CENTRAL UNIVERSITY OF KARNATAKA

KALABURAGI

(Established by an Act of the Parliament in 2009)

B.Tech. in Mathematics and Computing

SCHEME OF INSTRUCTION AND SYLLABI

(Effective from 2024-25)

DEPARTMENT OF MATHEMATICS

SCHOOL OF PHYSICAL SCIENCES

Vision and Mission of the Department of Mathematics

VISION

To be among the best Mathematics Departments in the country and to establish an international reputation as a centre for research and teaching in Mathematics.

MISSION

- To attract motivated and talented students to the undergraduate, master's and doctoral programmes of the Department.
- To provide a stimulating teaching and research environment for the undergraduate, post graduate students and research scholars of the Department.
- To provide the best possible facilities for our students, particularly in the areas of computer facilities, library facilities and administrative support.

About the Dept. of Mathematics, CUK:

The Department of Mathematics was established in 2012 as a constituent of the School of Physical Sciences. Mathematics is important for all the departments of CUK. The Department of Mathematics shares the vision of our University in striving for excellence in teaching and research. Currently the Department not only teaches various topics in Mathematics to undergraduate and postgraduate students of different engineering and science departments, but also runs its own UG, PG & PhD courses in Mathematics. The curriculum of UG and PG courses are designed in a unique way to nurture future industry professionals and scientists. The frontier areas of research of the department include Fluid Mechanics, Number Theory, Computational Fluid Dynamics, Numerical Analysis, Theory of Hydrodynamic Stability and Mathematical Theory of Control. The laboratories in the Department and the computer centre are equipped with modern facilities to provide a good work environment. The students are trained in several computer programming languages like C, C++, and FORTRAN. They also gain exposure in handling problems through mathematical software's like MATLAB, Mathematica, Python, Scilab, Maple, R etc.

The academic programmes of the Department are designed to attract motivated and talented students to the master's and doctoral programmes of the Department. The faculty strives to provide a stimulating learning environment for the undergraduate, post graduate and doctoral students of the Department. To meet these objectives, the Department is setting up excellent computer facilities, library facilities and also provides good administrative support.

Programmes Offered:

Programme	Duration
B.Tech. in Mathematics and Computing	8 semesters
M.Sc. Mathematics	4 semesters
PhD. Mathematics	Minimum 3 years (6 Semesters)

About the Programmes:

B.Tech. in Mathematics and Computing

The B.Tech. Mathematics and Computing undergraduate program was started in the academic year 2023-24. This programme covers the basic courses in sciences and engineering along with programming, multidisciplinary courses, skill enhancement and value added courses, core foundational courses from pure mathematics, applied mathematics, statistics, and computing laboratory courses on machine learning, artificial intelligence, data analytics using computational software. It also covers advanced mathematics and computational mathematics electives along with minor and major research projects. After successful completion of this Mathematics and computing program, students will be able to pursue their dream of being industry professionals and also provide an opportunity for higher education in mathematics, computer science, artificial intelligence, etc. in most of the premier institutions/universities across the globe.

M.Sc. Mathematics

The Department of Mathematics offers a 4 semester (2 year) Master's degree programme to prepare students for a career in teaching and research. The entire curriculum is designed to prepare a student to enter a research career in multi-disciplinary areas of science and technology in Research Organizations and Industry. The students could also take up a teaching career especially after acquiring a PhD. degree. Further, this program helps the students to orient themselves towards a career in the industry. The main objective of the M.Sc. Mathematics program is to provide students with a strong theoretical background in mathematics for pursuing research in both pure and applied mathematics.

Thrust Areas of Research:

Finite Difference Methods; Computational Fluid Dynamics; Semi-analytical Techniques; Fluid Dynamics; Convective heat transfer in Nano and Hybrid Nanofluids (Theoretical and Experimental Studies); Bio Mechanics; Numerical Analysis; Number Theory; Theory of Partitions; q-series; special functions; Graph Theory; Mathematical Theory of Control; Fractional Differential Equations and Partial Differential Equations.

Learning Outcomes-Based Curriculum Framework (LOCF)

Name of the School: **School of Physical Sciences**

Department: **Mathematics**

Program: B. Tech in Mathematics and Computing

MISSION STATEMENTS:

MS-1. To attract motivated and talented students by providing a stimulative teaching and research environment where they can learn and develop the mathematical and computational skills needed to formulate and solve real-world problems.

MS-2. To inculcate innovative skills and ethical practices among students to meet societal expectations.

MS-3. To provide the best possible facilities and produce professionally competent, socially committed students through quality education and research.

MS-4. To build skilled IT professionals where computing is required for solving real-world problems.

MS-5. To groom the students to become technically competent and skilled intellectual professionals to address the challenges in the current computing areas.

Qualification Descriptors (QDs)

QD-1: Ability to understand the use of various mathematical concepts with computational techniques for problem solving & interpretation, and also the program core to address the challenges faced in mathematics and other related interdisciplinary fields.

QD-2: Facilitate as a deep learner and progressive careers in teaching, academia, research organizations, national/international laboratories and industry.

QD-3: Building professional competence in terms of applying mathematics and computer science knowledge in interdisciplinary projects and research.

QD-4: Communicate effectively with team members, engage in applying technologies and lead teams in the industry.

QD-5: Ability to adopt critical thinking, right moral and ethical values that compassionately foster the scientific temper with a sense of social responsibility.

QD-6: An ability to design, implement and evaluate a computer-based system, process, component, or programme to meet stakeholder needs. Also, assess the computing systems from the viewpoint of quality, security, privacy, cost, utility, etiquette and ethics.

Mapping Qualification Descriptors (QDs) with Mission Statements (MS)

	MS-1	MS-2	MS-3	MS-4	MS-5
QD-1	3	2	1	1	1
QD-2	1	2	3	3	2
QD-3	1	1	2	3	3
QD-4		2	2		2

QD-5		3	2	1	2
QD-6		2	1	3	3

Write '3' in the box for 'High-level' mapping, 2 for 'Medium-level' mapping, 1 for 'Low-level' mapping.

Program Learning Outcomes (PLOs)

PLO-1: Ability to develop logical and critical thinking, formulate, analyze, and solve real-world engineering problems through mathematical & computational techniques and perform the computations.

PLO-2: Gain and apply the knowledge of basic scientific and mathematical fundamentals to understand nature and apply it to develop new theories and models. Also, the use of research-based knowledge and research methods including designing of physical/computational experiments and evolving appropriate procedures to a given problem.

PLO-3: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling to complex computer science and engineering activities with an understanding of the limitations.

PLO-4: Design solutions for complex computer science and engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.

PLO-5: Analyze large data samples and discover knowledge to provide solutions to engineering problems. Also, communicate effectively on complex engineering activities with the engineering community and with society at large, such as comprehending and writing effective reports and design documentation, making effective presentations, and giving and receiving clear instructions.

PLO-6: To develop computing and technological advances for the appropriate societal problems. Also, understanding the impact of professional engineering solutions in societal and environmental contexts, and demonstrating the knowledge of, and need for sustainable development.

PLO-7: To analyze, create and develop algorithms and computing systems by applying mathematical and statistical approaches in interdisciplinary applications.

PLO-8: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's work as a member and leader in a team, to manage projects and in multidisciplinary environments.

PLO-9: The ability to function effectively in teams to accomplish a common goal. Also, apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PLO-10: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Mapping of Program Learning Outcomes (PLOs) with Qualification Descriptors (QDs)

	QD-1	QD-2	QD-3	QD-4	QD-5	QD-6
PLO-1	3	2	3	1	1	2
PLO-2	1	1	3	1	3	3
PLO-3	2	1	2	1	2	3
PLO-4		2	2		2	3
PLO-5	1	2	2	2	3	3
PLO-6	1	1	1	1	3	3
PLO-7	3	1	3	1	2	2
PLO-8	2	1	2	2	2	2
PLO-9			1	3	3	1
PLO-10	1	1			2	3

Write '3' in the box for 'High-level' mapping, 2 for 'Medium-level' mapping, 1 for 'Low-level' mapping.

CENTRAL UNIVERSITY OF KARNATAKA, KALABURAGI

PROPOSED MODEL CURRICULUM COMPONENTS

Comparison of suggested breakup of AICTE and CUK Curriculum

Credit Distribution for B. Tech. Mathematics and Computing Program (2024-2025 batch and onwards)

Category of Courses	Proposed Credits by CUK	AICTE Suggested Credits	Comparison
Basic Science Courses (BSC)	19	23	-4
Engineering Science Courses (ESC)	27	29	-2
Humanities and Social Sciences including Management courses (HSC)	10	16	-6
Program Core Courses (PCC)	55	59	-4
Departmental Elective Courses (DEC)	21	12	9
Open Elective Courses including Mandatory Courses (OPC)	10	9	1
Program Major Research Core Project (PRC)/Skill Development (SD)/Summer Internship (SI)	24	15	9
Total	166	163	3

	B. Tech (Mathematics and Computing) Credits in Each Semester								
	I	II	III	IV	V	VI	VII	VIII	TOT
BSC	3	5	0	8	3	0	0	0	19
ESC	8	6	2	5	3	0	3	0	27
HSC	2	0	3	0	0	5	0	0	10
PCC	6	4	14	8	7	9	7	0	55
DEC	0	0	0	0	6	6	6	3	21
OPC	3	5	2	0	0	0	0	0	10
PRC/SD	0	2	0	0	3	1	4	12	22
Internship	0	0	-	-	-	-	2	0	2
	22	22	21	21	22	21	22	15	166

Minor Degree (As per NEP 2020 suggested by AICTE): Artificial Intelligence, Machine Learning and Data Science (AI, ML & DS)

It is proposed to award minor degree for B. Tech students in Mathematics and Computing.

For example, a B. Tech student of Mathematics and Computing can graduate with regular degree in Mathematics and Computing and a minor in Artificial Intelligence, Machine Learning and Data Science (AI, ML & DS).

The minor degree can be awarded under the following conditions:

1. The students will be eligible to receive minor degree when they take additional courses constituting 18 credits between 5th to 8th semesters.
2. The minor degree courses will be over and above the B. Tech. credit requirements (164 Credits).
3. Minor degree will be allocated on merit basis on completion of 4th semester. At present, the minimumCGPA 7.0 with no backlog courses may be considered for minor degree eligibility.
4. Separate grade sheets are to be issued for the courses of Minor Degree.

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Department of Mathematics
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B. Tech in Mathematics and Computing Course Structure for the academic year 2024-2025.

Semester-I							
S. No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	UMATC10100	Differential Calculus	3	1	0	**04**	**PCC**
2	UMATC10101	Integral Calculus	2	0	0	**02**	**PCC**
3	UMATC10102	Engineering Physics	3	0	0	**03**	**BSC**
4	UMACC10100	Introduction to Electrical Engineering	2	0	2	**03**	**ESC**
5	UMACC10101	Introduction to Computing	2	0	4	**04**	**ESC**
6	UMAPC10100	Computer Aided Engineering Graphics	0	0	2	**01**	**ESC**
7	-	Multidisciplinary Course	3	0	0	**03**	**OPC**
8	-	A course on English Language	2	0	0	**02**	**HSC**
		TOTAL	**17**	**1**	**8**	**22**	

Semester-II							
S. No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	UMATC20103	Theory of Computation	3	0	0	**03**	**BSC**
2	UMATC20104	Probability and Statistics	3	1	0	**04**	**PCC**
3	UMACC20102	Introduction to Electronics and Communication Engineering	2	0	2	**03**	**ESC**
4	UMACC20103	Matrix Computations	1	0	2	**02**	**BSC**
5	UMAWC20100	Programming Workshop (Data Analytics using R Programming and GPU computing)	2	0	2	**03**	**ESC**
6	UMACS20100	Introduction to Python Programming	1	0	2	**02**	**SD**
7	-	Multidisciplinary Course	3	0	0	**03**	**OPC**
8	-	A course on Environmental Sciences (Mandatory Course)	2	0	0	**02**	**OPC**
		TOTAL	**17**	**1**	**8**	**22**	

Summer Internship – I#

Semester-III							
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	UMATC30200	Linear Algebra	3	1	0	**04**	**PCC**
2	UMATC30201	Introduction to Number Theory	3	0	0	**03**	**PCC**
3	UMATC30202	Compiler Design	3	0	0	**03**	**PCC**
4	UMATC30203	Enumerative Combinatorics	3	0	0	**03**	**PCC**
5	UMACC30200	Convex Optimization	2	0	2	**03**	**HSC**
6	UMACC30201	Programming in C++ with OOPs	1	0	2	**02**	**ESC**
7	UMAPC30200	Computing Lab for Linear Algebra & Number Theory	0	0	2	**01**	**PCC**
8	-	A course on Indian Constitution/Essence of Indian Knowledge Tradition (Mandatory Course)	2	0	0	**02**	**OPC**
		TOTAL	**17**	**1**	**6**	**21**	

