which are read in by node 0 and distributed among the other nodes. The results are calculated and collected onto node 0, which prints them. You can assume that n, the order of the vectors, is evenly divisible by COMM_SIZE.

x) A ping-pong is a communication in which two messages are sent, first from process A to process B (ping) and then from process B back to process A (pong). Timing blocks of repeated ping-pongs is a common way to estimate the cost of sending messages (assume any message). Write a ping-pong program using the C clock function on your system. How long does the code have to run before clock gives a nonzero run-time?

xi) Parallel merge sort starts with n/comm_size keys assigned to each node. It ends with all the keys stored on node 0 in sorted order. To achieve this, it uses the same tree-structured communication that we used to implement a global sum. However, when a node receives another node's keys, it merges the new keys into its already sorted list of keys. Write a MPI program that implements parallel merge sort. Node 0 should read in n and broadcast it to the other nodes. Each node should use a random number generator to create a local list of n/comm_size ints. Each node should then sort its local list, and node 0 should gather and print the local lists. Then the nodes should use tree-structured communication to merge the global list onto node 0, which prints the result.

xii) Implement binary search in MPI such that, the search utilizes the insertion sort algorithm and the binary search algorithm to search for a number in a list of numbers. The program does the following:

   a. Root node (P0) generates an array of random numbers and (numranks) number of nodes.
   b. Node 0 splits the array into parts and distributes them among all other nodes.
   c. Node 0 generates a random key and sends it to all other nodes.
   d. Each node sorts its part of the array using the insertion sort algorithm and searches for the key in its sorted part of the array using the binary search algorithm and sends the result to the process 0.
   e. Node 0 collects the results from all other nodes in the communicator and decide whether the key is in the array.

xiii) Implement 15-puzzle problem in MPI to get the solution. The program does the following:

   a. Process 0 will generate Input matrix of size 5 x 5 with all random elements.
   b. All new possible solutions (matrix) will get executed by other nodes to get another possible solution and so on.
   c. Once the final solution is generated, that node sends the message to all along with its rank.

xiv) Consider the array assignment used to demonstrate the distribution of data among multiple nodes and the communications required to accomplish that distribution. The root node (P0) initiates (numrank-1) number of all nodes and then distributes an equal portion of the array to each node. Each node receives his portion of the array and performs a simple value assignment to each of its elements. The value assigned to each element is simply that element's index in the array plus 1. Each node then sends its portion of the array back to the root node. As the root node receives a portion of the array from each node, selected elements are displayed.

Data Mining

Course Code & Course Title:	MALA 4XX Data Mining		
Course Type:	DE		
Name of the programme(s):	B.Tech. in Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

Identify the scope and necessity of Data Mining and Data Analytics, how to describe the data, prediction and prescription, how to select and design a model, analysis and programming of various algorithms required for mining and exaction of information to solve real-time problems and to develop further interest in research and design of new Mining Algorithms.

2.	**Course Outcomes:**
CO1	To help in the fundamental understanding of the analytical techniques and data mining tools
CO2	To help to generate the necessary and effective approach so that any useful information can be extracted from datasets of any size
CO3	An exposure to computer programming and analytics software use and, thus, the ability to quickly acquire technological know-how demanded on the job
CO4	Design, and evaluate various models to use the knowledge gained in the program to add significant value in a professional setting

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Know your data and dataset, Pre-processing tools, Sampling, Statistical Modelling, Univariate and multivariate Analysis, Graphical descriptors.		CO1	2
Inferential Statistics, T-test, Z-Test, Hypothetical testing and usage, ANOVA, Applications Datasets for Classification,		CO1	2

Regression, Logistics Regression, SVM, ANN, Model Selection, criterion and Evaluation of regression methods.	CO1, CO2	3
Associative Mining, Rule mining, Associations and Correlations, Analysis for unstructured, semi-structured datasets- big data Analytics.	CO1, CO3	3
Clustering and Predictive Analytics – Clustering algorithms, evaluation and understanding, Applications and demonstration for Active Learning, Reinforcement Learning.	CO3, CO4	3

4.	**Text books**

i) Charles Lang, George Siemens, Alyssa Wise, and Dragan Gašević (Eds), Learning Analytics, Creative Commons License 4.0, ISBN: 978-0-9952408-3-4.

ii) Douglas C. Montgomery, and George C. Runger.; Applied statistics and probability for engineers. John Wiley, ISBN 978-1-119-40036-3.

iii) Hastie Trevor, et al.; The elements of statistical learning. Vol. 2. No. 1. New York: Springer,2009, ISBN: 978-0-387-84857-0.

iv) Jiawei Han, Micheline Kamber, Morgan Kaufmann**,** Data mining - Concepts & Techniques, 2nd Edition, 2006, ISBN 13: 978-1-55860-901-3.

5.	**Reference Book(s) and Other Required Material**

i) Vipin Kumar, Tan, Steinbach, Introduction to Data Mining, Pearson 2014, ISBN 10: 0-273-76922-7.

ii) Witten, Frank, Hall Morgan Kaiffman, Data Mining, 2014, ISBN 978-0-12-374856-0.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	---	---	---	---	---	---	---	3	---	---	1	2	3	2	3
CO2	---	3	---	---	---	---	---	---	---	---	---	2	3	2	3
CO3	3	---	---	---	3	---	---	---	---	---	---	2	3	2	3
CO4	3	---	---	---	3	---	---	---	---	---	---	2	3	2	3

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Topics in Distributed Systems

Course Code & Course Title:	CSL4XX Topics in Distributed Systems		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)	Operating Systems Course		

1.	**Course Objective:**

Given the knowledge of operating systems and sequential program design, the students of the B.Tech. Mathematics and Computing will be able to design and develop fault tolerant and efficient distributed algorithms to solve large problems where data and control is distributed over different nodes.

2.	**Course Outcomes:**
CO1	Student will understand Distributed System fundamentals (Level 1 & 2) · Define key concepts, characteristics, and challenges of distributed systems. · Explain different architectural models, inter-process communication techniques, and distributed file systems.
CO3	Student will be able to apply Distributed algorithms (Level 3) · Implement inter-process communication using sockets, RPC, and RMI. · Develop and apply clock synchronization, leader election, and mutual exclusion algorithms in distributed environments.
CO3	Student will be able to analyze deadlock detection and fault tolerant system (Level 4) · Compare and evaluate various distributed deadlock detection, termination detection, and agreement protocols. · Assess the performance and reliability of fault tolerance techniques such as commit protocols and voting mechanisms.
CO4	Student will be able to evaluate fault-tolerant distributed applications (Level 5) · Design and develop fault-tolerant distributed applications using recovery mechanisms like checkpointing and logging. · Propose efficient solutions for distributed resource management and system scalability.

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Differentiate between different types of faults and fault handling techniques in order to implement fault tolerant systems.		CO1	1

Inter-process and inter-node communication using Sockets – connection oriented and connection-less, Remote Procedure Calls, Remote Method Invocation	CO1, CO2	2
Distributed File System Design and Implementation, Case Studies of NFS, Andrew File Systems, HDFS, Distributed Resource Management.	CO1, CO2	2
Clock Synchronization Techniques, Network Time Protocol, Logical Clocks, Vector Clocks	CO1, CO2	2
Causally Ordered Broadcast and Unicast, Termination Detection – Ring based and Dijkstra Scholten algorithms, Leader Election – Ring based, Franklin's algorithm and Bully Algorithm	CO1, CO2	2
Distributed Mutual Exclusion – Token based algorithms – Lamport's, Ricart-Agarwala, Maekawa's algorithms, non-Token based Algorithms – Suzuki Kasami, Raymond's algorithms, comparison of different algorithms.	CO1, CO2	2
Distributed Deadlock Detection, Resource and Communication Deadlocks – Centralized technique, Distributed technique - edge chasing and path pushing algorithms, Hierarchical technique, Recovery from Deadlocks.	CO3	2
Fault Tolerance, Handling Crash faults –Two phase commit protocol, non-blocking three phase commit protocol, Birman-Joseph Atomic Broadcast Protocol, Voting techniques for fault tolerance.	CO3	2
Recovery – forward and backward recovery, undo-redo logs, Coordinated and Uncoordinated Check pointing and Recovery algos	CO4	2
Agreement protocols – LSP Oral Messages, Agreement using Signed Messages	CO4	1

4.	**Text books**

i) Coulouris, "Distributed Systems", AWL Press. Pearson Education

ii) Singhal and Shivratri, "Advanced concepts in Operating Systems", McGraw Hill

iii) Tanenbaum, "Modern Operating Systems", PHI Learning.

5.	**Reference Book(s) and Other Required Material**

i) Pradeep K. Sinha, Distributed Operating Systems*: Concepts and Design*, PHI Learning.

ii) Hagit Attiya & Jennifer Welch, Distributed Computing: Fundamentals, Simulations, and Advanced Topics, Wiley.

iii) M.L. Liu, Distributed Computing: Principles and Applications, Pearson Education.

iv) Gerard Tel, Introduction to Distributed Algorithms, Cambridge University Press.

6.	**Evaluation Details:**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	---	---	3	---	2	---	2	1	1	3	3	2	3
CO2	3	3	1	3	3	---	---	---	---	1	---	3	3	1	3
CO3	3	3	---	---	---	---	---	1	---	---	---	3	3	2	3
CO4	3	3	---	3	3	3	2	---	2	---	---	3	3	2	3

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

i) Write a Java program to display the server's date and time details at the client end.

ii) Implement a simple message transfer from client to server and server to client process using TCP/IP in Java.

iii) The message entered in the client is sent to the server and the server encodes the message and returns it to the client. Encoding is done by replacing a character by the character next to it i.e. a as d, b as e …z as c. This process is done using Socket Programming. Implement and test the client and server program in Java for the problem statement given above.

iv) Implement the Math Server program Using Java.

v) Develop client server program in Java to upload file to the server & download from the server.

vi) Develop a TCP client/server application in 'Java' for transferring a text file from client to server?

vii) Implement a TCP based server program in Java to authenticate the client's Username and Password. The authenticity of the client must be sent as the reply message to the client.

viii) Design a program to send a message from multiple clients to the server using thread.

ix) Write a Java socket program to develop a simple Chat application using UDP.

x) Write a Java program to implement an Echo TCP server. Test the working of the server by writing a client application.

xi) Implement a TCP based server program in Java to provide a resource to two clients using the concept of Mutual Exclusion.

xii) Implement a TCP based server program in Java to deal the issue of a client performing the two transactions simultaneously using serializability.

xiii) Create distributed systems with socket programming (as like in assignments 2 and 3). Create multiple- client and server environment. Create a log-file and for each client, server maintains them. A client can make multiple requests to server (you can refer previous assignments). Client can ask it's log file as one of the requests. But the client has to send the log file back after reading it. Among the all processes there is a deamon process, which tries to corrupt log file. The server should be capable of tracing this information. After the request is processed the

server can check immediately or at regular intervals of time for the following things and correct them,

a. If the client corrupts the log file, the server should name the client as deamon and notify other clients.
b. The system has to recover from this.
c. Use any error recovery approaches to go back to the previous points. (Maintain a log for this)

xiv) Program to implement Lamport's Distributed Mutual Exclusion Algorithm.

xv) Program to implement Lamport's Logical Clock Algorithm.

xvi) Program to implement Edge Chasing distributed deadlock detection algorithm.

xvii) Prepare storage at Server side, where multiple clients can access the storage. Whenever a client requests a file check whether it is present or not, if present, check whether it is being read or write by another client or not, if not process the request. Notify the operations in the form of messages

a. When a file being read by client notify the read only operation to requesting client.
b. When a file being write by client notify the no access to the requesting client.

xviii) Implement resource allocation b/w clients using socket programming (an application of mutual exclusion).

xix) Show by example that, in the Koo–Toueg checkpointing algorithm, if processes do not block after taking a tentative checkpoint, then global checkpoint taken by all processes may not be consistent.

xx) Design a checkpointing and recovery algorithm that uses vector clocks.