Semester-IV							
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	UMATC40204	Scientific Computing for Engineers	3	1	0	**04**	**ESC**
2	UMATC40205	Introduction to Artificial Intelligence and Machine Learning	3	0	0	**03**	**PCC**
3	UMATC40206	Real Analysis	3	1	0	**04**	**BSC**
4	UMATC40207	Ordinary Differential Equations	3	1	0	**04**	**PCC**
5	UMATC40208	Modern Algebra	3	1	0	**04**	**BSC**
6	UMAPC40201	Lab on Artificial Intelligence and Machine Learning	0	0	2	**01**	**PCC**
7	UMAPC40202	Lab on Scientific Computing	0	0	2	**01**	**ESC**
		TOTAL	**15**	**4**	**4**	**21**	

Summer Internship – II#

Semester-V							
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	UMATC50300	Transforms and Applications	3	0	0	**03**	**ESC**
2	UMATC50301	Fluid Mechanics	3	0	0	**03**	**BSC**
3	UMATC50302	Partial Differential Equations	3	0	0	**03**	**PCC**
4	UMATC50303	Database Management Systems (DBMS)	3	0	0	**03**	**PCC**
5		Departmental Elective I (Mathematics)	3	0	0	**03**	**DEC**
6		Departmental Elective II (Computing)				**03**	**DEC**
7	UMAPC50300	DBMS Lab	0	0	2	**01**	**PCC**
8	UMACS50300	OOPS with JAVA Lab	2	0	2	**03**	**SD**
		TOTAL				**22**	

Semester-VI							
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	UMATC60304	Operations Research	3	1	0	**04**	**HSC**
2	UMATC60305	Complex Analysis	3	0	0	**03**	**PCC**
3	UMATC60306	Computational Topology and Data Analysis	3	0	0	**03**	**PCC**
4	UMACC60300	Computational Graph Theory	2	0	2	**03**	**PCC**
5		Departmental Elective III (Mathematics)	3	0	0	**03**	**DEC**
6		Departmental Elective IV (Computing)				**03**	**DEC**
7	UMAPC60301	Optimization Lab	0	0	2	**01**	**HSC**
8	UMAPR60300	Mini Project	0	0	2	**01**	**PRC**
		TOTAL				**21**	

Summer Internship – III#

#: The students should do at least one Summer Internship at the end of first/ second/ third year with duration of minimum 30-45 days at Institutes/Organizations/Industries and produce the certificate of completion to the department. The internship credits (2) will be added in the seventh semester.

Semester-VII							
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	UMATC70400	Functional Analysis	3	0	0	**03**	**PCC**
2	UMATC70401	Cryptography	3	0	0	**03**	**ESC**
3	UMATC70402	Advanced Scientific Computing for Engineers	3	0	0	**03**	**PCC**
4		Departmental Elective V (Mathematics)	3	0	0	**03**	**DEC**
5		Departmental Elective VI (Computing)				**03**	**DEC**
6	UMAPC70400	Lab on Advanced Scientific Computing	0	0	2	**01**	**PCC**
7	UMAPR70400	Project Work Part – A	0	0	8	**04**	**PRC**
8	UMAPI70400	Summer Internship#	0	0	4	**02**	**SI**
		TOTAL				**22**	

Semester-VIII							
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1		Departmental Elective VII (Mathematics/Computing) (course related to Project Work)*				**03**	**DEC**
2	UMAPR80401	Project Work Part – B (with option of Industrial Training /Internship)	0	0	20	**10**	**PRC**
3	UMATS80400	Comprehensive Viva Voce	0	2	0	**02**	**SD**
		TOTAL				**15**	

*If the students are in Industrial training, the elective course examination related to project work may be conducted online.

Total Credits for all Eight Semesters: 166

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List of Departmental Electives (V Semester)

S.No	Course Code	Course Title	L	T	P	Credits	Cat. Code
Departmental Elective I (Mathematics)							
1	UMATL50300	Advanced Algebra	3	0	0	**03**	**DEC**
2	UMATL50301	Mathematical Theory of Control	3	0	0	**03**	**DEC**
3	UMATL50302	Mathematical Modeling	3	0	0	**03**	**DEC**
4	UMATL50303	Advanced Differential Equations	3	0	0	**03**	**DEC**
5	UMATL50304	Tensor Analysis & Differential Geometry	3	0	0	**03**	**DEC**
6	UMATL50305	Computational Linear Algebra	3	0	0	**03**	**DEC**
Departmental Elective II (Computing)							
1	UMACL50300	Deep Learning	2	0	2	**03**	**DEC**
2	UMACL50301	Big Data Analytics	2	0	2	**03**	**DEC**
3	UMACL50302	Signal Processing	2	0	2	**03**	**DEC**
4	UMATL50306	Computer Architecture	3	0	0	**03**	**DEC**
5	UMATL50307	Fuzzy Sets and Fuzzy logic	3	0	0	**03**	**DEC**
6	UMATL50308	Financial Mathematics	3	0	0	**03**	**DEC**

List of Departmental Electives (VI Semester)

S.No	Course Code	Course Title	L	T	P	Credits	Cat. Code
Departmental Elective III (Mathematics)							
1	UMATL60309	Measure and Integration	3	0	0	**03**	**DEC**
2	UMATL60310	Coordinate Geometry	3	0	0	**03**	**DEC**
3	UMATL60311	Special Functions	3	0	0	**03**	**DEC**
4	UMATL60312	Mathematics for Biology	3	0	0	**03**	**DEC**
5	UMATL60313	Introduction to Modular Forms	3	0	0	**03**	**DEC**
6	UMATL60314	Continuum Mechanics	3	0	0	**03**	**DEC**
Departmental Elective IV (Computing)							
1	UMATL60315	Design & Analysis of Algorithms	3	0	0	**03**	**DEC**
2	UMACL60303	Internet of Things	2	0	2	**03**	**DEC**
3	UMATL60316	Finite Difference Methods	3	0	0	**03**	**DEC**
4	UMACL60304	Image Processing	2	0	2	**03**	**DEC**
5	UMATL60317	Data Mining	3	0	0	**03**	**DEC**
6	UMACL60305	Web Technologies	2	0	2	**03**	**DEC**

List of Departmental Electives (VII Semester)

S.No	Course Code	Course Title	L	T	P	Credits	Cat. Code
Departmental Elective V (Mathematics)							
1	UMATL70400	Algebraic Topology	3	0	0	**03**	**DEC**
2	UMATL70401	Classical Mechanics	3	0	0	**03**	**DEC**
3	UMATL70402	Advanced Operations Research	3	0	0	**03**	**DEC**
4	UMATL70403	Theory of Partitions	3	0	0	**03**	**DEC**
5	UMATL70404	Lie Group Theory and Applications	3	0	0	**03**	**DEC**
6	UMATL70405	Boundary Layer Theory	3	0	0	**03**	**DEC**
Departmental Elective VI (Computing)							
1	UMATL70406	Finite Element Method	3	0	0	**03**	**DEC**
2	UMACL70400	Computational Fluid Dynamics	2	0	2	**03**	**DEC**
3	UMACL70401	Computer Graphics	2	0	2	**03**	**DEC**
4	UMACL70402	Cloud Computing	2	0	2	**03**	**DEC**
5	UMACL70403	Elements of Data Science	2	0	2	**03**	**DEC**
6	UMACL70404	Computational Statistics	2	0	2	**03**	**DEC**

List of Departmental Electives (VIII Semester)

Departmental Elective VII (Mathematics/ Computing)							
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	UMATL80407	Finite Volume Method	3	0	0	**03**	**DEC**
2	UMATL80408	Ramanujan's Theta Functions and Applications to Number Theory	3	0	0	**03**	**DEC**
3	UMATL80409	Spline Functions and their Applications	3	0	0	**03**	**DEC**
4	UMATL80410	Optimal Control Theory	3	0	0	**03**	**DEC**
5	UMATL80411	Advanced Functional Analysis	3	0	0	**03**	**DEC**
6	UMATL80412	Perturbation Methods	3	0	0	**03**	**DEC**
7	UMATL80413	Wavelets	3	0	0	**03**	**DEC**
8	UMATL80414	Advanced Fluid Mechanics	3	0	0	**03**	**DEC**
9	UMACL80405	Parallel Computing	2	0	2	**03**	**DEC**
10	UMATL80415	Riemannian Geometry	3	0	0	**03**	**DEC**
11	UMACL80406	Multi Objective Programming	2	0	2	**03**	**DEC**
12	UMATL80416	Bio-fluid Mechanics	3	0	0	**03**	**DEC**
13	UMACL80407	Computational Science	2	0	2	**03**	**DEC**
14	UMACL80408	Computational Biology	2	0	2	**03**	**DEC**
15	UMACL80409	Monte Carlo Simulation	2	0	2	**03**	**DEC**
16	UMATL80417	Cyber Security	3	0	0	**03**	**DEC**
17	UMACL80410	Quantum Computing	2	0	2	**03**	**DEC**
18	UMATL80418	Quantum Mechanics	3	0	0	**03**	**DEC**
19	UMATL80419	Block Chain Technologies	3	0	0	**03**	**DEC**

*Minor Degree Specialization: Artificial Intelligence, Machine Learning and Data Science (AI, ML & DS)

Courses for Minor in AI, ML & DS							
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Offered sem**
1	UMATM50300	Advanced Mathematical Tools for Machine Learning	3	0	0	**03**	**5th**
2	UMACM50300	Data Analysis and Visualization with Python	1	0	2	**02**	**5th**
3	UMATM60301	Search Methods in Artificial Intelligence	3	0	0	**03**	**6th**
4	UMACM60301	Machine Learning in Practice	2	0	2	**03**	**6th**
5	UMATM70400	Statistics for Data Science	3	0	2	**04**	**7th**
6	UMATM70401	Multiagent Systems in AI and ML	3	0	0	**03**	**7th**
		TOTAL	**15**	**0**	**6**	**18**	

*The decision to offer the Minor Degree may be deferred for two years during which the department will assess the infrastructural and manpower provisions and other administrative support. After two years, if the situation is not favourable, the department may decide to drop the Minor Degree.

Essentials:

- The Department may suggest suitable alternative related course through MOOCs (NPTEL, SWAYAM etc.) under any category in the entire course structure based on the requirement.
- No minor degree course should be matched with the courses listed in I-VIII semesters including Departmental Electives. In case if a minor course is matching with any of the courses listed in the proposed curriculum then the Department shall suggest an alternative minor course.
- The students should take prior approval from the Department before choosing the MOOCs course.

Semester-I

Course Code: UMATC10100	Title of the Course: Differential Calculus
L-T-P: 3-1-0	Credits: 4
Semester: I	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Calculate the limit and examine the continuity and understand the geometrical interpretation of differentiability.

CLO-2: Understand the consequences of various mean value theorems.

CLO-3: Understand the conceptual variations while advancing from one variable to several variables in calculus.

CLO-4: Learn to trace the Cartesian, polar and parametric curves.

CLO-5: Know the concepts of envelopes and evolutes.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	2	2	2	3	2			1
CLO2	3	3	2	2	2	3	2	1		1
CLO3	3	3	3	3	2	3	2	2		1
CLO4	3	3	1	3	2	3	2	2	1	
CLO5	3	3	1	2	2	2	2		2	2

Each Course Learning Outcome (CLOs) may be mapped with one or more Program Learning Outcomes (PLOs). Write '3' in the box for 'High-level' mapping, 2 for 'Medium-level' mapping, 1 for 'Low-level' mapping.

Course Details:

Unit-I: Elementary set theory, convergence of sequences and series of real numbers, ε-δ definition of limit and continuity of a real valued function; differentiability and its geometrical interpretation, Rolle's theorem, Mean value theorem, Cauchy's mean value theorem and their geometrical interpretations, Maclaurin's and Taylor's theorems for expansion of a function, Taylor's theorem in finite form with Lagrange, Cauchy and Roche– Schlömilch forms of remainder.

Unit-II: Functions of several variables, partial differentiation, total differentiation, Euler's theorem, Taylor's theorem and generalization, maxima and minima of functions of several variables – Lagrange's method of multipliers, change of variables – Jacobians.

Unit-III: Curvature, asymptotes of general algebraic curves, parallel asymptotes, asymptotes parallel to axes, symmetry, concavity and convexity, points of inflection, tangents at origin, multiple points, position and nature of double points, tracing of Cartesian, polar and parametric curves, envelopes and evolutes.