Introduction to Internet of the Things

Course Code & Course Title:	CSL429 Introduction to Internet of the Things		
Course Type:	DE		
Name of the programme(s):	B. Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Computer Networks		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

Gives technical knowledge and skills to build Internet of Things (IoT) systems to the seventh semester B.Tech. Mathematics and Computing students, after successfully completion of computer networks course.

Students will be able to:

i) Describe what IoT is and how it works.
ii) Recognize the factors that contributed to the emergence of IoT.
iii) Determine the right sensors, actuators and communication protocols to use in a particular IoT system.
iv) Use various IoT protocols for connectivity and communication.
v) Understand to design an IoT device to work with a Cloud Computing infrastructure.
vi) Know how the IoT data is travelled to the cloud and in between cloud providers.
vii) Define the infrastructure for supporting IoT deployments.
viii) Design and program IoT devices.

2.	**Course Outcomes:**
CO1	Understand the definition and significance of the Internet of Things and how IoT differs from traditional network systems
CO2	Explain about the IoT Architecture, Protocols, IoT6 and the hardware/software used to design an IoT device
CO3	Explore the relationship between IoT, cloud, fog computing, big data and SDN
CO4	Identify Program Raspberry PI wireless microcontroller unit for various IoT applications

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**

Introduction to IoT: Building Blocks of IoT, Characteristics of IoT, Introduction to Various Sensors and Actuators, IoT Protocols, Physical Design of IoT. Domain Specific to IoT, Networking aspects of IoTs like IoT services, gateways, and technology. Protocols for IoT Service Discovery, DNS, mDNS Services discovery, IoT challenges. Architecture for IoT using Wireless Technology, 5G, SDN, NFV, UWB, ISO 18000 7 DASH7, LPWAN. IoT System Management. Energy Harvesting on Power Consumption for IoT Devices.	CO1	4
Logical Design of IoT: Connectivity Technologies, Protocols like - IEEE 802.15.4, ZigBee, 6LoWPAN, Wireless HART, Z-wave, ISA100.11A, Bluetooth, EPCglobal, Ad-hoc Piconets, NFC and RFID. Comparison between these protocols. Machine-to-Machine Communications, Difference between IoT and M2M, Service Oriented Device Architecture for Device Integration. IoT Communication Model, APIs, Enabling Technologies. Communication Protocols in IoT Networks like MQTT, CoAP, REST interface, XMPP, AMQP.	CO2	4
Developing Internet of thing, Interoperability and Implementation of IoT, Design and Implementation using Python, IoT Physical Devices & Endpoints. Programming IoT devices, Integration of Sensors, Actuators and other electronic components with IoT, e.g. Arduino, Raspberry Pi. IoT Physical Servers, Aspects of Device-to-Cloud (D2C) Integration, Cloud Infrastructure for: Next-Generation Device Applications.	CO3	4
The IoT Data Handling and Analytics, Smart Phone Services, IoT Platform as a Service (PaaS). IoT applications into Cloud-to-Cloud (C2C) Integration Paradigm, Sensor-to-Cloud Integration Concept. Fog/Edge Computing Paradigm. Study of Various Tools used for IoT. Case Studies illustrating IoT Design e.g. Connected Vehicles, Smart Cities and Smart Homes, Agriculture, Environment, Healthcare, Activity Monitoring, Smart Grid, Industrial IoT.	CO4	3

4.	**Text books:**

i) Arshdeep Bahga and Vijay Madisetti, "Internet of Things: A Hands-on Approach", Research Scientist in cloud computing, IoT and Big Data Analytics and Professor, respectively at Georgia Institute of Technology, USA. (Universities Press-2017).

ii) Pethuru Raj and Anupama C. Raman, A Cloud Infrastructure Architect and A Curriculum Architect for the Smarter Cities Brand, Respectively at CoE, "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", IBM Bangalore. (CRC Press, Taylor & Francis Group-2017).

5.	**Reference Book(s) and Other Required Material:**

i) Research papers (will be provided during the course)

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Mid Term - 25%, End Term - 50%, Lab Assignment - 20%, Internal Evaluation - 5%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	0	0	3	0	2	2	1	1	0	1	3	2	3
CO2	3	3	1	1	3	2	2	0	1	0	0	1	2	2	3
CO3	3	3	0	1	0	0	2	2	0	0	0	1	1	2	3
CO4	3	3	2	0	2	0	0	0	0	0	0	3	3	1	3
CO5	3	3	0	0	3	0	2	2	1	1	0	1	3	2	3

8.	**List of Indicative Laboratory Experiment (if applicable):**

i) Use DHT Sensor and CPU Fan. When the temperature goes up, the FAN should get ON and vice versa. Upload Actual/random sensor data on AWS cloud; also send the same on either email or on mobile.

ii) Use Light Sensor and LED. In Dark LED should glow and vice versa. Upload Actual/random sensor data on AWS cloud; also send the same on either email or on mobile.

iii) Use Soil Sensor and LED. When moisture level goes below threshold value, the LED should glow and vice versa. Upload Actual/random sensor data on AWS cloud; also send the same on either email or on mobile.

iv) Use Ultrasonic Sensor and LED. When any object is detected closer than the threshold value, the LED should glow and vice versa. Upload Actual/random sensor data on AWS cloud; also send the same on either email or on mobile.

v) Use Node Red to transfer data from HTTP command and serial port to AWS cloud. Upload Actual/random sensor data on AWS cloud; also send the same on either email or on mobile.

vi) Use MQTT.fx tool and MQTT Explorer to send JSON packet to AWS Cloud. Upload Actual/random sensor data on AWS cloud; also send the same on either email or on mobile.

vii) Use Camera module to capture images using Raspberry PI.

viii) Use DHT Sensor and CPU Fan. When the temperature goes up, the FAN should get ON and vice versa using Raspberry PI.

ix) Use Ultrasonic Sensor and LED. If the object is far away LED will be OFF and vice versa, using Raspberry PI controller board. Also plot these readings (distance) using plot function.

x) Use DHT Sensor and CPU Fan. When temperature goes up, the FAN should get ON and vice versa using Raspberry PI Controller Board as client and send these reading to the server.

xi) Use Ultrasonic Sensor and LED. If the object is far away LED will be OFF and vice versa, using Raspberry PI controller board as client and send these reading to the server.

xii) Use LED and Light sensor, In the dark LED should glow and when light falls on the sensor the LED goes OFF, using Raspberry PI controller board as client and send these reading to the server.

xiii) Use LED and Light sensor, In the dark LED should glow and when light falls on the sensor the LED goes OFF, using Raspberry PI controller board as client and send these reading to the server.

xiv) Using traditional switch topology (traditional_switch.py) shows how Ethernet table is created in Mininet. How it discovers neighbor using 'arp' protocol. Show these packets on Wireshark and how it works. Also show how to check/show MAC table.

xv) Using linear topology with four switches shows how Ethernet table is created in Mininet. Show these packets on Wireshark and how it works. Also show how to check/show MAC table and total bridges along with all addresses.

xvi) Using Single topology with four/eight switches shows how Ethernet table is created in Mininet. Show these packets on Wireshark and how it works. Also show how to check/show MAC table and total bridges along with all addresses.

xvii) Using tree topology with three levels and four children each, shows how Ethernet table is created in Mininet. Show these packets on Wireshark and how it works. Also show how to check/show MAC table and total bridges along with all addresses.

xviii) Use any topology and explain all Openflow messages in chronological order on Wireshark.

xix) Show using command and by running proper controller, briefly explain Proactive controller and Reactive controller. Also show how to run multiple controllers in single command.

Network Security

Course Code & Course Title:	MALA 4XX Network Security		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Computer Networks, Cryptography		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this course is to teach the concepts of securing computer network protocols, based on the application of cryptography techniques

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	To understand the concepts involved in the basics of cryptography, Key Management and Distribution and be able to apply it to solve related problems
CO2	To understand the concepts involved in User Authentication And apply it to solve related problems.
CO3	To understand the concepts involved in Mining Data Streams and apply it to solve related problems.
CO4	To understand the concepts involved in Malicious Software, Network Access Control, IP Security, Transport-Level Security and Electronic Mail Security and be able to apply it to solve related problems
CO5	To understand the concepts involved in user authentication, security (network, IP, email) Firewalls and Intrusion Detection Systems, Blockchains, Cloud Security and IoT security and be able to apply it to solve related problems.

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Basic of cryptography, including conventional and public-key cryptography, hash functions, authentication, and digital signatures.		CO1	1

Key Management and Distribution: Symmetric Key Distribution, Distribution of Public Keys, X.509 Certificates, Public-Key Infrastructure.	CO1	1
User Authentication: Remote User-Authentication Principles, Remote User-Authentication Using Symmetric Encryption, Kerberos Systems, Remote User Authentication Using Asymmetric Encryption.	CO2	2
Malicious Software: Viruses, Worms, System Corruption, Attack Agents, Information Theft ï¿½ Keyloggers, Phishing, Spyware Payload Stealthing, Backdoors, Rootkits, Distributed Denial of Service Attacks.	CO3	2
Network Access Control: Network Access Control, Extensible Authentication Protocol, IEEE 802.1X Port-Based Network Access Control.	CO3, CO5	2
IP Security: IP Security Overview, IP Security Policy, Encapsulating Security Payload, Combining Security Associations, Internet Key Exchange (IKE).	CO3, CO5	2
Transport-Level Security: Web Security Considerations, Secure Sockets Layer, Transport Layer Security, HTTPS standard, Secure Shell (SSH) application.	CO3. CO5	1
Electronic Mail Security: Pretty Good Privacy, S/MIME, DomainKeys Identified Mail. Wireless Network Security: Mobile Device Security, IEEE 802.11i, Wireless LAN Security.	CO3, CO5	1
Firewalls and Intrusion Detection Systems: Intrusion Detection Password Management, Firewall Characteristics Types of Firewalls, Firewall Basing, Firewall Location and Configurations.	CO4, CO5	1
Adv. Topics include Blockchains, Cloud Security and IoT security.	CO4, CO5	1
There will be 4-5 programming assignments involving the use of tools, libraries and packages such as Wireshark, OpenSSL and Snort.	CO4, CO5	1

4.	**Text books**

i) Gregor N. Purdy, Linux iptables Pocket Reference, O'Reilly, 2004, ISBN-13: 978-0596005696.

ii) J. Michael Stewart, Network Security, Firewalls and VPNs, Jones & Bartlett Learning, 2013, ISBN-10: 1284031675, ISBN-13: 978-1284031676.

iii) Michael Gregg, The Network Security Test Lab, Drea MTech Press, 2015, ISBN-10: 8126558148, ISBN-13: 978-8126558148.

iv) Michael Rash, Linux Firewalls, No Starch Press, October 2007, ISBN: 978-1-59327-141-1.