Course References:

1. Howard Anton, I. Bivens & Stephan Davis, Calculus (10th edition), Wiley India, 2016.
2. Gabriel Klambauer, Aspects of Calculus, Springer-Verlag, 1986.
3. Gorakh Prasad, Differential Calculus (19th edition), Pothishala Pvt. Ltd, 2016.
4. Jerrold Marsden, Anthony J. Tromba & Alan Weinstein, Basic Multivariable Calculus, Springer India Pvt. Limited, 2009.
5. James Stewart, Multivariable Calculus (7th edition), Brooks/Cole Pub Co, Cengage, 2012.
6. Walter Rudin, Principles of Mathematical Analysis, McGraw Hill Book Co, 1976.
7. Robert G. Bartle, The Elements of Real Analysis (2nd edition), John Wiley & Sons, 1976.
8. S.C. Malik, Mathematical Analysis, Wiley – Eastern, 1984.
9. R.K. Jain and S.R.K. Iyengar, Advanced Engineering Mathematics, Narosa Publishing House, 2020.
10. Erwin Kreyszig, Advanced Engineering Mathematics (10th Edition), John Wiley and Sons.

Course Code: UMATC10101	**Title of the Course: Integral Calculus**
L-T-P: 2-0-0	**Credits: 2**
Semester: I	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Inter-relationship amongst the line integral, double and triple integral formulations.

CLO-2: Understand the consequences of various mean value theorems.

CLO-3: Applying Green, Gauss and Stokes' theorems in real world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	2	2	2	3	2			1
CLO2	3	3	2	2	2	3	2	1		1
CLO3	3	3	3	3	2	3	2	2		1

Course Details:

Unit-I: Fundamental theorem of integral calculus and mean value theorems, Evaluation of plane areas, volume and surface area of a solid of revolution and lengths. Convergence of Improper integrals – Beta and Gamma functions – properties – differentiation under integral sign. Double and triple integrals – evaluation of surface areas and volumes – change of order of integration- change of variables in double and triple integrals.

Unit-II: Scalar and vector fields, vector differentiation, level surfaces – directional derivative - gradient of scalar field, divergence and curl of a vector field - Laplacian - line and surface integrals, Green's theorem in plane- Gauss divergence theorem- Stokes' theorem and its applications.

Course References:

1. Howard Anton, I. Bivens & Stephan Davis, Calculus (10th edition), Wiley India, 2016.
2. Gabriel Klambauer, Aspects of Calculus, Springer-Verlag, 1986.
3. Gorakh Prasad, Differential Calculus (19th edition), Pothishala Pvt. Ltd, 2016.
4. Jerrold Marsden, Anthony J. Tromba & Alan Weinstein, Basic Multivariable Calculus, Springer India Pvt. Limited, 2009.
5. James Stewart, Multivariable Calculus (7th edition), Brooks/Cole Pub Co, Cengage, 2012.
6. Walter Rudin, Principles of Mathematical Analysis, McGraw Hill Book Co, 1976.

7. Robert G. Bartle, The Elements of Real Analysis (2nd edition), John Wiley & Sons, 1976.
8. S.C. Malik, Mathematical Analysis, Wiley – Eastern, 1984.
9. R.K. Jain and S.R.K. Iyengar, Advanced Engineering Mathematics, Narosa Publishing House, 2020.
10. Erwin Kreyszig, Advanced Engineering Mathematics (10th Edition), John Wiley and Sons.

Course Code: UMATC10102	**Title of the Course: Engineering Physics**
L-T-P: 3-0-0	**Credits: 3**
Semester: I	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Apply classical laws to various dynamic systems.

CLO-2: Applying methodologies of classical mechanics to understand rotational motion of the rigid bodies.

CLO-3: Applying principles of mechanics to understand the elastic and viscous behaviour of the systems.

CLO-4: Know the fundamentals of fluid mechanics.

CLO-5: Understanding the applications of nanomaterials.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	2	2	2	2	3	1		1
CLO2	3	3	2	2	2	2	2		2	1
CLO3	2	3	3	3	3	2	3	2	2	1
CLO4	3	3	2	3	2	3		1		
CLO5	3	3	2	1	2	3	2	3	2	2

Course Details:

Unit-I (Newtonian Mechanics): Newton's laws of motion, inertial and non-inertial systems, Simple applications of Newton's laws: Particles in equilibrium, Dynamics of particles etc., Forces of friction, Motion in one, two, and 3 dimensions: Free falling motion, Projectile motion.

Unit-II (System of Particles and Rotational Motion): Dynamics of a system of particles: Variable mass problems, Center of mass, Rigid body description, Angular velocity and angular momentum, Torque, Calculation of moment of inertia (M.I): M.I of a rectangular lamina, uniform solid sphere.

Unit-III (Elasticity and Plasticity): Stress, Strain, Hook's law, Stress and Strain diagram, Different elastic modulus and their relations, Calculation of elastic constants: Searle's method.

Unit-IV (Introduction to Fluid Mechanics, Nano and Functional Materials): Introductory definitions, Types of Fluids and their properties, Archimedes' principle, Surface tension, Pressure difference: surface film and contact angle, capillarity; Fluid dynamics: Equations of continuity, Bernoulli's equation and its applications, Viscosity, Poiseuille's law, Stoke's law, Reynolds number. History and classification of nanomaterials, Properties and applications of nanomaterials, Fabrication techniques: Physical methods. Functional materials: Introduction, Classification, Properties, Applications.

Course References:

1) An introduction to Mechanics, D Klepner and R. Kolenkow (Cambridge University Press).
2) Mechanics, D. S. Mathur (S.Chand & Co.).
3) R. K. Bansal, Fluid Mechanics and Hydraulic Machines (Lakshmi Publications)
4) University Physics, FW Sears, MW Zemansky & HD Young 13/e, 1986 (Addison-Wesley).
5) Mechanics Berkeley Physics course, vol. 1, Charles Kittel, et. al, 2007 (Tata McGraw-Hill).
6) Physics, Resnick, Halliday & Walker 9/e, 2010 (Wiley).
7) Engineering Mechanics, Basudeb Bhattacharya, 2nd edt. 2015 (Oxford University Press).
8) University Physics, Ronald Lane Reese, 2003 (Thomson Brooks/Cole).
9) Functional Materials Preparation, Processing and Applications, S. Banerjee, A.K. Tyagi, 1st edit (Elsevier).

Course Code: UMACC10100	**Title of the Course: Introduction to Electrical Engineering**
L-T-P: 2-0-2	**Credits: 3**
Semester: I	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Apply basic laws and analyze DC electrical circuits.

CLO-2: Apply basic laws and analyze AC electrical circuits.

CLO-3: Understand electrical machines working principle and their applications.

CLO-4: Understand domestic electrical safety, wiring and different measuring instrument.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	2	2	2	2	2	1		1
CLO2	3	3	2	2	2	2	2		2	1
CLO3	3	3	2	3	3	2	3	2	2	1
CLO4	3	3	2	3	2	3	2	1		

Course Details:

Unit-I: Basics of DC Circuits

D. C. Circuits covering, Ohm's Law and Kirchhoff's Laws; Analysis of series, parallel and series-parallel circuits; Power and energy; Electromagnetism, Faradays Laws, Lenz's Law, Fleming's Rules, Statically and dynamically induced EMF.

Unit-II: Basics of AC Circuits

Single Phase A.C. Circuits covering, Generation of sinusoidal voltage- definition of average value, root mean square value, form factor and peak factor of sinusoidal voltage and current and phasor representation of alternating quantities.

Unit-III: Electrical Machines and Electrical safety

DC Machines: Working principle of DC machine as a generator and a motor.

AC Machines: Transformers, Principle of operation and construction of single phase transformers. Electrical safety, wiring and different measuring instrument

ELECTRICAL ENGINEERING LABORATORY (Practical's)

Sl. No	List of Experiments
1.	Understanding basic electrical components, tools, domestic wiring and meters.
2.	Demonstration of cut-out sections of AC & DC machines.
3.	Verification of KCL and KVL for DC Circuit.
4.	Two way and three-way control of lamp and formation of truth table.
5.	Demonstration of significance of Pipe and Plate Earthing

Course References:

1. Ritu Sahdev (2022), Basic Electrical Engineering, Khanna Book Publishing.
2. Nagrath I.J. and D. P. Kothari (2001), Basic Electrical Engineering, Tata McGraw Hill.

Course Code: UMACC10101	**Title of the Course: Introduction to Computing**
L-T-P: 2-0-4	**Credits: 4**
Semester: I	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Understand the use of input, output functions and structure of C program.

CLO-2: Write the programs using control statements in C.

CLO-3: Write the programs using loop statements in C.

CLO-4: Handle operations like searching, insertion, deletion, and traversing mechanism etc. on various data structures.

CLO-5: Use linear and non-linear data structures like stacks, queues, linked list etc.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1		1		2		3		1		
CLO2	3			2					2	3

CLO3		2	1		2		1	2		
CLO4	1			3			2		1	
CLO5		2				2		2	1	

Course Details:

Unit-I (Introduction to Computing and C++ Programming Fundamentals): Introduction to Computing-Computational Software-Programming Languages, Open source software Vs. Commercial software. Introduction to C++ Programming-Data Types – Variables – Operations – Expressions and Statements – Conditional Statements – Functions – Recursive Functions – Arrays – Single and Multi-Dimensional Arrays.

Unit-II (C++ Programming-Advanced Features): Structures – Union – Enumerated Data Types – Pointers: Pointers to Variables, Arrays and Functions – File Handling – Preprocessor Directives. Practice the programs on the concepts covered in Units I & II.

Unit-III (Linear and Non-Linear Data Structures): Abstract Data Types (ADTs) – List ADT – Array-Based Implementation – Linked List – Doubly- Linked Lists – Circular Linked List – Stack ADT – Implementation of Stack – Applications – Queue ADT – Priority Queues – Queue Implementation – Applications. Trees – Binary Trees – Tree Traversals – Expression Trees – Binary Search Tree – Hashing – Hash Functions – Separate Chaining – Open Addressing – Linear Probing– Quadratic Probing – Double Hashing – Rehashing. Practice the programs on the concepts covered in Units III & IV.

Unit-IV (Sorting and Searching Techniques): Insertion Sort – Quick Sort – Heap Sort – Merge Sort –Linear Search – Binary Search. Practice the programs on sorting and searching techniques.

Course References:

1. Brian W. Kernighan, Rob Pike, “The Practice of Programming”, Pearson Education, 1999.

2. Shah Yi, Mh Thaker, “Programming In C++”, First Edition, USA ISTE, 2002.

3. Stanley B. Lippman, Josée Lajoie and Barbara E. Moo, “C++ Primer”, Fifth Edition,O’Reilly, 2013.

4. Alfred V. Aho, John E. Hopcroft, Jeffrey D. Ullman, “Data Structures and Algorithms”, Pearson Education,1983.

5. E. Balaguruswamy, “C and Data Structures”, 4th Edition, Tata Mc Graw Hill.

6. The C++ Programming Language (4th Edition) By Bjarne Stroustrup.

Course Code: UMAPC10100	Title of the Course: Computer Aided Engineering Graphics
L-T-P: 0-0-2	Credits: 1
Semester: I	Type of the Course: Practical

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Understand the points with all quadrant systems.

CLO-2: Understand the lines drawing in first quadrant systems.

CLO-3: Apply the concepts of planes to draw the projections.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	2	3	2	1	3	2	1		
CLO2	2	2	2	2		2	2			
CLO3	2	2	3	2	2	1	1	2		

Course Details:

Unit-I (Introduction to Computer Aided Sketching): Drawing Instruments and their uses, BIS conventions, Lettering, Dimensioning and free hand practicing. Introduction to Solid Edge standard toolbar/menus. Co-ordinate system, points, axes, poly-lines, square, rectangle, polygons, splines, circles, ellipse, text, move, copy, off-set, mirror, rotate, trim, extend, break, chamfer, fillet, curves, constraints viz. tangency, parallelism, inclination and perpendicularity. Dimensioning conventions.

Unit-II (Orthographic Projections): Projections of points, Projections of straight lines (First Angle Projection), True and apparent lengths and Projections of plane surfaces.

Course References:

1. Bhatt N.D., Panchal V.M. & Ingle P.R. (2014), Engineering Drawing, Charotar Publishing House.
2. A Primer on Computer Aided Engineering Drawing-2006, Published by VTU, Belgaum.
3. Fundamentals of Engineering Drawing with an Introduction to Interactive Computer
4. Graphics for Design and Production- by Luzadder Warren J., Duff John M., Eastern Economy
5. Edition, 2005- Prentice Hall of India Pvt. Ltd., New Delhi.
6. Engineering Graphics by K.R. Gopalakrishna, 32nd edition, 2005- Subash Publishers Bangalore.
7. Shah, M.B. & Rana B.C. (2008), Engineering Drawing and Computer Graphics, Pearson Education
8. Agrawal B. & Agrawal C.M. (2012), Engineering Graphics, TMH Publication
9. Engineering Graphics & Design, A.P. Gautam & Pradeep Jain Khanna Publishing House
10. Narayana, K.L. & P Kannaiah (2008), Text book on Engineering Drawing, Scitech Publishers. (Corresponding set of) CAD Software Theory and User Manuals.
11. https://nptel.ac.in/courses/112/103/112103019/# (online resource)

Course Code: XXXXXXXXXX	***Title of the Course: Multidisciplinary Course**
L-T-P: 3-0-0	**Credits: 3**
Semester: I	**Type of the Course: Theory**

*The students have the flexibility to choose a course related to interdisciplinary (multidisciplinary) from other Departments or through Massive Open Online Courses (MOOC's) NPTEL, SWAYAM etc. based on their choice. Accordingly, the course code may be given. However, the MOOC's course must be approved by the Department.

Course Code: XXXXXXXXXX	***Title of the Course: A course on English Language**
L-T-P: 2-0-0	**Credits: 2**
Semester: I	**Type of the Course: Theory**

*The Department may decide to choose a course related to the English Language from the Department of English or through Massive Open Online Courses (MOOC's) NPTEL, SWAYAM etc. based on the requirement. Accordingly, the course code may be given. The L-T-P mode may be changed as per the Department requirement.

Semester-II

Course Code: UMATC20103	Title of the Course: Theory of Computation
L-T-P: 3-0-0	Credits: 3
Semester: II	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Understand the basic concepts of Automata.

CLO-2: Classify and create the Languages.

CLO-3: Design the Automata to accept the given language.

CLO-4: Design the Turing machine.

CLO-5: Find the equivalences among machines.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	1	2	1	1	1	1	3	1
CLO2	1	2		2	1	1	2	2	3	2
CLO3	1	3	1	3	2	2	1	1	3	3
CLO4	2	2		3	2	1	1	1	3	2
CLO5	1	2	2	2	1	3	1	2	3	1

Course Details:

Unit-I: Preliminaries: Sets, Relations, Equivalence relation, partition, Transitive closures, Kleene' closure, Strings, Alphabets, Languages, Recursive definitions.

Unit-II: Regular Languages and Finite Automata: Regular Expressions, Regular Languages, Finite State Machines, Deterministic finite automata (DFA), Non-deterministic finite automata (NFA), Nondeterministic finite automata with e moves (NFA-epsilon), epsilon - closure, Equivalence of DFA, NFA and NFA- epsilon, Language accepted by Finite Automata, Kleene's Theorem.

Unit-III: Properties of Regular Sets: Properties of the Languages accepted by finite automata, Regular and non-regular languages, Minimal finite automata, Pumping lemma, Myhill - Nerode theorem. Closure properties of Regular languages.

Unit-IV: Context Free Languages and Pushdown Automata: Context free grammars (CFG), context free languages (CFL), closure properties of context free languages, Chomsky normal form, Greibach normal form, Pumping lemma for CFL, parsing, Pushdown automata (PDA), CFG for PDA, PDA for CFG, phrase structured grammars and languages and context sensitive grammars and languages. **Turing Machines:** Turing machine model, example, Modification of Turing machines, Church's hypothesis and Non-deterministic Turing machines.

Course References:

1. Hopcroft J. and Ullman J.D., Introduction to Automata Theory, Languages and Computation, Narosa Publishing, 1989.
2. Martin, J.C., Introduction to Languages and the Theory of Computation, Tata McGraw Hill, 2009.
3. Carrel J. and Long D., Theory of finite automata with an introduction to formal languages, Prentice Hall, 1989.

Course Code: UMATC20104	**Title of the Course: Probability and Statistics**
L-T-P: 3-1-0	**Credits: 4**
Semester: II	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Understand the idea and usage of probability functions for discrete and continuous random variables to formulate a solution tool for probabilistic problems in different scientific domains.

CLO-2: Know Monte Carlo methods in statistics.

CLO-3: Apply the different methods of sampling for discrete and continuous cases to do computations for different science, engineering, and real life problems.

CLO-4: Apply Maximum likelihood estimator for estimating a population parameter.

CLO-5: Find a curve of best fit for a given data, and linear regression and to analyze the data samples.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	2	2	3	1	3	1	-	1
CLO2	3	3	2	1	2	1	3	1	-	1
CLO3	3	3	2	1	3	2	3	1	-	1
CLO4	3	3	2	1	3	2	3	1	-	1
CLO5	3	3	2	1	3	3	3	1	-	3

Course Details:

Prerequisites: Random variable and sample space - notion of probability - axioms of probability - empirical approach to probability - conditional probability - independent events - Bayes' Theorem.

Unit-I: Probability distributions with discrete and continuous random variables - Mathematical expectation - moment generating function - joint probability mass function, marginal distribution function, joint density function. Chebyshev's inequality - weak law of large numbers - Bernoulli trials - the Binomial, Exponential, Poisson, normal distributions and multivariate distributions.

Unit-II: Introduction to Monte Carlo methods, Pseudo random Number Generation, Sampling Discrete Random Variables: Inverse Transform Method, Discrete: Accept-Reject Algorithm, Composition Method, Sampling Continuous Random Variables: Inverse Transform Method. Continuous: Accept-reject Algorithm with examples, Box-Muller method. Continuous: Ratio-of-Uniforms method, examples and code, miscellaneous methods in sampling, Sampling from multivariate distributions.

Unit-III: Introduction to testing of hypothesis tests of significance for large and small samples, chi-square test for goodness of fit, t and F tests, theory of estimation, Simple Importance Sampling: Examples, bias, variance, consistency, optimal proposals.

Weighted importance sampling: Examples, Maximum likelihood function, MLE examples.

Unit-IV: Linear and polynomial fitting by the method of least squares - linear correlation and linear regression, analysis of variance, linear regression as MLE, penalized regression, No-closed form MLEs, Review of Taylor series Approximations.

Course References:

1. S. C. Gupta and V. K. Kapur, "Fundamentals of Mathematical Statistics", (2008), S. Chand & Sons.
2. V. K. Rohatgi and A.K. Md. Ehsanes Saleh, "An Introduction to Probability theory and Mathematical Sciences", (2001), Wiley.
3. Sheldon Ross, "Simulation", Elsevier, Fifth Edition.
4. Christian Robert and George Casella, "Monte Carlo Statistical Methods" (2004), Springer.
5. Sheldon Ross, "A First Course in Probability", sixth edition, Pearson Education.
6. Miller and Freund's, Probability and Statistics for Engineers, 8th edition, 2011.

Course Code: UMACC20102	**Title of the Course: Introduction to Electronics and Communication Engineering**
L-T-P: 2-0-2	**Credits: 3**
Semester: II	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

After completing this course, the students should be able to:

CLO-1: Describe the operation of Diodes and BJT.

CLO-2: Design and explain the construction of rectifiers, regulators, and amplifiers.

CLO-3: Describe the general operating principles of optoelectronic devices and photodetectors.

CLO-4: Explain the different number system and their conversions and construct simple combinational and sequential logic circuits using Flip-flops.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	3	2				1	2	
CLO2	3	2	3		2		1		3	1
CLO3	2	3	1	2		3	2		3	2
CLO4	2	3	2	3	2	1		3		2

Course Details:

Unit-I: Semiconductors: Bonding forces in solids, Energy bands, Metals, Semiconductors and Insulators, Direct and Indirect semiconductors, Electrons and Holes, Intrinsic and Extrinsic materials, Conductivity and Mobility, Drift and Resistance, Effects of temperature and doping on mobility, Hall Effect.

Unit-II: Forward and Reverse biased junctions: Qualitative description of Current flow at a junction, Reverse bias, Reverse bias breakdown- Zener breakdown, avalanche breakdown, Rectifiers. Optoelectronic Devices, Photodiodes: Current and Voltage in an Illuminated Junction, Solar Cells, Photodetectors. Light Emitting Diode.

Unit-III: Digital Electronics Fundamentals: Difference between analog and digital signals, Number system – Binary, Hexadecimal, Conversion – Decimal to binary, Hexagonal to decimal and vice-versa, Boolean Algebra, Basic to Universal gates, Half and full adder, Multiplexer, Decoder, SR and JK flip-flops, Shift register, 3 bit Ripple counter

List of Experiments:

1. Analyze the I-V Characteristics of normal PN Junction.
2. Analyze the I-V Characteristics of the Zener Diode.
3. Study and Analyze the I-V Characteristics of the CE Configuration of BJT.
4. Study and Analyze the I-V Characteristics of the CB Configuration of BJT.
5. Study and Analyze the I-V Characteristics of the CC Configuration of BJT.
6. To construct a Half-wave rectifier circuit and analyze its output.

Course References:

Textbooks:

1. Ben. G. Streetman, Sanjay Kumar Banergee, “Solid State Electronic Devices”, 7th Edition, Pearson Education, 2016, ISBN 978-93-325-5508-2.
2. Thomas L. Floyed, “Electronic Devices” Pearson Education, 9th Edition, 2012.

References:

1. D.P. Kothari, I.J. Nagarath, "Basic Electronics," 2nd Edn. McGraw Hill, 2018.
2. S. M. Sze, Kwok K. Ng, "Physics of Semiconductor Devices," 3rd Edition, Wiley, 2018.

Course Code: UMACC20103	**Title of the Course: Matrix Computations**
L-T-P: 1-0-2	**Credits: 2**
Semester: II	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Understand the basic matrix operations and solutions of matrices using various methods. Learn the basics of Matlab software and its operation.

CLO-2: Solve the matrix and other problems using Matlab.

CLO-3: Apply Matlab programming knowledge to solve real-life problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	3		2					
CLO2	3	2	3	3			2			
CLO3	3	3	3			3		2		

Detailed Syllabus:

Unit-I: Introduction to matrices, the rank of a matrix, invariance of rank under elementary transformations. Reduction to standard forms (Gauss Elimination, Gauss-Jordan and LU Decomposition), solutions of linear homogeneous and non-homogeneous equations.

Unit-II: Complex matrices and types of complex matrices, characteristic polynomial; Eigenvalues, Eigenvectors and their properties, Cayley-Hamilton theorem and its applications, minimal polynomial, Diagonalization of a matrix.

Unit-III: Introduction to Matlab, plotting and visualization, solutions of the matrix and other problems/methods covered in Units- I & II using Matlab Programming. Explanations of some real-life applications of Mathematics using Matlab Programming.

Course References:

1. A.I. Kostrikin, Introduction to Algebra, Springer Verlag, 1984.
2. S. H. Friedberg, A. L. Insel and L. E. Spence, Linear Algebra, Prentice Hall of India Pvt. Ltd., New Delhi, 2004.
3. Richard Bronson, Theory and Problems of Matrix Operations, Tata McGraw Hill, 1989.
4. Frank Ayres, Jr., Theory and Problems of Matrices, Schaum's Outline Series, 1989.
5. Rudra Pratap, Getting Started with Matlab, A quick introduction for Scientists and Engineers, Oxford University Press, 2019.
6. Raj Kumar Bansal, Ashok Kumar Goel, Manoj Kumar Sharma, Matlab and its Applications in Engineering, Pearson Education India, 2009.
7. Amos Gilat, Matlab, An introduction with applications, 4th Edition, Wiley, 2011.
8. Misza Kalechman, Practical Matlab Applications for Engineers, City University of New York, CRC Press, 2009.

Course Code: UMAWC20100	**Title of the Course: Programming Workshop (Data Analytics using R Programming and GPU computing)**
L-T-P: 2-0-2	**Credits: 3**
Semester: II	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Understand the fundamentals of R, loading and retrieval techniques of data. Also, analyse, interpret correlation and regression, the underlying relationships between different variables.

CLO-2: Learn mathematical and statistical computations, programming and simulations.