5.	**Reference Book(s) and Other Required Material**

i) M. Speicher, R. Perlman, C. Kaufman, Network Security: Private Communications in a Public World, Prentice Hall, 2002, ISBN-13: 978-0-13-664360-9.

ii) William Stallings, Cryptography and Network Security: Principles and Practice, 6th Edition, Pearson, 2014, ISBN-13: 9780133354690.

6.	**Evaluation Details:**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	---	1	---	---	---	---	---	---	---	1	2	3	2	3
CO2	2	2	1	---	---	---	---	---	---	---	---	2	3	2	3
CO3	1	3	2	---	---	---	---	---	1	2	---	2	3	2	3
CO4	---	2	---	2	2	2	---	1	1	2	1	2	3	2	3
CO5	1	1	3	2	1	1	---	2	1	1	---	2	3	2	3

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

i) Study and implement basic cryptographic techniques including symmetric encryption (AES/DES), public key cryptography (RSA), hash functions, digital signatures, and message authentication using tools such as OpenSSL.

ii) Generate public and private keys and demonstrate key management and distribution using Public Key Infrastructure (PKI) concepts including X.509 certificates.

iii) Demonstrate remote user authentication mechanisms using symmetric and asymmetric encryption methods and study authentication systems such as Kerberos.

iv) Capture and analyze network packets using Wireshark to study protocols such as HTTP, HTTPS, TLS, and SSH and observe secure communication.

v) Study and analyze different types of malicious software such as viruses, worms, spyware, phishing attacks, keyloggers, backdoors, and distributed denial of service attacks.

vi) Implement and study network access control mechanisms including Extensible Authentication Protocol (EAP) and IEEE 802.1X port-based authentication.

vii) Configure and analyze IP security mechanisms including security policies, Encapsulating Security Payload (ESP), security associations, and Internet Key Exchange (IKE).

viii) Demonstrate transport layer security by implementing SSL/TLS protocols and secure communication using HTTPS and SSH.

ix) Install and configure an intrusion detection system using Snort to monitor network traffic and detect suspicious activities.

x) Study advanced security concepts including wireless network security (IEEE 802.11i), mobile device security, blockchain basics, cloud security, and IoT security.

Cluster Computing

Course Code & Course Title:	MALA 4XX Cluster Computing		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Basic knowledge of Operating Systems and Computer Networks		
Course Equivalence: Course Code(s) & Name(s)	Nil		

1.	**Course Objective:**

The objective of this course is to expose students to the fundamentals and significance of cluster computing, including its architecture, administration, fault tolerance, performance issues, and real-life applications in high-performance and distributed computing environments.

2.	**Course Outcomes:**
CO1	Understand the architecture of cluster computers and their components.
CO2	Acquire knowledge of cluster setup, configuration, and system administration.
CO3	Analyse dependability trade-offs and limitations in computer system dependability.
CO4	Identify sources of faults, their prevention mechanisms, and their impact on clustered systems.
CO5	Analyse load sharing and load balancing algorithms along with their performance characteristics.

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction to Cluster Computing, Scalable Parallel Computer Architectures, Low-Cost Parallel Computing, Cluster Computers and their Architecture		CO1	2
Classification of Clusters, Cluster Components, Network Services, Cluster Middleware, Single System Image, Resource Management and Scheduling, Programming Environments and Tools, Applications, Representative Cluster Systems, Clusters of SMPs		CO1, CO2	2

Cluster Setup and Administration: Cluster Installation, Security Issues, System Monitoring, System Tuning, Software Development Tools	CO2	1
Constructing Scalable Services: Environment, Resource Sharing, Locality, Prototype Implementation and Extensions	CO3	2
Dependable Clustered Computing: Dependable Parallel Computing, Critical Computing, Dependability Concepts, Cluster Architectures, Fault Detection, Fault Masking, Recovery Techniques	CO3, CO4	2
High Throughput Computing Clusters: Condor Architecture, System Administration Issues	CO4	1
Performance Models and Simulation: Performance Issues, Cost Models for Effective Parallel Computing	CO5	1
Meta computing: Evolution, Design Objectives, Issues, Projects, and Environments	CO5	1
Process Scheduling, Load Sharing and Load Balancing: Job and Resource Management Systems, RMS Challenges, Parallel Job Scheduling, Rigid and Malleable Jobs, Co-scheduling and Batch Scheduling	CO5	2
Load Sharing and Fault Tolerance Managers: Checkpointing, Dynamic Load Balancing, Task Mapping, Static and Dynamic Scheduling Techniques	CO5	1

4.	**Text books**

i) Buyya, R., High Performance Cluster Computing: Architectures and System*s*, Vol. 1, Prentice Hall, 2007, ISBN: 9780130137845.

ii) Koren, I., and Krishna, C. M., Fault-Tolerant Systems, Morgan Kaufmann, 2007, ISBN: 9780120885251.

5.	**Reference Book(s) and Other Required Material**

i) Coulouris, G., Dollimore, J., Kindberg, T., and Blair, G., Distributed Systems*:* Concepts and Design, 5th Edition, Pearson Education, 2012, ISBN: 9780132143011.

ii) Tanenbaum, A. S., and Van Steen, M., Distributed Systems, 2nd Edition, Pearson Education, 2007, ISBN: 9780132392273.

6.	**Evaluation Details:**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	2	2	---	2	3	---	---	---	---	1	---	2	3	2	3
CO2	2	2	---	2	3	---	---	---	---	1	---	2	3	2	3
CO3	2	2	---	2	3	---	---	---	---	1	---	2	3	2	3
CO4	2	2	---	2	3	---	1	---	---	1	---	2	3	2	3
CO5	3	2	---	2	3	---	---	---	---	1	---	2	3	2	3

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Coding Theory

Course Code & Course Title:	MALA 4XX Coding Theory		
Course Type:	DE		
Name of the programme(s):	B.Tech. in Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)	Nil		

1.	**Course Objective:**

This is a first-level graduate course on coding theory, which will introduce students to some of the classical methods in coding theory. Through concrete examples of code construction, where simple, yet powerful mathematical tools are put to use, the course is expected to improve students' insights into the mathematical foundations.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Use algebraic techniques to construct efficient codes
CO2	Identify the parameters of a given code and the quality of a given code
CO3	State and prove the limits on achievable code performance

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Binary block codes, Minimum distance, Error-detecting capability and error-correcting capability.		CO1	2
Linear block codes: Linear block codes, Generator matrix, Parity-check matrix. Dual code, Alternate characterizations of minimum distance for linear block codes, Repetition code, Single-parity-check code, Hamming Code, Bounds on Codes – Singleton Bound, Hamming bound, Gilbert-Varshamov bound, Plotkin bound. Asymptotic version of these bounds.		CO1, CO2	4

Decoding of linear block codes: Maximum a-posteriori probability (MAP) decoding, Maximum likelihood (ML) decoding, Standard Array Decoding.	CO2	3
Cyclic codes: Review of Finite fields, Polynomial description of cyclic codes, generator and check polynomials, Roots of cyclic codes, BCH codes, Reed-solomon codes. Berlekamp-Welch decoding algorithm.	CO2, CO3	3
LDPC codes binary expander codes, Sipser-Spielman decoding algorithm, introduction to iterative decoding.	CO2, CO3	2

4. Text books

i) Ron M. Roth, Introduction to Coding Theory, Cambridge University Press, 2006.

ii) Tom Richardson, Rudiger Urbanke, Modern Coding Theory, Cambridge University Press, 2009.

iii) J. H. van Lint, Introduction to Coding Theory, Springer, 1999.

iv) Shu Lin, Daniel J. Costello, Error Control Coding: Fundamentals and Applications, Prentice-Hall, 1982.

v) W. Cary Huffman, Vera Pless, Fundamentals of Error-Correcting Codes, Cambridge University Press, 2010.

5. Reference Book(s) and Other Required Material

i) Parikshit Gopalan, Cheng Huang, Huseyin Simitci, and Sergey Yekhanin, On the locality of codeword symbols, IEEE Transactions on Information Theory, 58(11) pp 6925–6934, 2012.

ii) P. Vijaykumar, Error Correcting Codes, NPTEL Course. https://nptel.ac.in/courses/117/108/117108044.

6. Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	---	2	2	---	---	---	---	1	---	2	3	2	3
CO2	3	3	---	2	2	---	---	---	---	1	---	2	3	2	3
CO3	3	3	---	2	2	---	---	---	---	1	---	2	3	2	3

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Advanced Operation Research

Course Code & Course Title:	MALA 4XX Advanced Operations Research		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Optimization		
Course Equivalence: Course Code(s) & Name(s)	Nil		

1.	**Course Objective:**

The course aims to equip students with the knowledge and skills to formulate, analyse, and solve complex optimization problems, particularly those involving multiple conflicting objectives. The course will cover both classical and modern techniques, with a focus on real-world applications in fields like supply chain management, portfolio optimization, and engineering design.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Understand the fundamental concepts of operations research
CO2	Apply operations research techniques to solve complex problem
CO3	Develop problem-solving and decision-making skills
CO4	Appreciate the role of operations research in various fields

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Constrained Optimization with Single Objective: Linear Programming: Resource allocation problems (e.g., production planning, transportation), Diet problems, Portfolio optimization Integer Programming,		CO1	2
Non-Linear Programming (NLP): Optimal control problems, Economic modelling, Supply Chain Management: Logistics optimization, Inventory management,		CO2	3
Constrained Optimization with Multiple Objective: Concept of Pareto optimality and Pareto front, Challenges in MOO compared to		CO3	2

single-objective optimization, Weighted Sum Method, ε-Constraint Method.		
Goal Programming, Genetic Algorithm, Particle Swarm Optimization, Application of Multi-objective Optimization in Supply chain management, Portfolio optimization.	CO4	3

4.	Text books

i) Deb, K., Sindhya, K., & Hakanen, J. Multi-objective optimization. In Decision Sciences (pp. 161-200). CRC Press, 2016. ISBN: 978-1138032422.

ii) D. G. Luenberger and Y. Ye, Linear and Nonlinear Programming, 4th Ed., Springer, 2016. ISBN: 978-3319188416.

iii) E. K. P. Chong and S. H. Zak, An Introduction to Optimization, 4th Ed., Wiley, 2013. ISBN: 978-1118279014.

iv) M. S. Bazaraa, H. D. Sherali and C. M. Shetty, Nonlinear Programming: Theory and Algorithms, 3rd Ed., Wiley, 2013. ISBN: 978-0471486008.

5.	Reference Book(s) and Other Required Material

i) D. Gale, The Theory of Linear Economic Models, The University of Chicago Press, 1989 ISBN: 978-0226279145.

ii) K. G. Murty, Linear Programming, Wiley, 1983. ISBN: 978-0471097235.

6.	Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	1	2	1	1	---	---	3	2	3	2	3	2
CO2	3	3	3	3	3	1	2	---	---	3	2	3	2	3	2
CO3	3	3	3	3	2	1	1	---	---	3	2	3	2	3	2
CO4	3	3	3	3	3	1	2	---	---	3	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):** Practical Assignments and Projects:

i) Solve operations research problems using various techniques.

ii) Develop and implement simulation models.

iii) Analyse real-world case studies using operations research tools.

iv) Explore applications of operations research in interdisciplinary field

Topics in Operator Theory

Course Code & Course Title:	MALA 4XX Topics in Operator Theory		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Topics in Functional Analysis		
Course Equivalence: Course Code(s) & Name(s)	Nil		

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance of Operator theory.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Find the representation of duals of some sequence and function spaces and understand definition, properties and applications of reflexive spaces
CO2	Understand definition, examples, properties of compact operators and prove results and theorems involving compact operators
CO3	Understand definition, properties and related theorems of eigen spectrum, approximate spectral, spectrum and resolvent for the operator defined on Banach and Hilbert spaces
CO4	Understand definitions, properties and related results of Adjoint of operator, self-adjoint operator, Normal operators on Banach as well as Hilbert spaces
CO5	Prove Spectral theorem and singular value representation for compact self-adjoint operators and Spectral theorem for self-adjoint operators

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Dual space considerations: Representation of duals of some sequence spaces and function spaces. Reflexivity, Weak and weak* convergences. Best Approximation in Reflexive spaces.		CO1	2
Operators on Banach and Hilbert spaces: Compact operators and its properties; Integral operators as compact operators;		CO2	3

Eigen spectrum, Approximate eigen spectrum, Spectrum and resolvent; Spectral radius formula; Spectral mapping theorem; Riesz-Schauder theory, Spectral results for normal Self-adjoint and unitary operators; Functions of self-adjoint operators.	CO3	2
Adjoint of operators between Hilbert spaces; Self-adjoint, Normal and unitary operators; Numerical range and numerical radius; Hilbert-Schmidt operators. Spectral results for Banach and Hilbert space operators	CO4	2
Spectral representation of operators: Spectral theorem and singular value representation for compact self-adjoint operators; Spectral theorem for self-adjoint operators.	CO5	3

4. Text books

i) B. V. Limaye, Functional Analysis, 2nd Ed., New Age International Publishers, 1996.

ii) M. Thamban Nair, Functional Analysis: A First Course, 2nd Ed., PHI learning Pvt. Ltd.

iii) W. Rudin, Functional Analysis (2nd Ed.), McGraw-Hill, 2006.

iv) Yosida, K., Functional Analysis (4th Edition), Narosa, 1974.

5. Reference Book(s) and Other Required Material

i) E. Kreyszig, Introductory Functional Analysis with Applications. John Wiley & Sons, 1978.

ii) Conway, J. B., A Course in Functional Analysis, Springer, New York, 1990.

iii) Simmons G. F. Introduction to Topology and Modern Analysis, McGraw-Hill Kogakusha, Tokyo, 1963.

6. Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO2	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO3	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO4	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2
CO5	3	2	1	---	---	---	---	---	---	---	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Introduction to Wavelet Analysis

Course Code & Course Title:	MALA 4XX Introduction to Wavelet Analysis		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance and applicability of wavelet Analysis**.**

2.	**Course Outcomes:**
CO1	Understand wavelet basis and characterize continuous and discrete wavelet transforms
CO2	Understand multi resolution analysis and identify various wavelets and evaluate their time- frequency resolution properties
CO3	Implement discrete wavelet transforms with multirate digital filters
CO4	Design certain classes of wavelets to specification and justify the basis of the application of wavelet transforms to different fields

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Heuristic treatment of the wavelet transform – wavelet transform – Haar wavelet expansion		CO1	2
Haar functions and Haar series, Haar sums and Dyadic projections, completeness of the Haar functions, Haar series in C_0 and L_p spaces, pointwise Convergence of Haar series, construction of standard Brownian motion, Haar function representation of Brownian motion – Multiresolution analysis		CO2	3
Orthogonal systems, scaling functions, from scaling function to MRA, Meyer wavelets, from scaling function to orthonormal wavelet – Wavelets with compact support.		CO3	2

From scaling filter to scaling function, explicit representation of compact wavelets, Daubechies recipe, Hernandez-Weiss recipe, smoothness of wavelets - convergence properties of wavelet expansions.	CO4	2
Wavelet series in L^p spaces, large scale analysis, almost everywhere convergence, convergence at a preassigned point – Wavelets in several variables: tensor product of wavelets, general formulation of MRA and wavelets in R^d, Examples of wavelets in R^d.	CO4	3

4. Text books

i) Mark A. Pinsky, Introduction to Fourier analysis and wavelets, Cenage Learning India Pvt. Ltd, 2002.

ii) M.V.Altaisky, Wavelets Theory, Applications Implementation, University Press, 2009.

5. Reference Book(s) and Other Required Material

i) David F. Walnut, An Introduction to Wavelet Analysis Birkhäuser / Springer 2002 ISBN 9780817639624.

6. Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	2	---	---	---	---	---	---	2	3	2	3	2
CO2	3	3	2	2	---	---	---	---	---	---	2	3	2	3	2
CO3	3	3	2	2	---	---	---	---	---	---	2	3	2	3	2
CO4	3	3	2	2	2	---	---	---	---	---	3	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Computational Fluid Dynamics

Course Code & Course Title:	MALA 4XX Computational Fluid Dynamics		
Course Type:	DE		
Name of the programme(s):	B.Tech. in Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	**4**
Pre-requisites: Course Code(s) & Name(s)	Fluid Dynamics		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to expose students to understand and explore computational fluid dynamics to solve problems arising in Science and Engineering.

2.	**Course Outcomes:**
CO1	Understand the governing equations of compressible and incompressible viscous fluid flows
CO2	Apply the staggered grid, artificial compressibility, pressure correction and vortex methods
CO3	Apprehend compressible inviscid flows, central schemes with combined and independent space time discretization
CO4	Apply the concept of compressible viscous flows, Explicit, implicit and PISO (Pressure-Implicit with Splitting of Operators) methods
CO5	Apply the Structured and unstructured grid generation methods

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Review of the governing equations of Incompressible viscous flows, Stream function - vorticity approach.		CO1	2
Upwind schemes, Primitive variables, Staggered grid, Artificial compressibility, pressure correction and vortex methods.		CO1, CO2	3
Compressible inviscid flows, central schemes with combined and independent space time discretization.		CO2	2

Compressible viscous flows, Explicit, implicit and PISO methods.	CO3	2
Grid generation: Structured and unstructured grid generation methods.	CO3, CO4	3
Finite volume method: Finite volume method to convection-diffusion equations.	CO5	2

4. Text books

i) Ferziger, J. H. and Peric, M., Computational Methods for Fluid Dynamics. Third Edition, Springer Verlag, Berlin, 2003.

ii) John D Anderson, Jr., Computational Fluid Dynamics, The Basics with Applications, McGraw-Hill, 1995.

iii) P Wessling, Principles of Computational Fluid Dynamics, Springer, 1991.

5. Reference Book(s) and Other Required Material

i) Anderson, D. A., Tannehill, J. C. and Pletcher, R. H. Computational Fluid Mechanics and Heat Transfer. Taylor & Francis, 1997.

ii) Versteeg, H. K. and Malalasekara, W., Introduction to Computational Fluid Dynamics: The Finite Volume Method. Second Edition (Indian Reprint) Pearson Education, 2008.

6. Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	0	0	1	1	0	0	0	3	3	2	3	2
CO2	2	2	2	0	0	1	1	0	0	0	2	3	2	3	2
CO3	2	2	2	0	0	1	1	0	0	0	2	3	2	3	2
CO4	2	2	2	0	0	1	1	0	0	0	2	3	2	3	2
CO5	2	2	2	0	0	1	1	0	0	0	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Approximation Theory

Course Code & Course Title:	MALA 4XX Approximation Theory		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Real Analysis		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

This course aims to introduce the foundational concepts of approximation theory.

2.	**Course Outcomes:**
CO1	Understand the importance or applications of approximation of functions by other functions
CO2	Analyze best approximations in normed linear spaces
CO3	Analyze Inverse theorems for uniform trigonometric approximation
CO4	Analyze characterizations of best uniform approximants

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
The Theorems of Weierstrass, Bernstein, Fejer, and Korovkin, Stone's Approximation Theorem and the Stone-Weierstrass Theorem, Some applications.		CO1	2
Best approximation in normed spaces: some basic notions and results, Degree of uniform approximation by algebraic and trigonometric polynomials.		CO1, CO2	3
Modulus of continuity and moduli of smoothness - Jackson's theorems - Bernstein's inequality for trigonometric polynomials.		CO2	2
Inverse theorems for uniform trigonometric approximation, Bernstein and Markov inequalities for algebraic polynomials.		CO3	2

Characterizations of best uniform approximants - Theorems of Collatz and Schewdt, Collatz and Kolmogorov.	CO3, CO4	3
Haar systems and the Haar-Kolmogorov Theorems - Chebyshev's Alternation Theorem and some applications.	CO4	2

4. Text books

i) E.W.Cheney, An Introduction to Approximation theory, McGraw-Hill, 1st edition, 1966

ii) G. G. Lorentz, Approximation of Functions, New York, N.Y.: Chelsea Pub. Co., 1986

iii) T. J. Rivlin, An introduction to the approximation of functions, Courier Corporation, 1981.

iv) G. Meinardus, Approximation of Functions: Theory and Numerical Methods, Berlin; New York, Springer-Verlag, 1967.

5. Reference Book(s) and Other Required Material

i) I. P. Natanson, Constructive Function Theory, Volume I, Frederick Ungar, New York, NY, 1964.

ii) R. G. Bartle, The Elements of Real Analysis, Jhon Wiley, third edition, 2000.

6. Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	1	1	---	---	---	---	---	---	1	3	2	3	2
CO2	2	3	1	1	---	---	---	---	---	---	1	3	2	3	2
CO3	2	3	1	1	---	---	---	---	---	---	1	3	2	3	2
CO4	2	2	1	1	---	---	---	---	---	---	1	3	2	3	2

High - 3; Medium – 2; Low – 1

8. List of Indicative Laboratory Experiment (if applicable):

NA

Non-Linear Analysis

Course Code & Course Title:	MALA 4XX Non-Linear Analysis		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Real Analysis, Functional Analysis		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

To inculcate the students about various methods to solve problems involving the homogeneous and non-homogeneous operators.