CLO-3: Apply terminology commonly used in parallel computing, such as efficiency and speedup. Also, describe common GPU architectures and programming models.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10

CLO1	2	3	3	1	3	1	3	3		
CLO2	3	3	3	2	2	2	2			
CLO3	1	3	2	3	3	2	1			

Detailed Syllabus:

Unit-I (Introduction to R, R-Data Types and R-Function): Basic fundamentals, advantages of R over other Programming Languages, R Studio: R command Prompt, R script file, comments, installing a R Package and use of R-software, data editing, use of R as a calculator, functions and assignments, functions and matrix operations, missing data and logical operators, conditional executions and loops, data management with sequences, data management with repeats, sorting, ordering, and lists. Vector indexing, factors, Data management with strings, display and formatting.

Unit-II (Data Frames, Loading and Handling Data in R, Statistics and Data Analysis): Data management with display paste, split, find and replacement, manipulations with alphabets, evaluation of strings, data frames, import of external data in various file formats, statistical functions, compilation of data, graphics and plots, statistical functions for central tendency, variation, skewness and kurtosis, handling of bivariate data through graphics, correlations, programming and illustration with examples.

Unit-III (Introduction to GPU Computing and Memory): History, GPU Architecture, Clock speeds, CPU / GPU comparisons, Heterogeneity, Accelerators, Parallel Programming, CUDA OpenCL / OpenACC, Kernels Launch parameters, Thread hierarchy, Warps/Wavefronts, Threadblocks/Workgroups, Streaming multiprocessors, 1D/2D/3D thread mapping, Device properties, Simple Programs. **Memory:** Memory hierarchy, DRAM / global, local / shared, private / local, textures, Constant Memory, Pointers, Parameter Passing, Arrays and dynamic Memory, Multi-dimensional Arrays, Memory Allocation, Memory copying across devices, Programs with matrices, Performance evaluation with different memories.

Course References:

1. Introduction to Statistics and Data Analysis - With Exercises, Solutions and Applications in R By Christian Heumann, Michael Schomaker and Shalabh, Springer, 2016
2. The R Software-Fundamentals of Programming and Statistical Analysis -Pierre Lafaye de Micheaux, Rémy Drouilhet, Benoit Liquet, Springer 2013

3. A Beginner's Guide to R (Use R) By Alain F. Zuur, Elena N. Ieno, Erik H.W.G. Meesters, Springer 2009
4. Sandip Rakshit, R Programming for Beginners, McGraw Hill Education (India), 2017, ISBN : 978-93-5260-455-5.
5. Seema Acharya, Data Analytics using R, McGrawHill Education (India), 2018, ISBN: 978-93-5260-524-8.
6. Tutorials Point (I) simply easy learning, Online Tutorial Library (2018), R Programming, Retrieved from https://www.tutorialspoint.com/r/r_tutorial.pdf. (Online Resource)
7. Andrie de Vries, Joris Meys, R for Dummies, A Wiley Brand, 2nd Edition, John Wiley and Sons, Inc, 2015, ISBN: 978-1-119-05580-8.
8. David Kirk and Wen-mei Hwu, Programming Massively Parallel Processors: A Hands-On Approach, 2nd Edition, Publisher: Morgan Kaufman, 2012, ISBN: 9780124159921.
9. Shane Cook, CUDA Programming: A Developer's Guide to Parallel Computing with GPUs, Morgan Kaufman; 2012 (ISBN: 978-0124159334)

Course Code: UMACS20100	**Title of the Course: Introduction to Python Programming**
L-T-P: 1-0-2	**Credits: 2**
Semester: II	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Understand the basics of Python programming, including variables, data types, operators, control flow, functions, and modules.

CLO-2: Develop problem-solving skills using Python.

CLO-3: Use Python to analyze data and create visualizations.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	2	2	2	3	3	1		
CLO2	3	3	2	2	2	3	3		2	3
CLO3	3	3	2	1	3	3	3	2		

Course Details:

Unit-I (Introduction to Python, Conditionals & Loops): From processors to programming, high level and low level languages, compiled and interpreted languages, evolution of python, introduction to VSCode, introduction to Google Colab, Python variables, Python basic operators, Python data types, variables, declaring and using numeric data types: int, float etc., basic input-output operations, Boolean values, if, else and else if, Simple for loops in python, for loop using ranges, string, list and dictionaries, use of while loops in python, loop manipulation using pass, continue, break and else. Practice the programs on conditional statements and loops.

Unit-II (Strings, Lists and Functions): Assigning values in strings, string manipulations, string special operators, string formatting operators, triple quotes, raw string, unicode string, build-in-string methods, lists introduction, accessing values in list, list manipulations, list operations, indexing, slicing & matrices, use of tuple data type string, list and dictionary, string manipulation methods, programming using string, list and dictionary in-built functions, built-in functions and methods, functions, writing functions in Python, returning a result from a function, pass by value & pass by reference, function arguments & its types, recursive functions, file reading and writing. Practice the programs on strings, lists and functions.

Unit-III (Python Packages): Simple programs using the built-in functions of packages like Plotting with matplotlib - histograms, graphs, heatmaps, contour plots etc., basic statistical analysis with numpy and pandas, data reduction and filtering.

Course References:

1. Introduction to Python Programming, William Mitchell, Povel Solin, Martin Novak et al., NCLab Public Computing, 2012.
2. Introduction to Python Programming, ©Jacob Fredslund, 2007.
3. An Introduction to Python, John C. Lusth, The University of Alabama, 2011.
4. Introduction to Python, ©Dave Kuhlman, 2008.
5. Python for Data Analysis by Wes McKinney
6. Mastering python for data science, Samir Madhavan
7. A. B. Downey, Think Python, 2e: How to Think Like a Computer Scientist, O′Reilly, 2015.
8. Arockia Mary P, Problem Solving and Python Programming, Shanlax Publications, 2021.
9. Python: The Hard Way by Zed Shaw
10. C. Morris, “https://www.kaggle.com/learn/python,” [Online Resource].
11. “https://docs.python.org/3/tutorial/index.html,” [Online Resource].

Course Code: XXXXXXXXXX	*Title of the Course: Multidisciplinary Course
L-T-P: 3-0-0	Credits: 3
Semester: II	Type of the Course: Theory

*The students have the flexibility to choose a course related to interdisciplinary (multidisciplinary) from other Departments or through Massive Open Online Courses (MOOC's) NPTEL, SWAYAM etc. based on their choice. Accordingly, the course code may be given. However, the MOOC's course must be approved by the Department.

Course Code: XXXXXXXXXX	*Title of the Course: A course on Environmental Sciences (Mandatory Course)
L-T-P: 2-0-0	Credits: 2
Semester: II	Type of the Course: Theory

*The Department may decide to choose a course related to Environmental Sciences offered by the University or through Massive Open Online Courses (MOOC's) NPTEL, SWAYAM etc. based on the requirement. Accordingly, the course code may be given. However, the MOOC's course must be approved by the Department.

Semester-III

Course Code: UMATC30200	Title of the Course: Linear Algebra
L-T-P: 3-1-0	Credits: 4
Semester: III	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Understand the concepts of the terms span, linear independence, basis, and dimension, and apply these concepts to various vector spaces and subspaces.

CLO-2: Apply the concept of vector spaces using linear transforms, which is used in computer graphics and inner product spaces.

CLO-3: Solve problems in different areas of science and engineering.

CLO-4: Identify the importance of orthogonal property in spectral theory.

CLO-5: Apply the knowledge of linear algebra to resolve real-world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	2							
CLO2	3	2	2	2						
CLO3			3	3	1			2		
CLO4			2		2	2				
CLO5							3	2	3	2

Course Details:

Unit-I: Vector spaces, subspaces, linear combination, span, linear dependence and independence, basis, dimension, finite-dimensional vector space.

Unit-II: Linear transformations, basic properties, invertible linear transformation, matrices of linear Transformations, vector space of linear transformations, change of bases, similarity, applications.

Unit-III: Linear functional and adjoints, Hermitian, self-adjoint, unitary and normal operators, Spectral Theorem for normal operators. Inner product spaces, Gram-Schmidt orthonormalization, orthogonal projections.

Unit-IV: Bilinear forms, symmetric and skew-symmetric bilinear forms, quadratic forms, reduction of a quadratic form to a canonical form, classification of quadratic forms, Sylvester's law of inertia and applications.

Course References:

1. K. Hoffman and R. Kunze (2003), Linear Algebra, Prentice Hall of India, New Delhi.
2. M. Artin (1994), Algebra, Prentice Hall of India.
3. S. Kumeresan (2000), Linear Algebra, A Geometric approach, Prentice Hall India.
4. A.R. Vasishtha and A. K. Vasishtha (2004), Matrices, Krishna's educational publishers.
5. I. N. Herstein (1964), Topics in Algebra, Vikas Publishing House, New Delhi.
6. K.B. Datta (2006), Matrix and Linear Algebra, Prentice Hall of India, New Delhi.
7. L. Lipschutz and M. Lipson, Linear Algebra, McGraw Hill Education, India.

Course Code: UMATC30201	Title of the Course: Introduction to Number Theory
L-T-P: 3-0-0	Credits: 3
Semester: III	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Learn methods and techniques used in number theory and communicate effectively in both written and oral form.

CLO-2: Know about open problems in number theory, namely, the Goldbach conjecture and twin prime conjecture.

CLO-3: Demonstrate a basic understanding of number theoretic functions including Euler's Φ function and the Mobius μ-function.

CLO-4: Apply public cryptosystems, in particular, RSA.

CLO-5: Apply the Law of Quadratic Reciprocity and other methods to classify numbers as primitive roots, quadratic residues, and quadratic non-residues.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	3	1	2	1	2	3		
CLO2	3	2	3	2	3	2	2	2		
CLO3	3	2	3	1	3	1	2	1		
CLO4	3	3	2	2	1	1	2	1		
CLO5	3	2	1	2	1	1	2	1		

Course Details:

Unit-I: Division algorithm, Euclid's algorithm, prime numbers, fundamental theorem of arithmetic, distribution of primes, discussion of the Prime Number Theorem, the series of Reciprocals of primes, congruences, Goldbach conjecture, Twin-prime conjecture, Linear Congruence, Chinese remainder theorem, Fermat's little theorem, Wilson's theorem, Euler's theorem.

Unit-II: Elementary arithmetical functions, perfect numbers, Mersenne primes, and Fermat numbers, Irrational Numbers-Irrationality of the mth root of N, e, and π.

Unit-III: Primitive roots and indices, Quadratic residues, Legendre symbol, Gauss's Lemma, Quadratic reciprocity law, Jacobi symbol.

Unit-IV: Fermat's two square theorems, Lagrange's four-square theorem, Diophantine equations: $ax + by = c$, $x^2 + y^2 = z^2$, $x^4 + y^4 = z^4$, sums of two and four squares. Applications: Public key encryption, RSA encryption, and decryption with applications in security systems.

Course References:

1. D.M. Burton (2010), Elementary Number Theory, 7th Edition. McGraw-Hill Education.
2. G.H. Hardy and E.M. Wright (1975), An introduction to the Theory of Numbers, 4th Edition. Oxford University Press.
3. I. Niven, H. S. Zuckerman and H. L. Montgomery (2004), An Introduction to the Theory of Numbers, New York, John Wiley and Sons, Inc., 5thEd.
4. T. M. Apostol (1998), Introduction to Analytic Number Theory, Narosa Publishing House, New Delhi.
5. W.W. Adams and L.J. Goldstein (1972), Introduction to the Theory of Numbers, 3rd ed., Wiley Eastern. Neal Koblitz (1994). A Course in Number Theory and Cryptography (2nd edition). Springer-Verlag.
6. A. Baker (1984), A Concise Introduction to the Theory of Numbers, Cambridge University Press, Cambridge.

Course Code: UMATC30202	**Title of the Course: Compiler Design**
L-T-P: 3-0-0	**Credits: 3**
Semester: III	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Know enough of the theory (Parsing, Code generation, optimization).

CLO-2: Learn the tools (parser generators, code generators).

CLO-3: Understand the parser and its types.

CLO-4: Implement the compiler using syntax-directed translation method.

CLO-5: Build a compiler that converts from a non-trivial high level language to a machine code.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	2							2
CLO2	3	2	2	2						
CLO3	2		3	3	1			2		
CLO4			2		2	2				
CLO5	2						3	2	3	2

Course Details:

Unit I: Introduction, Lexical Analysis, Parsing – Part I

Unit II: Parsing – Part II, Parsing – Part III, Syntax Directed Translation

Unit III: Type Checking and Symbol Tables, Runtime Environment Management – Part I, Runtime Environment Management – Part II

Unit IV: Intermediate Code Generation – Part I, Intermediate Code Generation – Part II, Intermediate Code Generation – Part III

Course References:

1. Santanu Chattopadhyay, “Compiler Design”, PHI Learning Pvt. Ltd., 2015.
2. A.V. Aho, R. Sethi, J.D. Ullman, “Compilers Principles, Techniques and Tools”, Addison-Wesley, 1986.
3. https://onlinecourses.nptel.ac.in/noc21_cs07/preview.