2.	**Course Outcomes:**
CO1	Discuss the various concepts of the derivatives and their properties in Banach spaces
CO2	Explain the monotone operators, their properties and applications
CO3	Discuss the fundamentals of convexity, its characterizations and applications
CO4	Apply some fundamental fixed-point theorems and their applications

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Calculus in Banach spaces: Fréchet derivatives and Gateaux derivatives, chain rule, Taylor's expansions, mean value theorem, Implicit function theorem with applications, inverse function theorem, extrema of real valued function.		CO1	3
Monotone Operators: maximal monotone operators with properties, subjectivity theorem, sub-differentiability and monotonicity, strict, uniform and strong monotonicity, maximal monotone operator and their properties.		CO2	3
Convexity: convex sets, properties of convex sets, convex functions, strict and strong convexity, examples, and convexity preserving		CO3	3

operations, Equivalent definitions of convexity under differentiability assumptions.		
Fixed Point Theorems with Applications: Banach contraction mapping theorem, degree theory, Brouwer fixed point theorem, Leray-Schauder fixed point theorem, measure of noncompactness, condensing operators, Darbo's fixed point theorem with applications.	CO4	4

4. Text books

i) H. H. Bauschke and P. L. Combettes, Convex Analysis and Monotone Operator Theory in Hilbert Spaces, Springer New York, 2011.

ii) K. Deimling, Nonlinear Functional Analysis, Dover Publication, Inc. Mineola, New York, 1985.

iii) S. Kesavan, Nonlinear Functional Analysis: A First Course, Hindustan Book Agency, New Delhi, 2020.

5. Reference Book(s) and Other Required Material

i) K. Deimling, Nonlinear Functional Analysis, Dover Publication, Inc. Mineola, New York, 1985.

6. Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	2	1	---	1	---	---	---	1	2	3	2	3	2
CO2	3	2	1	---	---	---	---	---	---	1	2	3	2	3	2
CO3	3	3	2	---	---	---	---	---	---	1	2	3	2	3	2
CO4	3	2	2	1	---	1	---	---	---	2	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Queuing theory with Applications

Course Code & Course Title:	MALA 4XX Queuing theory with Applications		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this course is to expose students to understand the importance of stochastic process and queueing models along with real life applications.

2.	**Course Outcomes:**
CO1	Understand the concept of stochastic process along with applications and Markov chain
CO2	Be able to use the concept of several arrival processes
CO3	Understand the basic concept of M/M/ type queuing models
CO4	Be able to learn the technique of probability generating function and complete extraction of distributions

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Concept of stochastic processes and examples, State space and parameter space, Classification to recurrent and transient states, Markov chain and Markov process, Transition probability matrix, Stationary probabilities, Ergodicity.		CO1	3
Birth-death process, Poisson, compound Poisson, and Bernoulli processes and their relations with exponential and geometric distributions, Superposition of Poisson arrival process, Markovian arrival process.		CO2	3
Basic introduction to queueing queuing theory, Simple queueing models: M/M/1 with finite and infinite waiting space, M/M/c with		CO3	4

finite and infinite waiting capacity, M/M/1 with finite source (Machine repairing problem), Concept of group arrival and batch service, some batch service rules, Queues with group arrivals and batch service.		
Concept of embedded Markov chain technique, Construction of transition probability matrix of M/G/1 and GI/M/1 queues, and derivation of probability generating functions, Detailed extraction procedure of probability distribution, Numerical examples of computations in MAPLE software.	CO4	4

4. Text books

i) Chaudhry, M., Templeton, J. G., 1983. A First Course in Bulk Queues. Wiley, New York.

ii) Gross, D., Harris, C., 1998. Fundamentals of Queueing Theory. Wiley Inter-science, New York.

iii) Karlin.S and Taylor. H., 1975. A First course in Stochastic Processes. Academic Press, New York.

iv) Medhi, J., 2002. Stochastic Models in Queueing Theory. Academic Press, New York.

5. Reference Book(s) and Other Required Material

i) Chaudhry, M., Templeton, J. G., 1983. A First Course in Bulk Queues. Wiley, New York.

6. Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	1	---	1	1	---	---	---	1	3	2	3	2
CO2	3	2	1	1	---	1	1	---	---	---	1	3	2	3	2
CO3	3	2	1	1	---	1	1	---	---	---	1	3	2	3	2
CO4	3	2	1	1	---	1	1	---	---	---	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Stochastic calculus for Finance

Course Code & Course Title:	MALA 4XX Stochastic calculus for Finance		
Course Type:	BS/ES/HU/IC/DC/IE/DE/HM/OC		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Probability Theory and Computational Financial		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance of Stochastic calculus for Finance in science and engineering and apply acquired knowledge to practical problems.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Understand the fundamental concepts of probability theory and stochastic processes
CO2	Apply stochastic calculus to model financial assets and derivatives
CO3	Evaluate the risk and return of financial instruments
CO4	Utilize stochastic calculus techniques for financial decision-making

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Stochastic Processes: Stochastic processes, time series, Discrete-time and continuous-time processes, Examples: Brownian motion, Poisson process Markov Chains: Transition probability matrices, Classification of states, Stationary distributions, Martingales: Definition and properties, Martingale convergence theorems.		CO1	3
Brownian Motion: Standard Brownian motion, Properties: continuity, independence of increments, normality Brownian Motion with Drift: Definition and properties, Applications in finance.		CO2	3
Stochastic Calculus: Ito's Lemma: Derivation and applications, Geometric Brownian motion. Stochastic Integration: Ito integral,		CO2, CO3	3

Properties of the Ito integral. Stochastic Differential Equations (SDEs): Introduction to SDEs, Solution methods for SDEs, Derivation of the Black-Scholes-Merton equation.		
Applications in Finance: Asset Pricing: Risk-neutral pricing, Black-Scholes model for option pricing, Extensions of the Black-Scholes model. Interest Rate Models: Short-rate models (e.g., Vasicek, CIR) Bond pricing Risk Management: Value at Risk (VaR), Expected Shortfall (ES)	CO4	4

4. Text books

i) F. C. Klebaner, Introduction to Stochastic Calculus with Applications, 3rd Ed., Imperial College Press, 2012. ISBN: 978-1848168312.

ii) M. Baxter and A. Rennie, Financial Calculus, Cambridge University Press, 1996. ISBN: 978-0521552899.

iii) S. Shreve, Stochastic Calculus for Finance, Vol. I, Springer, 2004. ISBN: 978-0387401003.

iv) S. Shreve, Stochastic Calculus for Finance, Vol. II, Springer, 2004, ISBN: 978-0387401010.

5. Reference Book(s) and Other Required Material

i) A. Etheridge, A Course in Financial Calculus, Cambridge University Press, 2003. ISBN: 978-0521890779.

ii) R. J. Elliott and P. E. Kopp, Mathematics of Financial Markets, Springer, 1999. ISBN: 978-0387985534.

6. Evaluation Details:

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	2	1	2	1	---	---	---	2	2	3	2	3	2
CO2	3	2	2	2	3	1	---	---	-	2	3	3	2	3	2
CO3	3	2	2	2	3	1	---	---	-	3	3	3	2	3	2
CO4	3	3	3	3	3	1	---	---	-	3	3	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):** Practical Assignments and Projects:

i) Implement stochastic processes and option pricing models using programming languages like Python or MATLAB.

ii) Analyze financial data using stochastic calculus techniques.

iii) Simulate financial markets and evaluate the performance of different strategies.

Time Series Analysis

Course Code & Course Title:	MALA 4XX Time Series Analysis		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this course is to expose students to understand the importance of non-stationary processes and time-series models along with real life applicability.

2.	**Course Outcomes: After completing this course students will**
CO1	Understand the concept of ergodicity and auto correlation
CO2	Be able to understand the Fourier analysis of different signals
CO3	Understand the basic concept of Fisher's information and estimation of time domain properties
CO4	Be able to learn and apply time-series models along with case studies

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction & Overview: Review of Probability Theory and Applied Statistics. Introduction to Random Processes, Stationarity & ergodicity, Auto- and cross-correlation functions; Partial correlation functions, Linear random processes; Auto-regressive, Moving average and ARMA models		CO1	3
Models for non-stationary processes, Trends, heteroskedasticity and ARIMA models, Fourier analysis of deterministic signals, Discrete Fourier transform and periodogram, Spectral densities and representations, Wiener-Khinchin theorem, Harmonic processes, SARIMA models		CO2	4

Introduction to estimation theory, Goodness of estimators, Fisher's information, Estimation of time domain properties, Estimation of power S, Periodogram and PSD estimation, Bayesian estimators, Estimation of signal properties	CO3	3
Time-series models, Case studies	CO4	3

4.	**Text books**

i) Peter J. Brockwell and Richard A. Davies, 3rd Edition, Introduction to Time Series and Forecasting, Springer, 2013, ISBN: 978-3319298542.

ii) Wayne A. Fuller, Introduction to Statistical Time Series, 1st Edition, Wiley, 1995, ISBN: 978-0471287155.

iii) Peter J. Brockwell and Richard A. Davies, Time Series: Theory and Methods, 2nd Edition, Springer, 2019, ISBN: 978-1441903198.

5.	**Reference Book(s) and Other Required Material**

i) James D. Hamilton, Time Series Analysis, 1st Edition, Princeton University Press, 2020, ISBN: 978-0691042893.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1	1	1	---	---	---	1	1	3	2	3	2
CO2	3	2	1	1	1	1	---	---	---	1	1	3	2	3	2
CO3	3	2	1	1	1	1	---	---	---	1	1	3	2	3	2
CO4	3	2	1	1	1	1	---	---	---	1	1	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Fuzzy Logic and its Applications

Course Code & Course Title:	MALA 4XX Fuzzy Logic and Its Applications		
Course Type:	DE		
Name of the programme(s):	B.Tech. in Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	MAL XXX Neuro Fuzzy Techniques		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The course aims to introduce students to the concepts of fuzzy logic and its applications. Students will learn about fuzzy sets, fuzzy logic operations, fuzzy inference systems, and their applications in various fields, including control systems, decision-making, pattern recognition, and natural language processing.

2.	**Course Outcomes:**
CO1	Understand the basic concepts of fuzzy logic and its applications
CO2	Develop skills in designing and implementing fuzzy inference systems
CO3	Apply fuzzy logic techniques to solve real-world problems in various domains
CO4	Appreciate the advantages and limitations of fuzzy logic compared to classical logic

3.	Detailed Description of the Course		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction to Fuzzy Logic: Classical Logic vs. Fuzzy Logic: Crisp sets and membership functions, Fuzzy sets and membership degrees, Advantages and limitations of fuzzy logic, Fuzzy Set Operations: Union, intersection, complement, Algebraic operations Fuzzy Numbers: Definition and properties, Arithmetic operations on fuzzy numbers.		CO1	4
Fuzzy Inference Systems: Mamdani Fuzzy Inference System: Fuzzification, Rule base, Inference, Defuzzification Sugeno Fuzzy Inference System: Fuzzification, Rule base, Inference, Defuzzification.		CO2	3
Fuzzy Logic Applications: Control Systems: Fuzzy control design, Applications in robotics, process control, and consumer electronics, Decision Making: Fuzzy decision-making models, Applications in finance, medical diagnosis, and resource allocation. Pattern Recognition: Fuzzy pattern classification, Applications in image processing and data mining. Natural Language Processing: Fuzzy semantics and fuzzy logic in natural language understanding.		CO3	3
Advanced Topics in Fuzzy Logic: Fuzzy Logic in Machine Learning: Fuzzy rule-based systems, Fuzzy neural networks, Fuzzy clustering, Fuzzy Time Series: Fuzzy forecasting models, Applications in financial forecasting and demand prediction, Fuzzy Rough Sets: Combining fuzzy logic and rough set theory, Applications in data mining and knowledge discovery.		CO3, CO4	4

4.	Text books

i) Erich P. Klement, R. Mesiar and E. Pap, Triangular Norms, 1st Edition, Trends in Logic series, Kluwer Academic Publishing, 2000, ISBN: 978-0792364160.

ii) F. Höppner, F. Klawonn, R. Kruse and T. Runkler, Fuzzy Cluster Analysis, 1st Edition, Wiley, 1999, ISBN: 0-471-98864-2.

iii) M. Baczynski and B. Jayaram, Fuzzy Implications, 1st Edition, Studies in Fuzziness and Soft Computing Series, Springer-Verlag, 2008, ISBN: 978-3642088612.