Course Code: UMATC30203	Title of the Course: Enumerative Combinatorics
L-T-P: 3-0-0	Credits: 3
Semester: III	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Apply propositional logic and first-order logic to solve problems. Also, determine if a logical argument is valid or invalid.

CLO-2: Construct induction proofs involving summations, inequalities, and divisibility arguments. Also, implement the principles of counting, permutations, and combinatory to solve real-world problems.

CLO-3: Formulate and solve recurrence relations. Prove whether a given relation is an equivalence relation/poset and will be able to draw a Hasse diagram.

CLO-4: Develop and analyze the concepts of Boolean algebra

CLO-5: Develop and analyze the concepts of graph theory.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	2	2			1				
CLO2	2	3	3	1	2	1				
CLO3	3	3	2	1	3	3	2	1		
CLO4	2	3	3	1	2	3				
CLO5	3	2	3	1	2	2		1		

Course Details:

Unit-I: Combinations of sets, Finite and Infinite sets, uncountable infinite sets, the principle of inclusion and exclusion, mathematical induction. Propositions, fundamentals of logic, first-order logic, ordered sets. Two Basics of counting principles, Pigeonhole principle, Permutations, and combinations, Pascal's Identity, Vandermonde's Identity, Generalized Permutations, and combinations.

Unit-II: Coefficients of generating functions, applications of generating functions, Solving Recurrence Relations- Linear Homogeneous and Non- Homogeneous Recurrence relations, solution by the method of generating functions, sorting algorithm. Relations and functions: properties of binary relations, equivalence relations, and partitions, partial and total ordering relations, Transitive closure, and Warshal's algorithm.

Unit-III: Chains, Lattices, and algebraic systems, the principle of duality, basic properties of algebraic systems, distributive and complemented lattices, Boolean lattices and algebras, uniqueness of finite Boolean algebras, Boolean expressions, and functions.

Unit-IV: Graphs and planar graphs, multigraphs and weighted graphs, Trees and cut sets. Applications of Graph Theory.

Course References:

1. J. R. Mott, A. Kandel and Baker (2006), Discrete Mathematics for Computer Scientists, PHI.

2. C. L. Liu (1985), Elements of Discrete Mathematics, McGraw Hill.

3. J. P. Tremblay and R. Manohar (2004), Discrete Mathematical Structures with applications to Computer Science, McGraw Hill Book Co.

Course Code: UMACC30200	**Title of the Course: Convex Optimization**
L-T-P: 2-0-2	**Credits: 3**
Semester: III	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Know the fundamentals of convex sets and convex functions.

CLO-2: Understand the optimality conditions for unconstrained problems.

CLO-3: Learn the convex optimization over convex sets.

CLO-4: Know the KKT conditions and Duality.

CLO-5: Practice the programs on Convex Optimization.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	2		3		2		3	2
CLO2	3	2	2	2						
CLO3	2	3	3	3	1			2		2
CLO4	2		2		2	2				
CLO5	2	3					3	2	3	2

Course Details:

Unit I: Convex Sets, Convex Functions, Calculus of convex functions, Dual characterizations of convex sets.

Unit II: Optimality conditions for unconstrained problems, Gradient method, Optimality of Convex Programs.

Unit III: Convex Optimization, Optimization over convex sets.

Unit IV: KKT conditions and Duality, Convex Programs and Applications, Linear and Quadratic Programs.

Course References:

1. Amir Beck, Introduction to nonlinear Optimization, SIAM, 2018.
2. Stephen P. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004.

Course Code: UMACC30201	Title of the Course: Programming in C++ with OOPs
L-T-P: 1-0-2	Credits: 2
Semester: III	Type of the Course: Theory cum Practical

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Implement programs using classes and objects. Also, ability to develop applications for physical applications using OOP techniques.

CLO-2: Able to understand the overloading concept. Also, specify the forms of inheritance and use them in programs.

CLO-3: Analyze polymorphic behavior of objects. Also, understand virtual functions and polymorphism.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	3	2	1	3	3	2	2	2
CLO2	2	1	3	3	2	1	2	1	1	-
CLO3	3	1	3	2	1	2	-	-	-	-

Course Details:

Unit-I (Basic concepts of C++, Classes and Objects): Concept of C++; Object oriented languages – Applications of OOP, C++ Program with class-Nesting of member functions-private member functions-Arrays within a class- memory allocation for objects-Static data members-Arrays of objects-objects as Function arguments - Friend functions, inline function, Returning objects. Practice the C++ programs on nesting of member functions, memory allocation for objects, objects as function arguments, friend functions and inline functions.

Unit-II (Constructors, Destructors and Overloading): Multiple constructors in class-Constructors with default arguments copy constructor-Dynamic constructors; Overloading unary operators-overloading binary operators-overloading binary operators using Friends - Rules for overloading operators – function overloading, Type conversions. Practice the C++ programs on constructors with default arguments, copy and dynamic constructors, overloading unary and binary operators, function overloading and type conversions.

Unit-III (Inheritance): Defining derived classes-Single inheritance - Multilevel inheritance – Multiple inheritance - Hierarchical inheritance -Virtual base classes – Abstract classes, Pointers, Virtual functions and Polymorphism. Practice the C++ programs on single, multilevel, multiple and hierarchical inheritance, virtual base and abstract classes.

Course References:

1. Object-Oriented Programming in C++, Robert Lafore, Sams, 2001, Fourth Edition.
2. Object oriented programming with C++, E. Balaguruswamy, Tata McGraw Hill, 2008, Fourth Edition.
3. Object-Oriented programming in C++, Barkakati Nabajyoti, PHI, 1991.
4. The C++ Programming Language, Stroustroup Bjarne, Addison-Wesley,1991.

Course Code: UMAPC30200	Title of the Course: Computing Lab for Linear Algebra and Number Theory
L-T-P: 0-0-2	Credits: 1
Semester: III	Type of the Course: Practical

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Understand the fundamental computing operations in linear algebra and number theory.

CLO-2: Create, select, and apply appropriate techniques, resources, and modeling to complex engineering problems with an understanding of the limitations.

CLO-3: Apply the knowledge of mathematics and computing to solve real world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	3	2	2	2	2	1	2		
CLO2	3	3	1	2	2	2	1	2		
CLO3	2	3	1	2	2	2	1	2		

Course Details:

Unit-I: Practice on solving linear systems, linear combination of vectors, spanning set of a vector space, linearly independent set of vectors, basis for a vector space, investigate properties of the null space of a matrix, finding the basis of null-space of a matrix, properties of row and column spaces and finding the basis of them, inconsistent linear system, orthogonal projections, normal equation, polynomial interpolation using Matlab/Python.

Unit-II Practice on elementary Operations in number theory, Integer, and polynomial arithmetic, Euclidean algorithm, and continued fractions, Modular Arithmetic, Fermat's theorem, Chinese Remainder Theorem, Primality testing, Integer factorization and number theoretic functions using Matlab/Maple/Python.

Course References:

1. Rudra Pratap, Getting Started with Matlab, A quick introduction for Scientists and Engineers, Oxford University Press, 2019.
2. Raj Kumar Bansal, Ashok Kumar Goel, Manoj Kumar Sharma, Matlab and its Applications in Engineering, Pearson Education India, 2009.
3. Amos Gilat, Matlab, An introduction with applications, 4th Edition, Wiley, 2011.
4. Misza Kalechman, Practical Matlab Applications for Engineers, City University of New York, CRC Press, 2009.
5. Fausett L.V. , Applied Numerical Analysis Using MATLAB, 2nd Ed., Pearson Education, 2007.
6. https://in.mathworks.com/help/symbolic/number-theory-1.html (Online Resource)
7. Cleve Moler, Experiments with MATLAB, Electronic edition published by MathWorks, Inc., 2011.
8. Jessica Leung and Dmytro Matsypura, Python Language Companion to Introduction to Applied Linear Algebra: Vectors, Matrices, and Least Squares, 2020.
9. Archana Jadhav, Nandani Sakhare, Linear Algebra Using Python, Himalaya Publishing House Pvt. Ltd., 2018.
10. Jeffrey Hoffstein, Jill Pipher, and Joseph Silverman An Introduction to Mathematical Cryptography, 2nd Edition, Springer, 2014.

Course Code: XXXXXXXXXX	*Title of the Course: A course on Indian Constitution/Essence of Indian Knowledge Tradition (Mandatory Course)
L-T-P: 2-0-0	Credits: 2
Semester: III	Type of the Course: Theory

*The Department may decide to choose a course related to Indian Constitution/Essence of Indian Knowledge Tradition offered by the University or through Massive Open Online Courses (MOOC's) NPTEL, SWAYAM etc. based on the requirement. Accordingly, the course code may be given. However, the MOOC's course must be approved by the Department.

Semester-IV

Course Code: UMATC40204	Title of the Course: Scientific Computing for Engineers
L-T-P: 3-1-0	Credits: 4
Semester: IV	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Obtain numerical solutions of algebraic and transcendental equations.

CLO-2: Find numerical solutions of system of linear equations and check the accuracy of the solutions.

CLO-3: Learn about various interpolating and extrapolating methods to find numerical solutions.

CLO-4: Solve initial and boundary value problems in differential equations using numerical methods.

CLO-5: Apply various numerical methods in real life problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					
CLO2	2	2	1	2	3					
CLO3	2	1	1	2	3					
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3					

Course Details:

Unit-I: Numerical methods for solving algebraic and transcendental equations, round-off error and computer arithmetic, local and global truncation errors, algorithms and convergence, Bisection method, false position method, fixed point iteration method, Newton's method and secant method for solving equations.

Unit-II: Numerical Methods for solving linear systems, partial and scaled partial pivoting, LU decomposition and its applications, Thomas method for tridiagonal systems, Gauss-Jacobi, Gauss-Seidel methods.

Unit-III: Interpolation: Lagrange and Newton's interpolations, finite difference operators, Gregory-Newton forward and backward difference interpolations, Gauss forward and backward interpolations and its errors.

Unit-IV: Numerical differentiation and integration of first order and higher order approximation for first and second derivatives, numerical integration (Newton's Quadrature open and closed type): Trapezoidal rule, Simpson's rule and its error analysis, Boole's, Weddle's rule.

Unit-V: Initial value problems of differential equations, single step method: Euler's method, modified Euler's method, Picard's method and Runge-Kutta methods. Real life examples.

Course References:

1. Brian Bradie (2006), A Friendly Introduction to Numerical Analysis. Pearson.

2. C. F. Gerald and P. O. Wheatley (2008). Applied Numerical Analysis (7th edition), Pearson Education, India.

3. M.K. Jain, S. R. K. Iyengar and R. K. Jain (2012). Numerical Methods for Scientific and Engineering Computation (6th edition). New Age International Publishers.

4. Robert J. Schilling and Sandra L. Harris (1999). Applied Numerical Methods for Engineers Using MATLAB and C. Thomson-Brooks/Cole.

Course Code: UMATC40205	Title of the Course: Introduction to Artificial Intelligence and Machine Learning
L-T-P: 3-0-0	Credits: 3
Semester: IV	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Learn the fundamentals of artificial intelligence and machine learning.

CLO-2: Know different types of AI and ML algorithms.

CLO-3: Understand supervised, unsupervised and reinforcement learning.

CLO-4: Learn computer vision of AI that trains computers to capture and interpret information from image and video data.

CLO-5: Apply AI and ML to real-world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	2	2	3	1	3	1	1	1
CLO2	3	3	2	1	2	1	3	1	1	1
CLO3	3	3	2	1	3	2	3	1	1	1
CLO4	3	3	2	1	3	2	3	1	1	1
CLO5	3	3	2	1	3	3	3	1	1	3

Course Details:

Unit-I: Introduction to Artificial Intelligence (AI), Future of Artificial Intelligence, Characteristics of Intelligent Agents, Typical Intelligent Agents.

Unit-II: Introduction to machine learning (ML), probability for ML and linear regression, classification of machine learning problems, types of AI and ML algorithms, supervised, unsupervised and reinforcement learning etc.

Unit-III: Neural networks, introduction to cost functions, activation functions and optimization strategies. Types of neural networks: CNN, GNN theory and libraries, basics of decision trees.

Unit-IV: Introduction to Scikit, TensorFlow and PyTorch libraries, writing machine learning piplines, natural language processing and computer vision.