5.	Reference Book(s) and Other Required Material

i) George J Klir and Bo Yuan, Fuzzy sets and Fuzzy Logic: Theory and Applications, 1st Edition, Prentice -Hall of India, 1997, ISBN: 978-0131011717.

ii) E. Pap, Handbook of Measure Theory, 1st Edition, North Holland Publishers, 2002, ISBN: 978-0080533094.

6.	Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1	2	---	---	---	---	1	2	3	2	3	2
CO2	3	2	1	2	3	---	---	---	---	2	2	3	2	3	2
CO3	3	2	1	2	2	---	---	---	---	2	3	3	2	3	2
CO4	3	2	1	2	3	---	---	---	---	2	3	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

i) Implement fuzzy inference systems using programming languages like Python or MATLAB.

ii) Design and evaluate fuzzy controllers for real-world applications.

iii) Apply fuzzy logic techniques to solve problems in data mining, pattern recognition, or decision-making.

iv) Explore advanced topics like fuzzy neural networks or fuzzy time series analysis.

Biometrics

Course Code & Course Title:	MALA 4XX Biometrics		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	MAL XXX Neuro Fuzzy Techniques		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

To make students aware of basic structure of biometric systems, privacy and legal aspects of biometric data and conversant with evaluation procedure of a given biometric system.

2.	**Course Outcomes (Min. 3 & Max. 5):** After completing this course, student will be able to:
CO1	Understand the basic structure of biometric systems
CO2	Understand technical implementation of biometric systems and its challenges
CO3	Understand privacy and legal aspect of biometric data
CO4	Understand evaluation procedure of a given biometric system

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Person Recognition, Biometric Systems, Biometric Functionalities, Biometric System Errors, Design cycle of Biometric Systems, Applications of Biometric Systems, Security and Privacy issues.		CO1	3
Fingerprint recognition, friction and ridge pattern, fingerprint acquisition, sensing techniques, feature extraction, ridge orientation and frequency estimation, singularity extraction, minutiae extraction, matching, fingerprint indexing, synthesis, palmprint recognition		CO1, CO2	2
Face recognition sensors, cameras, Video sequences, Viola Jones face detection, appearance based, model based, texture-based face recognition, Principal Component Analysis, Linear Discriminant Analysis, Independent Component Analysis, Heterogeneous face recognition		CO1, CO2	2

Iris Recognition, Design, segmentation methods, normalization methods, encoding and matching	CO1, CO2	1
Additional biometric traits, Ear, Gait, Hand geometry, Ocular biometrics, Online and offline Signature authentication, soft biometrics.	CO1, CO2, CO3	3
Multibiometric, multi-sensor, multi-algorithm, multi-instance, multi-sample, multi-modal systems, processing architectures, processing sequence, sensor level, feature level, score level, rank level, and decision level fusion, Attacks on biometric systems, adversary attacks, user interface, processing, template databases.	CO2, CO3, CO4	3

4.	**Text books**

i) Anil K. Jain, Arun A. Ross, and Karthik Nandakumar, Introduction to Biometrics, 1st Edition, Springer, 2011, ISBN: 978-0387-77325-4.

ii) Arun A. Ross, Karthik Nandakumar, and Anil K. Jain, Handbook of Multibiometrics, 1st Edition, Springer, 2006, ISBN: 978-0387222967.

iii) John Chirillo and Scott Blaul, Implementing Biometric Security, 1st Edition, Wiley Eastern Publication, 2005, ISBN: 978-0764525025.

iv) Anil K Jain, Patrick Flynn, and Arun A Ross, Handbook of Biometrics, 1st Edition, Springer, 2010, ISBN: 978-0387222967.

v) Samir Nanavati, Michael Thieme and Raj Nanavati, Biometrics – Identity Verification in a Networked World, 1st Edition, John wiley and Sons, 2003, ISBN: 978-0471099451.

5.	**Reference Book(s) and Other Required Material**

i) Paul Reid, Biometrics for Network Security, 1st Edition, Pearson Education, 2004, ISBN: 978-0131015494.

ii) David D. Zhang, Automated Biometrics: Technologies and Systems, 1st Edition, Kluwer Academic Publishers, 2000, ISBN: 978-1-4613-7038-3.

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	3	1	2	1	---	---	---	---	---	---	3	2	3	2
CO2	3	3	1	2	1	---	---	---	---	---	---	3	2	3	2
CO3	3	3	1	2	1	---	---	---	---	---	---	3	2	3	2
CO4	3	3	1	2	1	---	---	---	---	---	---	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

NA

High Performance Computation

Course Code & Course Title:	MALA 4XX High Performance Computation		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3–0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Digital circuit and computer Architecture		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance of High-Performance Computation in science and engineering.

2.	**Course Outcomes (Min. 3 & Max. 5):** After completing this course, student will be able to:
CO1	To understand the concepts involved in Parallel Processing and apply it to solve related problems
CO2	To understand the concepts involved in Fundamental design issues in HPC and apply it to solve related problems
CO3	To understand the concepts involved in Benchmarking HPC and apply it to solve related problems
CO4	To understand the concepts involved in Scalable storage systems, Accelerated HPC and Power-aware HPC Design and apply it to solve related problems

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Parallel Processing Concepts; Levels and model of parallelism: instruction, transaction, task, thread, memory, function, data flow models, demand-driven computation		CO1	3
Parallel architectures: superscalar architectures, multi-core, multi-threaded, server and cloud		CO1, CO2	2
Fundamental design issues in HPC: Load balancing, scheduling, synchronization and resource management; Operating systems for		CO2	3

scalable HPC; Parallel languages and programming environments; OpenMP, Pthread, MPI, java, Cilk; Performance analysis of parallel algorithms; Fundamental limitations in HPC: bandwidth, latency and latency hiding techniques		
Benchmarking HPC: scientific, engineering, commercial applications and workloads	CO3	2
Scalable storage systems: RAID, SSD cache, SAS, SAN; HPC based on cluster, cloud, and grid computing: economic model, infrastructure, platform, computation as service; Accelerated HPC: architecture, programming and typical accelerated system with GPU, FPGA, Xeon Phi, Cell BE; Power-aware HPC Design: computing and communication, processing, memory design, interconnect design, power management; Advanced topics: peta scale computing; big data processing, optics in HPC, quantum computers.	CO4	4

4. Text books

i) Georg Hager and Gerhard Wellein, Introduction to High Performance Computing for Scientists and Engineers, 1st Edition, CRC Press Chapman and Hall/CRC Computational Science Series, 2010, ISBN: 978-1439811924.

ii) Vipin Kumar, Ananth Grama, Anshul Gupta, and George Karypis, Introduction to Parallel Computing, 2nd Edition, Pearson India, 2003, ISBN: 978-8131708071.

iii) John L. Hennessy and David A. Patterson. Computer Architecture: A Quantitative Approach, 5th Edition, Elsevier, 2011, ISBN: 978-0-12-383872-8.

iv) David B. Kirk and Wen-mei W. Hwu. Programming Massively Parallel Processors: A Hands-On Approach, 1st Edition, Elsevier India Private Limited, 2010, ISBN: 978-0323912310.

5. Reference Book(s) and Other Required Material

i) Michael T. Heath, Scientific Computing: An Introductory Survey, 2nd Edition, McGraw Hill Education India Private Limited, 2011, ISBN: 978-1259002281.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4

CO1	3	2	3	3	2	2	---	---	---	---	---	2	3	2	3
CO2	3	2	3	3	2	2	---	---	---	---	---	2	3	2	3
CO3	3	2	3	2	2	2	---	---	---	---	---	2	3	2	3
CO4	3	3	3	2	2	2	---	---	---	---	---	2	3	2	3

High - 3; Medium – 2; Low – 1High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

HPC programming assignments: Hands on experiment and programming on parallel machine and HPC cluster using Pthread, OpenMP, MPI, Nvidia Cuda and Cilk. Also, there will be some hands-on experiments on standard multiprocessor simulators or cloud simulators.

Topic in Bioinformatics

Course Code & Course Title:	MALA 4XX Topic in Bioinformatics		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	MAL4XX Design analysis and Algorithms		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

Given the knowledge of string-based and statistical algorithms in Bioinformatics, a students will be able to model biological problems as theoretical computational formulations and reapply the solutions back to the biological world.

2.	**Course Outcomes (Min. 3 & Max. 5):** After completing this course, student will be able to:
CO1	This course introduces students to the basic string based computational methods and algorithms that can be used to understand the cell and biological systems
CO2	Students will know algorithms and programming techniques like dynamic programming, hashing, and suffix trees
CO3	The course focuses on computational approaches to: genetic and physical mapping; genome sequencing, assembly, and annotation
CO4	This course will help students develop a multidisciplinary approach to the systematic analysis and modelling of complex biological phenomena

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Basics of biology, Sequences: Problem statement, Edit distance and substitution matrices, Global and local alignments, Spliced alignment, Space-efficient sequence alignment, Multiple alignment.		CO1	2
Structures: Protein alignment, Protein structure prediction Phylogenetic trees: Large parsimony and small parsimony problems, Probabilistic approaches, Grammar-based approaches		CO2	3

Overview of Gene Control, Working of Genetic Switches, Introductory Systems Biology, The biochemical paradigm, genetic paradigm and the systems paradigm	CO3	3
Building an Organism Starting from a Single Cell -Quorum Sensing – Programmed Population Control by Cell-Cell Communication and Regulated Killing; Gene regulation at a single cell level-Transcription Networks -basic concepts -coherent Feed Forward Loop (FFL) and delay gate -The incoherent FFL -Temporal order, Signaling networks and neuron circuits -Aspects of multi-stability in gene networks. Modelling biological systems, Hidden Markov models	CO4	4
Miscellaneous topics: Pathways and networks, Microarrays, Biomedical images, Genetic Algorithms and applications,	CO4	2

4.	**Text books**

i) Neil C. Jones and Pavel A. Pevzner, An Introduction to Bioinformatics Algorithms, 1st Edition, MIT Press, 2004, ISBN: 978-0262101066.

ii) Dan Gusfield, Algorithms on Strings, Trees and Sequences, 1st Edition, Cambridge University Press, 1997, ISBN: 0-521-58519-8.

iii) Uri Alon, An Introduction to Systems Biology: Design Principles of Biological Circuits, 1st Edition, Chapman and Hall/CRC Press, 2006, ISBN: 978-1584886426.

5.	**Reference Book(s) and Other Required Material**

6.	**Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]**

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7.	**Relationship of Course Outcomes to Program Outcomes:**

Mapping with POs (Departmental Reference)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PO1 2	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	2	---	2	---	---	---	---	2	---	---	---
CO2	3	2	2	2	2	---	2	---	---	---	---	2	---	---	---
CO3	3	2	2	2	2	---	2	---	---	---	---	2	---	---	---
CO4	3	2	2	2	2	---	2	---	---	---	---	2	---	---	---
CO5	3	2	2	2	2	---	2	---	---	---	---	2	---	---	---

High - 3; Medium – 2; Low – 1;

8.	**List of Indicative Laboratory Experiment (if applicable):**

NA

Advanced Data Mining

Course Code & Course Title:	MALA 4XX Advanced Data Mining		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Data Mining		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this subject is to expose students to understand the importance of Advanced Data Mining in science and engineering and apply acquired knowledge to practical problems.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	To understand the concepts involved in Sequential Pattern Mining and apply it to solve related problems
CO2	To understand the concepts involved in Mining Time series and stream data and apply it to solve related problems
CO3	To understand the concepts involved in Graph Mining and apply it to solve related problems
CO4	To understand the concepts involved in Distributed Data Mining and apply it to solve related problems

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Sequential Pattern Mining: Concepts, primitives, scalable methods for mining sequential patterns – GSP, SPADE, PrefixSpan, Mining Closed Sequential Patterns, Mining Multidimensional and Multilevel sequential Patterns.		CO1	3

Mining Time series Data: Periodicity Analysis for Time-Related Sequence Data, Trend analysis, Similarity search in Time-series analysis.	CO2	3
Mining Data Streams: Methodologies for stream data processing and stream data systems, Frequent pattern mining in stream data, Sequential Pattern Mining in Data Streams, Classification of dynamic data streams, Class Imbalance Problem.	CO2	3
Graph Mining: Mining frequent subgraphs, finding clusters, hub and outliers in large graphs, Graph Partitioning; Web Mining, Mining the web page layout structure, mining web link structure, mining multimedia data on the web, Automatic classification of web documents and web usage mining.	CO3	3
Distributed Data Mining: Distribute data mining framework, Distributed data source, Distributed data mining techniques, Distributed classifier learning, distributed clustering, distributed association rule mining and Challenges of distributed data mining.	CO4	3

4. Text books

i) Jiawei Han and Micheline Kamber, Data Mining Concepts and Techniques, 2nd Edition, Elsevier, 2011, ISBN: 978-1-55860-901-3.

ii) Pang Ning Tan, Michael Steinbach, and Vipin Kumar, Introduction to Data Mining, 1st Edition, Pearson Education, 2006, ISBN: 978-81-317-1472-0.

5. Reference Book(s) and Other Required Material

i) Guozhu Dong and Jian Pei, Sequence Data Mining, 1st Edition, Springer, 2007, ISBN: 978-0-387-69936-3.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	2	2	2	---	---	---	---	---	2	2	3	2	3
CO2	3	2	2	2	2	---	---	---	---	---	2	2	3	2	3
CO3	3	2	2	2	2	---	---	---	---	---	2	2	3	2	3
CO4	3	2	2	2	2	---	---	---	---	---	2	2	3	2	3

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

NA

Quantum Computing

Course Code & Course Title:	MALA 4XX Quantum Computing		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Nil		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

This course aims at introducing computer science students to the upcoming domain of quantum computing and quantum information. This course should enable students to understand, design and develop quantum algorithms/applications.

2.	**Course Outcomes (Min. 3 & Max. 5):**
CO1	Understand fundamentals of Quantum computing concepts through the requisite topics in Mathematics and Physics
CO2	Being able to design quantum algorithms by understanding the difference between classical algorithms and quantum algorithms
CO3	Able to code the quantum algorithms using the related technologies like Microsoft Q#
CO4	Understand and design applications of quantum computing in different areas like cryptography and machine learning. Design and development of an application using quantum computing

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction to quantum mechanics, Hilbert space, unitary and stochastic dynamics, classical and quantum information, density operators and correlation.		CO1	3
Mathematics for quantum computing, Characteristics of a computational system, classical computation, quantum circuits and qubit operations, quantum entanglement.		CO2	3
Quantum search algorithms, Shor factorization, Deutsch Algorithm, Deutsch-Jozsa Algorithm, Simon Problem, Grover's		CO3	4

Search Algorithm, Quantum Fourier Transform, Period Finding, Method of Continued Fraction, Quantum error Correction Codes, Quantum noise and quantum operations, fault-tolerant computation.		
Quantum information and applications, Entropy and information, Classical Information Theory, Shannon Entropy, Shannon entropy, Von Neumann Entropy, Classical Cryptography RSA Algorithm, Quantum Cryptography – BB 84 protocol, B-92 and Eckart protocol, Practical realization of a quantum computer, Basic Quantum computing with tools like Microsoft Q#, IBM Quiskit etc. Introduction to Quantum Machine Learning.	CO4	4

4. Text books

i) Michael A. Nielsen and Issac L. Chuang, Quantum Computation and Quantum Information, 1st Edition, Cambridge University Press, 2013, ISBN: 978-1107619197.

ii) Mikio Nakahara and Tetsuo Ohmi, Quantum Computing, 1st Edition, CRC Press, 2008, ISBN: 978-0750309837.

iii) N. David Mermin, Quantum Computer Science, 1st Edition, Cambridge University Press, 2007, ISBN: 978-0521876582.

5. Reference Book(s) and Other Required Material

i) Leonard S. Woody, Essential Mathematics for Quantum Computing, 1st Edition, Packt Publishing Limited, 2022, ISBN: 978-1801073141.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	---	---	---	---	---	---	---	---	2	3	2	3
CO2	3	2	2	1	1	---	---	---	---	---	---	2	3	2	3
CO3	3	2	2	2	1	---	---	---	---	---	---	2	3	2	3
CO4	3	2	2	2	2	1	1	---	---	---	---	2	3	2	3

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Deep Learning

Course Code & Course Title:	CSL502 Deep Learning		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3–0-2	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Neuro Fuzzy Techniques		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

Introduce students to major deep learning algorithms, the problem settings, and techniques and foster their abilities in designing and implementing soft computing-based solutions for real-world problems.

2.	**Course Outcomes:**
CO1	Identify the deep learning algorithms and modeling which are more appropriate for various types of learning tasks in various domains (Understanding)
CO2	Perform detailed analysis of leading machine learning approaches and popular NN like CNN, FCNN, ImageNet, ResNet, RNN, etc. (Applying, Analysing, Evaluating)
CO3	Implement deep learning algorithms and solve real-world problems such as image classification, image segmentation and natural language processing (NLP) and present as mini project (Applying, Analysing, Creating)
CO4	Evaluate the performance of different deep learning models (e.g., with respect to the bias-variance trade-off, overfitting and underfitting, estimation of test error). (Analysing)
CO5	Design and analyse solutions using pertinent optimization, regularization, and hyperparameter selection on deep models. (Analysing, Creating)

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Introduction - Machine Learning & ANN Review What is deep learning? DL successes; syllabus & course logistics. Feedforward Deep Networks – Review - Architecture, Backpropagation Gradient Descent; Output units, hidden units.		CO1	3

Regularization for Deep Learning, Optimization Methods- SGD, Momentum method, Adaptive first order methods, Batch Normalization, Initialization Strategies. Convolutional Neural Networks - Introduction, Visualizing Convolutional Networks, Variants (Locally Connected Networks, Tiled CNNs, Dilated Convolutions), Motivations: Neuroscientific, Motivations: Efficiency, Equivariance, Invariance, parameter tying.	CO2, CO5	4
Sequence Learning with NNs - Recurrent Neural Networks, Design Patterns for RNNs, Intro to long term dependencies and gated architectures, Challenges with Long Term Dependencies, Reservoir Computing (basic idea), Long Short-Term Memory and GRU	CO3	3
Various Real-life Applications of DNN – Projects for Image & Video processing, NLP, Machine Translation, Program Debugging, Program Analysis, Software Engineering, etc.	CO4	3

4. Text books

i) Ian Goodfellow, Yoshua Bengio, and Aaron Courville, Deep Learning, 1st Edition, MIT Press, 2016, ISBN: 978-0002457620.

ii) Michael Nielsen, Neural Networks and Deep Learning, 1st Edition, Determination Press, 2015.

iii) Eugene Charniak, Introduction to deep learning, 1st Edition, MIT Press, 2019, ISBN: 978-9368083016.

5. Reference Book(s) and Other Required Material

i) Jurgen Schmidhuber, Technical Report: Deep Learning in Neural Networks: An Overview.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	1	---	1	---	---	---	---	---	---	---	3	2	3	2
CO2	3	1	3	1	---	---	---	---	---	---	---	3	2	3	2
CO3	3	3	3	---	---	---	---	---	---	---	---	3	2	3	2
CO4	1	2	3	1	---	---	---	---	---	---	---	3	2	3	2
CO5	3	1	---	3	---	---	---	---	---	---	---	3	2	3	2

High - 3; Medium – 2; Low – 1;

8.	List of Indicative Laboratory Experiment (if applicable):

i) Retail: Customer Footfall Prediction and Behaviour Analysis
Assignment Description: You are tasked with developing a software solution to analyse customer behaviour in a retail store using deep learning. Use a CNN to classify activities (e.g., browsing, picking items, waiting) from surveillance video frames. Implement an LSTM to analyse the sequence of these activities to predict customer footfall during peak and non-peak hours. Provide insights into how the combined approach can optimize staffing and inventory management. Submit your code, documentation, and a short report on your findings.

ii) Autonomous Vehicles: Lane Departure Warning System
Assignment Description: Design a lane departure warning system for autonomous vehicles using deep learning. Train a CNN to identify lane markings and boundaries from real-world road images. Use an LSTM to process sequential images and predict lane departure events based on vehicle trajectory. Evaluate your model's performance using metrics such as accuracy and false positive rate. Provide a brief discussion on potential real-world challenges and your solution's scalability. Submit the trained model and a detailed implementation report.

iii) Healthcare: Diagnosis of Diseases
Assignment Description: Create a deep learning pipeline for diagnosing diseases using images. Use a CNN to extract features from images and classify them into healthy and disease categories. Integrate a Deep Autoencoder to identify anomalies in the dataset that may represent rare disease cases. Provide a visualization of the autoencoder’s reconstruction errors for anomalous images. Document your findings and discuss the potential of this approach for real-world medical applications. Submit your model, code, and a project report.

iv) Finance: Fraud Detection in Transaction Sequences
Assignment Description: Develop a fraud detection system using transaction data. Implement a Deep Autoencoder to detect unusual patterns in transactional features. Use an LSTM to analyze the temporal sequence of transactions and classify them as fraudulent or non-fraudulent. Train your model on a synthetic or publicly available dataset and evaluate it using precision, recall, and F1-score. Discuss how your solution can be adapted to real-world financial systems. Submit the model code, evaluation metrics, and a summary report. 5.Natural Language Processing (NLP): Multimodal Sentiment Analysis

v) Assignment Description: Build a multimodal sentiment analysis system that combines textual and visual data. Use a CNN to extract features from images representing facial expressions or related visuals. Implement an LSTM to analyze text data and combine its output with the CNN features to classify sentiment (e.g., positive, negative, neutral). Test your model on a publicly available multimodal sentiment analysis dataset and report its accuracy. Discuss the importance of multimodal approaches in NLP applications. Submit the model implementation, test results, and a brief write-up of your findings.