Course References:

1. Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach, 2nd edition
2. Andrew Ng, Machine Learning, 2018.
3. Ian Goodfellow, Yoshua Bengio, and Aaron Courville, Deep Learning, 2016.
4. Andriy Burkov, The Hundred-Page Machine Learning Book, 2019.
5. Peter Flach, Machine Learning: The art and Science of Algorithms that make sense of Data, 2012.
6. Bart Kosko, Neural Networks and Fuzzy Systems, 1994.
7. Christopher M. Bishop, Pattern Recognition and Machine Learning, 2016.
8. Ellis Horowitz and Sartaj Shani, Fundamentals of Data Structures, 1982.
9. Kenneth H. Rosen, Discrete Mathematics and its Applications, 2017.
10. Martin C. Brown, Python the Complete Reference, 2018.
11. S. Russell, P. Norvig, Artificial Intelligence: A Modern Approach, 2010.
12. Simon Haykin, Neural Networks, 2005.
13. B. Yagna Narayana, Artificial Neural Networks, PHI, 2012.
14. N. P. Padhy – Artificial Intelligence and Intelligence Systems, OXFORD publication, 2005.

Course Code: UMATC40206	**Title of the Course: Real Analysis**
L-T-P: 3-1-0	**Credits: 4**
Semester: IV	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Describe the real line as a complete, ordered field.

CLO-2: Identify challenging problems in real variable theory and find their appropriate solutions.

CLO-3: Deal with axiomatic structure of metric spaces and generalize the concepts of sequences
and series, and continuous functions in metric spaces.

CLO-4: Test whether a given improper integral can be convergent.

CLO-5: Use theory of multiplications of series and infinite products in solving problems arising in different fields of science and engineering.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	1		2			1				
CLO2		3			2		3			
CLO3				2			3			
CLO4			2				2			
CLO5		3		1		2				

Detailed Syllabus:

Unit-I: Elementary set theory, finite, infinite, bounded, unbounded, countable and uncountable sets, Cantor set. Real number system as a complete ordered field, Archimedean property, Dedekind cuts, supremum, infimum. Continuity, differentiability, functions of bounded variation, absolutely continuous, uniform continuous of a function of a single variable.

Unit-II: Sequences and series, power series, radius of convergence, product of series, re-arrangements, arbitrary series, absolute and conditional convergence.

Unit-III: Riemann integration, classification of Riemann integration, classification of improper integrals, tests for convergence of Beta and Gamma functions, differentiation of integral with variable limits.

Unit-IV: Metric space, limit, continuity, connectedness, compactness.

Course References:

1. Walter Rudin (1976), Principles of Mathematical Analysis, McGraw Hill Book Co.
2 T. M. Apostol (1987), Mathematical Analysis, Narosa Publications.
3. Richard R. Goldberg (1976), Methods of Real Analysis, second edition, John Wiley & Sons.
4. Robert G. Bartle (1976), The Elements of Real Analysis, second edition, John Wiley & Sons.
5. Kenneth A. Ross (2013), Elementary Analysis: The Theory of Calculus, second edition, Springer, New York.
6. Torence Tao (2006), Analysis I, Hindustan Book Agency, India.
7. Torence Tao (2006), Analysis II, Hindustan Book Agency, India.
8. S.C. Malik (1984), Mathematical Analysis, Wiley – Eastern.

Course Code: UMATC40207	Title of the Course: Ordinary Differential Equations
L-T-P: 3-1-0	Credits: 4
Semester: IV	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Understand the origin of ordinary differential equations.

CLO-2: Learn various techniques for getting exact solutions of solvable first-order and linear differential equations of higher order theoretically and computationally.

CLO-3: Apply the Picard's and Power series concepts to resolve the first and higher-order linear differential equations.

CLO-4: Solve arbitrary order differential equations using various methods and computing techniques.

CLO-5: Apply the ordinary differential equations to resolve the day-to-day problems arising in physical, chemical, biological, and other disciplines.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	2							
CLO2	3	3	2	2						
CLO3			3	3				2		
CLO4				3	2	3				
CLO5							2		2	2

Course Details:

Unit-I: Basic concepts and genesis of ordinary differential equations, Equations in which variables are separable, Homogeneous equations, Exact differential equations, Linear differential equations, and equations reducible to linear form, First-order higher degree equations solvable for x, y and p. Clairaut's form and singular solutions. Statement of Picard's theorem for the existence and uniqueness of the solutions of the first-order differential equations. Applications of First order differential equations.

Unit-II: Statement of existence and uniqueness theorem for linear differential equations, General theory of linear differential equations of second order with variable coefficients, Solutions of homogeneous linear ordinary differential equations of second order with constant coefficients, Transformations of the equation by changing the dependent/independent variable, Method of variation of parameters and method of undetermined coefficients, Reduction of order, Coupled linear differential equations with constant coefficients, autonomous system. Applications.

Unit-III: Principle of superposition for a homogeneous linear differential equation, Linearly dependent and linearly independent solutions on an interval, Wronskian and its properties, Concept of a general solution of a linear differential equation, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler-Cauchy equation, Method of variation of parameters and method of undetermined coefficients, Inverse operator method, Sturm-Liouville problems. Applications of higher-order linear differential equations.

Unit-IV: Power series method, Frobenius method, Legendre's equation, Legendre polynomials, Rodrigue's formula, Orthogonality of Legendre polynomials, Bessel's equation, Bessel function of first and second kinds, error functions and their properties, Recurrence relations. Applications.

Course References:

1. George F. Simmons, *Differential Equations with Applications and Historical Notes* (3rd edition), CRC Press, Taylor & Francis, 2017.
2. Shepley L. Ross, *Differential Equations* (3rd edition), Wiley India, 2007.
3. E.A. Coddington, *An Introduction to Ordinary Differential Equations*, PHI Learning, 1999.
4. U. Tyn Myint, *Ordinary Differential Equations*, Elesvier North- Holland, 1978.
5. E.D. Rainville and P.E. Bedient, *Elementary Differential Equations*, McGraw Hill, NewYork, 1969.
6. E.A. Coddington and N. Levinson, *Theory of ordinary differential equations*, McGraw Hill, 1955.
7. A.C. King, J. Billingham and S. R. Otto, *Differential equations*, Cambridge University Press, 2006.
8. S.L. Ross, *Differential equations*, 3rd edition, John Wiley & Sons, New York, 1984.
9. Erwin Kreyszig, *Advanced Engineering Mathematics* (10th edition). Wiley, 2011.
10. Daniel A. Murray, *Introductory Course in Differential Equations*, Orient, 2003.

Course Code: UMATC40208	Title of the Course: Modern Algebra
L-T-P: 3-1-0	Credits: 4
Semester: IV	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Apply the knowledge of Algebra to attain good mathematical maturity and enables to build mathematical thinking and skill.

CLO-2: Understand the concepts of homomorphism and isomorphism between groups.

CLO-3: Apply class equations and Sylow theorems to compute different problems.

CLO-4: Explore the properties of the principle ideal domain, Euclidean domain, Unique factorization domain, polynomial rings, and field extensions.

CLO-5: Design, analyze, and implement the concepts of Gauss Lemma, Einstein's irreducibility criterion, etc.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	2	2	2	1	1	1			
CLO2	2	3	2	1	3	2	2			
CLO3	1	2	3	1	3	3	1			
CLO4	2	1	2	2	3	2	1			
CLO5	1	1	2	2	2	2				

Course Details:

Unit-I: Groups, subgroups, normal subgroups, quotient groups, cyclic groups, permutation groups, cosets and Lagrange's theorem, Group homomorphisms, Automorphisms, Isomorphisms, Fundamental theorems of group homomorphisms, Cayley's Theorem.

Unit-II: Class equations, Sylow theorems, Direct Products, Fundamental Theorem of Finite Abelian groups.

Unit-III: Rings, introduction to fields, ideals, prime and maximal ideals, quotient rings, unique factorization domain, principal ideal domain, Euclidean domain.

Unit-IV: Polynomial rings and irreducibility criteria. Computing the group and ring theory problems in real life.

Course References:

1. G. A. Gallian (2013), Contemporary Abstract Algebra, Narosa Publishers.
2. I. N. Herstein (1975), Topics in Abstract Algebra, Wiley Eastern Limited.
3. D. S. Dummit, R. M. Foote (1999), Abstract Algebra, Second Edition, John Wiley & Sons, Inc.
4. Surjeet Singh and Qazi Zameeruddin (1994), Modern Algebra, Vikas Publishing House.
5. N. Jacobson (2009), Basic Algebra-I, 2nd ed., Dover Publications.
6. Darek F. Holt, Bettina Eick and Eamonaa. Obrien. (2005), Handbook of computational group theory, Chapman & Hall/CRC Press.
7. J. B. Fraleigh (2002), A first course in abstract algebra, 7th ed., Addison-Wesley Longman.

Course Code: UMAPC40201	**Title of the Course: Lab on Artificial Intelligence and Machine Learning**
L-T-P: 0-0-2	**Credits: 1**
Semester: IV	**Type of the Course: Practical**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Learn Python programming in artificial intelligence and machine learning.
CLO-2: Gain hands-on experience with AI and ML algorithms.
CLO-3: Apply AI and ML to real-world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	2	2	3	1	3	1	1	1
CLO2	3	3	2	1	2	1	3	1	1	1
CLO3	3	3	2	1	3	2	3	1	1	1

Course Details:

Unit-I: Introduction to Python Programming in artificial intelligence and machine learning. Working with data analysis using Python to implement and evaluate artificial intelligence and machine learning algorithms.

Unit-II: Practice the programs on linear regression using Python, Neurons, neural networks and multilayer perceptrons in Python, Binary classification problem, Multiclass classification problem, Regression problem, Graph Neural Network problem. Programs on applying artificial intelligence and machine learning algorithms to real-world problems.

Course References:

1. Wes McKinney, Python for Data Analysis, 2nd edition 2018.
2. Al Sweigart, Automate the Boring Stuff with Python, 2015.
3. Zed A. Shaw, Learn Python3: The Hard Way, 2017.
4. Andrew Ng, Machine Learning, 2018.
5. Ian Goodfellow, Yoshua Bengio, and Aaron Courville, Deep Learning, 2016.
6. Andriy Burkov, The Hundred-Page Machine Learning Book, 2019.

Course Code: UMAPC40202	**Title of the Course: Lab on Scientific Computing**
L-T-P: 0-0-2	**Credits: 1**
Semester: IV	**Type of the Course: Practical**

Course Learning Outcomes (CLOs)

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

CLO-1: Understand to learn the programming techniques to get numerical solutions of algebraic and transcendental equations.

CLO-2: Write the programs to get numerical solutions of system of linear equations and integrals.

CLO-3: Implement and execute the numerical codes for the initial value problems in differential equations.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					
CLO2	2	2	1	2	3					
CLO3	2	1	1	2	3					
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3					

Course Details:

Unit-I: Programs on Bisection method, false position method, fixed point iteration method, Newton’s method and secant method, LU decomposition, Thomas method, Gauss-Jacobi, Gauss-Seidel methods using Python/Matlab/Mathematica etc.

Unit-II: Programs on interpolation, numerical integration and numerical solutions of ODE using Python/Matlab/Mathematica etc.

Course References:

1. Brian Bradie (2006), A Friendly Introduction to Numerical Analysis. Pearson.

2. C. F. Gerald & P. O. Wheatley (2008). Applied Numerical Analysis (7th edition), Pearson Education, India.

3. M.K. Jain, S. R. K. Iyengar & R. K. Jain (2012). Numerical Methods for Scientific and Engineering Computation (6th edition). New Age International Publishers.

4. Robert J. Schilling & Sandra L. Harris (1999). Applied Numerical Methods for Engineers Using MATLAB and C. Thomson-Brooks/Cole.

Semester-V

Course Code: UMATC50300	Title of the Course: Transforms and Applications
L-T-P: 3-0-0	Credits: 3
Semester: V	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Gain knowledge of a wide range of mathematical techniques and application of mathematical methods/tools in other scientific and engineering domains.

CLO-2: Know the connections between the mathematical series and other scientific and humoristic disciplines.

CLO-3: Apply principles of mathematical reasoning and their use in understanding, analyzing and developing formal arguments.

CLO-4: Use Fourier series, Laplace transform and Z-transform.