Modules and Fields

Course Code & Course Title:	MALA 4XX Modules and Fields		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Abstract Algebra		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The objective of this course is to expose students to understand the importance of theory of modules and fields.

2.	**Course Outcomes:**
CO1	Understand fundamental concepts including modules, free modules, semi and semi-simple modules
CO2	Analyze and implement the concepts of isomorphism between modules for solving different types of algebraic problems
CO3	Understand the basic concepts of Noetherian and Artinian modules
CO4	Gain a deeper understanding of field extensions
CO5	Understand the basics of Galois theory and apply this theory to solutions of cubic and quartic polynomials, and in-solvability of quintic and higher degree polynomials

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Review of Rings, Modules, Free modules, Cartesian products and direct sums of modules, quotient modules, Simple and semisimple modules, isomorphism theorems. Modules over principal ideal domains and applications.		CO1, CO2	3-4
Noetherian and Artinian rings/Modules, Hilbert basis theorem. Jordan-Holder theorem. Projective/Injective modules.		CO3	3
Field extensions. Algebraic/transcendental elements, Algebraic extensions. Finite fields, Cyclotomic fields. Splitting field of a		CO4	3-4

polynomial. Algebraic closure of a field, Uniqueness. Normal, separable, purely inseparable extensions. Primitive elements, simple extensions.		
Fundamental theorem of Galois theory. Solvability by radicals- Solutions of cubic and quartic polynomials, Insolvability of quintic and higher degree polynomials.	CO5	3

4. Text books

i) D. S. Dummit and R. M. Foote, Abstract Algebra, John Wiley & Sons Inc, 3rd Ed. 2004.

ii) S. Lang, Algebra, 3rd Edition, Springer-Verlag (India), 2004.

5. Reference Book(s) and Other Required Material

i) C. Musili, Introduction to Rings and Modules, Narosa Publishing House, New Delhi 1994.

ii) Jacobson, N., Basic Algebra II, Hindustan Publishing Corporation, 1991.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO2	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO3	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO4	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO5	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Introduction to Game Theory

Course Code & Course Title:	MALA 4XX Introduction to Game Theory		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Probability Theory, Introduction to Linear Algebra		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

This course introduces the mathematical study of strategic decision-making, focusing on the analysis of games and strategies used in competitive and cooperative situations. Applications in economics, biology, political science, and computer science will be explored.

2.	**Course Outcomes:**
CO1	Understand basic concepts and frameworks of game theory
CO2	Analyze strategic interactions in different types of games
CO3	Apply game-theoretic tools to real-world problems
CO4	Solve games using various equilibrium concepts
CO5	Explore advanced topics like repeated games and evolutionary game theory

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
What is Game Theory? Types of Games: Cooperative vs. Non-cooperative, Zero-sum vs. Non-zero-sum, Symmetric vs. Asymmetric, Simultaneous vs. Sequential. Examples of Games in Real Life: Economic markets, political elections, biological interactions.		CO1	2
Representation of Games: Players, strategies, and payoffs. Dominant Strategy Equilibrium. Nash Equilibrium: Definition and examples. Mixed Strategies: Randomization in strategy choice.		CO2	2
Games with Sequential Moves: Representation as game trees. Backward Induction: Finding subgame perfect equilibria. Imperfect Information and Information Sets.		CO3	2-3

Finitely and Infinitely Repeated Games, Folk Theorem: Cooperation in repeated games. Applications: Collusion in oligopoly markets. Games with Incomplete Information, Bayesian Nash Equilibrium. Applications: Auctions, Bargaining, Mechanism Design.	CO4	3-4
Evolutionarily Stable Strategies (ESS), Replicator Dynamics, Applications in Biology: Natural selection and animal behavior. Cooperative vs. Non-Cooperative Games, Coalitions and the Core, Shapley Value. Applications: Voting systems, resource allocation.	CO5	3-4

4. Text books

i) Osborne, M. J. An Introduction to Game Theory, Oxford University Press.

ii) Fudenberg, D., & Tirole, J., Game Theory, MIT Press.

iii) Gibbons, R., A Primer in Game Theory, Pearson.Weibull, J. W., Evolutionary Game Theory, MIT Press.

5. Reference Book(s) and Other Required Material

i) Klemperer, P., Auctions: Theory and Practice, Princeton University Press.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	2	2	1	1	---	---	---	—	2	3	2	3	2
CO2	2	2	2	2	1	1	---	---	---	—	2	3	2	3	2
CO3	2	2	2	2	1	1	---	---	---	—	2	3	2	3	2
CO4	2	2	2	2	1	1	---	---	---	—	2	3	2	3	2
CO5	2	2	2	2	1	1	---	---	---	—	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Basic Algebraic Geometry

Course Code & Course Title:	MALA 4XX Basic Algebraic Geometry		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Abstract Algebra		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

The course aims at introducing algebraic geometry, that is, the theory of algebraic varieties, and the most important notions and techniques to study these.

2.	**Course Outcomes:** After completing this course students will be able to
CO1	explain and apply basic concepts and results from the theory of affine algebras
CO2	understand the concepts of affine and projective varieties
CO3	define and use fundamental notions and constructions and knows results in algebraic geometry connected to the Zariski topology, affine and projective varieties, their regular functions, rational functions, Zariski tangent space and singularities, as well as morphisms and rational maps between varieties
CO4	perform an elementary analysis of simple varieties, in particular answer questions on irreducible components and singularities.

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Rings and ideals, Rings of fractions, Unique factorization, Integral dependence, Tensor Products, Transcendence bases.		CO1	2
Algebraic Sets, Algebraic varieties, The Hilbert basis theorem, The Zariski topology, Morphisms of Affine algebraic varieties, Dimension, The Hilbert Nullstellensatz, Regular functions; the coordinate ring, Equivalence of algebra and geometry, the spectrum of a ring.		CO1, CO3	3-4

Projective spaces, projective varieties, Morphism of Projective Varieties, Automorphisms of Projective space. Tangent Space at a point, Smooth points, Bertini's theorem, Gauss Mapping.	CO2, CO3	3-4
Resolution of Singularities, Rational maps, Birational equivalence, Blowing up along an ideal, hypersurfaces.	CO4	3-4

4. Text books

i) Shafarevich, Igor R. Basic algebraic geometry. 1. Varieties in projective space. Third edition. Translated from the 2007 third Russian edition. Springer, Heidelberg, 2013.

ii) Musili, C. Algebraic geometry for beginners. Texts and Readings in Mathematics, 20. Hindustan Book Agency, New Delhi, 2001.

5. Reference Book(s) and Other Required Material

i) Hartshorne, Robin. Algebraic Geometry. Springer New York. Edition 1. 1997. ISBN: 978-0-387-90244-9

ii) Smith, Karen E.; Kahanpää, Lauri; Kekäläinen, Pekka; Traves, William. An invitation to algebraic geometry. Universitext. S pringer-Verlag, New York, 2000.

iii) Abhyankar, Shreeram S. Algebraic geometry for scientists and engineers. Mathematical Surveys and Monographs, 35. American Mathematical Society, Providence, RI, 1990.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4
CO1	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO2	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO3	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2
CO4	3	2	---	---	---	---	---	---	---	1	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA

Modern Theory of Partial Differential Equations

Course Code & Course Title:	MALA 4XX Modern Theory of Partial Differential Equations		
Course Type:	DE		
Name of the programme(s):	B.Tech. Mathematics and Computing		
L – T – P	3-1-0	**No. of Credits**	4
Pre-requisites: Course Code(s) & Name(s)	Real Analysis, Linear Algebra and Functional Analysis		
Course Equivalence: Course Code(s) & Name(s)			

1.	**Course Objective:**

This course aims to provide a rigorous foundation in the theory of distributions, Sobolev spaces, and the methods for analysing partial differential equations (PDEs) through functional analytic techniques. It aims to equip students with essential tools to understand and solve elliptic, parabolic, and hyperbolic PDEs, preparing them for advanced research in applied mathematics and related fields.

2.	**Course Outcomes:** Upon successful completion of this course, students will be able to:
CO1	Understand and utilize the theory of distributions, including convolutions and Fourier transforms, to analyse PDEs and identify fundamental solutions
CO2	Apply Sobolev space theory, including embedding and compactness theorems, trace theory, and Poincaré inequalities, to study the regularity and approximation properties of PDE solutions
CO3	Formulate and solve weak forms of elliptic boundary value problems using variational methods, the Lax-Milgram lemma, and Galerkin's method, and apply these to eigenvalue problems
CO4	Demonstrate an understanding of operator semigroups and their application to evolution equations, particularly for heat, and wave, using the Hille-Yosida theorem

3.	**Detailed Description of the Course**		
Topics		**CO(s) Addressed**	**Duration in weeks**
Theory of distributions: supports, test functions, regular and singular distributions, generalized derivatives.		CO1	2-3

Sobolev spaces: definition and basic properties, approximation by smooth functions, dual spaces, trace and embedding results (without proof).	CO2	3-4
Elliptic Boundary Value Problems: abstract variational problems, Lax-Milgram Lemma, weak solutions and well-posedness with examples, regularity results, maximum principles, and eigenvalue problems.	CO3	3-4
Semigroup Theory and Applications: exponential map, C0-semigroups, Hille-Yosida and Lummer-Phillip's theorems, applications to heat and wave equations.	CO4	3-4

4. Text Books

i) Lawrence C. Evans, Partial Differential Equation, American Mathematical Society, 2nd ed, 2010.

ii) S. Kesavan, Topics in Functional Analysis and Applications, New Age International Publisher, 2nd ed, 2015.

iii) D. Gilbarg, N.S Trudinger, Elliptic partial differential equations of second order (Vol. 224, No. 2). Berlin: Springer.

5. Reference Book(s) and Other Required Material

i) M. Renardy and R.C Rogers, An Introduction to Partial Differential Equations, 2nd Editions, Springer Verlag International Edition, New York, 2004.

6. Evaluation Details: [Refer Table No. 5 of Academic Ordinances, Rules and Regulations]

Weightage: Mid semester: 20-30% Internal Assessment: 10-20% End semester: 50-60%

7. Relationship of Course Outcomes to Program Outcomes:

Mapping with POs (Departmental Reference)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	---	---	---	---	---	---	---	2	3	2	3	2
CO2	3	3	2	---	---	---	---	---	---	---	2	3	2	3	2
CO3	3	3	2	---	---	---	---	---	---	---	2	3	2	3	2
CO4	3	3	2	---	---	---	---	---	---	---	2	3	2	3	2

High - 3; Medium – 2; Low – 1;

8. List of Indicative Laboratory Experiment (if applicable):

NA