CLO-5: Learn how to expand a function in a Fourier series, and under what conditions such an expansion is valid. They will be aware of the connection between this and integral transforms (Fourier and Laplace) and be able to use the latter to solve mathematical problems relevant to the physical sciences.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	3	3	2	2	1	-	1	2	1
CLO2	2	3	2	1	2	1	-	1	3	1
CLO3	2	3	2	2	1	1	1	1	3	1
CLO4	2	3	2	1	2	1	-	1	3	1
CLO5	2	3	2	1	2	1	-	1	3	1

Course Details:

Unit-I: Introduction to Laplace transform, Laplace of some standard functions, Existence conditions for the Laplace Transform, Shifting theorems, Laplace transform of derivatives and integrals, Inverse Laplace transform and their properties, Convolution theorem, Initial and final value theorem, Laplace transform of periodic functions, error functions, Heaviside unit step function and Dirac delta function, Applications of Laplace transform to solve ODEs, Finite Laplace Transform: Definition and properties, Shifting and scaling theorem.

Unit-II: Introduction to Fourier series, Trigonometric Fourier series and its convergence. Fourier series of even and odd functions, Gibbs phenomenon, Fourier half-range series, Parseval's identity, Complex form of Fourier series.

Unit-III: Introduction to Fourier Transforms, Fourier integrals, Fourier sine and cosine integrals, Complex form of Fourier integral representation, Fourier transform, Fourier transform of derivatives and integrals, Fourier sine and cosine transforms and their properties, Convolution theorem, Application of Fourier transforms to Boundary Value Problems.

Unit-IV: Introduction to Z–transform, inverse Z-transform of elementary functions, Shifting theorems, Convolution theorem, Initial and final value theorem, Application of Z-transforms to solve difference equations, Hankel Transform: Basic properties of Hankel Transform, Hankel Transform of derivatives, Mellin Transform: Definition and properties of Mellin transform, Shifting and scaling properties, Mellin transforms of derivatives and integrals, Applications of Mellin transform.

Course References:

1. Kreyszig, E., "Advanced Engineering Mathematics", John Wiley & Sons, 2011.

2. Jain, R.K. and Iyengar, S.R.K., "Advanced Engineering Mathematics", Narosa Publishing House, 2019, 5^{th} Edition.

3. Hildebrand F. B., "Methods of Applied Mathematics", Courier Dover Publications, 1992.

4. Debanth L. and Bhatta D., Integral Tranforms and Their Applications, 2nd edition, Taylor and Francis Group, 2007.

5. Hwei p. hsu., “Schaum's outlines of theory and problems of signals and systems”.

6. Murray r. Spiegel., “Schaum's outline of theory and problems of Laplace transforms”.

Course Code: UMATC50301	**Title of the Course: Fluid Mechanics**
L-T-P: 3-0-0	**Credits: 3**
Semester: V	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After completing this course successfully, the students will be able to:

CLO-1: Understand the fundamental concepts in fluid mechanics.

CLO-2: Apprehend Euler's and Bernoulli's concepts, and real-world applications of it.

CLO-3: Relate the Milne-Thomson circle theorem and the theorem of Blasius to real-world problems.

CLO-4: Identify the relationship between stress and strain.

CLO-5: Apply the Navier−Stokes equations and energy equation to real-world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3			3	3			3	2	
CLO2	3			2				3	3	
CLO3	2			3				2	3	
CLO4	3			2	3			3	3	
CLO5	2			3	2			3	3	

Course Details:

Unit-I: Introduction to fluid mechanics, Basic properties of the fluid, Classification of fluids, Methods of describing fluid motion, the velocity of a fluid particle, Material, local and convective derivatives, the equation of continuity, acceleration of fluid, conditions at a rigid boundary, Streamlines, path lines, and streak lines.

Unit-II: Euler's equation of motion, Bernoulli's equation, Complex potential, Sources, Sinks, doublets and vortices, Two-dimensional motion of rigid bodies, the Milne-Thomson circle theorem, Blasius theorem and its applications. Theory of irrotational motion, Stoke's theorem, Kelvin's minimum energy, and circulation theorems.

Unit-III: General theory of stress and rate of strain, Newton's law of viscosity, body and surface forces, stress and strain relations. The Navier-Stokes equations and the energy equation.

Unit-IV: Dynamical similarity, Inspection and Dimensional analysis, Laminar flow of viscous incompressible fluids, velocity, and temperature distribution in steady laminar flow with constant fluid properties.

Course References:

1. Frank Chorlton (2004), Fluid Dynamics, CBS Publishers, Delhi.
2. S. W. Yuan (1976), Foundations of Fluid Mechanics, Prentice Hall.
3. C. S. Yih (1969), Fluid Mechanics, McGraw-Hill.
4. G. K. Batchelor (2000), An Introduction to Fluid Dynamics, Cambridge.
5. D. Tritton (1977), Physical Fluid Dynamics, Oxford.
6. L. M. Milne Thomson (1960), Theoretical Hydrodynamics, Macmillan Company, New York.

7. R.W. Fox, P.J. Pritchard and A.T. McDonald (2009), Introduction to Fluid Mechanics, Seventh Edition, John Wiley & Sons.

8. P.K. Kundu, I.M. Cohen, D.R. Dowling (2016), Fluid Mechanics, Sixth Edition, Academic Press.

Course Code: UMATC50302	**Title of the Course: Partial Differential Equations**
L-T-P: 3-0-0	**Credits: 3**
Semester: V	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Analyze the origin of first-order partial differential equations, classification and geometrical interpretation of PDEs.

CLO-2: Classify the second-order differential equations and ability to solve the homogeneous & non-homogeneous linear partial differential equations.

CLO-3: Solve the wave equation by separating variables and integral transforms.

CLO-4: Solution of Laplace equation in Cartesian and polar coordinates in Rectangular and circular regions

CLO-5: Apply the knowledge of PDE to resolve real-world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	3							
CLO2	3	3	2	2						
CLO3			3	2				2		
CLO4				3	2	2				
CLO5							2			2

Course Details:

Unit-I: Introduction to PDE, Basic definitions, Origin of PDEs, Classification of PDEs, Geometrical interpretation, Linear, quasi-linear, nonlinear Equations-Method of characteristics, Lagrange method.

Unit-II: Introduction to second-order PDE, Definitions of Linear and Nonlinear equations, solutions of linear Homogeneous and non-homogeneous with constant coefficients, Variable coefficients, Classification of second-order linear partial differential equations, Canonical forms of equations in two independent variables.

Unit-III: Wave equation: Solution by the method of separation of variables and integral transforms, wave equation in cylindrical and spherical polar coordinates. **Laplace equation:** Solution by separating variables and integral transforms, Solution by Cartesian and polar Coordinates-Rectangular regions, circular regions.

Unit-IV: Diffusion equation: Solution by the method of separation of variables and integral transforms, Maximum Minimum principle for the diffusion equation.

Course References:

1. I. N. Sneddon (2006), Elements of partial differential equations, McGraw-Hill, New York.
2. L Debnath (2007), Nonlinear PDE's for Scientists and Engineers, Birkhauser, Boston.
3. F. John (1971), Partial differential equations, Springer.
4. Jeffery Cooper (1998), Introduction to partial differential equations with matlab, Birkhauser,
5. Clive R Chester (1971), Techniques in partial differential equations, McGraw-Hill.
6. W. E. Williams (1980), Partial differential equations, Clarendon Press, Oxford.
7. Tyn Myint-U and Lokenath Debnath (2007), Linear Partial Differential Equations for Scientists and Engineers, Fourth Edition, Birkhauser.
8. R.P. Agarwal and D. O'Regan (2009), Ordinary and Partial Differential Equations, Springer-Verlag.
9. Ioannis P Stavroulakis and Stepan A Tersian (1999), Partial differential equations- an introduction with mathematica and maple, world - Scientific, Singapore.
10. F. Treves (1975), Basic linear partial differential equations, Academic Press.
11. M.G. Smith(1967), Introduction to the theory of partial differential equations, Van Nostrand.

Course Code: UMATC50303	**Title of the Course: Database Management Systems (DBMS)**
L-T-P: 3-0-0	**Credits: 3**
Semester: V	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Understand the functional components of database management system with the development of E-R model for real world applications.

CLO-2: Construct the queries using Relational Algebra, Relational Calculus and SQL.

CLO-3: Apply the concepts of SQL and its use to construct the databases.

CLO-4: Design the relational databases using various normal forms and integrity constraints.

CLO-5: Interpret the concepts of authorization, transfer of privileges, and query processing.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1		1		2		3		1		
CLO2	3			2					2	3
CLO3		2	1		2		1	2		
CLO4	1			3			2		1	
CLO5		2				2		2	1	

Course Details:

Unit-I: Introduction: Purpose of Data base systems, Data independence, Data models, Database languages, Data storage, Querying and Time management, Database users and administrators.

Unit-II: Entity-Relation Model: Entities, Entities and relationships, Mapping constraints, E-R diagrams; Extended entity-relationship features: Specialization, Generalization and Aggregation; Design of E-R database scheme. Relational Model: Structure of relational database, Relational algebra; Extended relational algebra operations; Modifying the database and views; Tuple relational calculus; Domain relational calculus.

Unit-III: Integrity Constraints: Domain constraints, Referential integrity, Assertions, Triggers, Functional dependencies. Relational Database Design: Pitfalls in relational database design, First, Second, Boyce-Codd, Third, Fourth and Fifth normal forms.

Unit-IV: Security and Integrity: Security and integrity violations, Transfer of privileges, Authorization on views and schema. Query Processing: Overview of query processing, Structure of query optimizer.

Course References:

1. Database System concepts, A. Silberschatz, H.F. Korth, and S. Sudarshan, McGraw Hill, NewYork, 2021, Seventh Edition.

2. Database Management Systems, R. Ramkrishnan, and J. Gehrke, McGraw Hill, 2014, Third Edition.

3. Principles of Database Systems, Jeffery D. Ullman, Galgotia, 1994, Third Edition.

4. Fundamentals of Database System, E. Ramez, N. Shamkant, Pearson, 2017, Seventh Edition.

Online Resources:

1. https://www.youtube.com/watch?v=IoL9Ve2SRwQ&list=PL3pGy4HtqwD3Ov1J2UBTfsLgx UzUktTAM

2. https://www.youtube.com/watch?v=bGyHqvQW6JY&list=PLwZJjHGjgrZqJ9yQZ WJb5gBJcKMr9Ixp

Course Code: UMAPC50300	**Title of the Course: DBMS Lab**
L-T-P: 0-0-2	**Credits: 1**
Semester: V	**Type of the Course: Practical**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Create the queries using DDL and DML commands.

CLO-2: Construct the queries using the relational constraints, joins, set operations, and aggregate functions.

CLO-3: Implement the integrity constraints on various databases.

CLO-4: Create queries using various data types.

CLO-5: Develop the queries using triggers and assertions.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1		1		2		3		1		
CLO2	3			2					2	3
CLO3		2	1		2		1	2		
CLO4	1			3			2		1	
CLO5		2				2		2	1	

Course Details:

Unit-I: Introduction to SQL: DDL, DML, DCL Statements, Built-in Functions and Aggregate Functions, Sub Query, Nested Sub Queries, Modification of the Database.

Unit-II: Intermediate SQL: Join Expressions, Views, Integrity Constraints, SQL Data Types and Schemes, Authorization.

Unit-III: Advanced SQL: Triggers and Assertions. PL/SQL, Data types, Control Structures, Error handling mechanism, Subprograms (procedures and functions), Stored procedures, Data base triggers and exception.

Course References:

1. Database System concepts, A. Silberschatz, H.F. Korth, and S. Sudarshan, McGraw Hill, NewYork, 2021, Seventh Edition.

2. Database Management Systems, R. Ramkrishnan, and J. Gehrke, McGraw Hill, 2014, Third Edition.

3. Principles of Database Systems, Jeffery D. Ullman, Galgotia, 1994, Third Edition.

4. Fundamentals of Database System, E. Ramez, N. Shamkant, Pearson, 2017, Seventh Edition.

Online Resources:

1. https://www.youtube.com/watch?v=IoL9Ve2SRwQ&list=PL3pGy4HtqwD3Ov1J2UBTfsLgx UzUktTAM

2. https://www.youtube.com/watch?v=bGyHqvQW6JY&list=PLwZJjHGjgrZqJ9yQZ WJb5gBJcKMr9iXP

Course Code: UMACS50300	**Title of the Course: OOPS with JAVA Lab**
L-T-P: 2-0-2	**Credits: 3**
Semester: V	**Type of the Course: Theory Cum Practical**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Introduce the fundamental concepts of Java.

CLO-2: Provide a foundation to use basic concepts in Java.

CLO-3: Learn to write Java Scripts.

CLO-4: Explore various Exception Handling mechanisms.

CLO-5: Understand the basic knowledge to use Java with OOP terminology.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1		1		2		3		1		
CLO2	3			2					2	3
CLO3		2	1		2		1	2		
CLO4	1			3			2		1	
CLO5		2				2		2	1	

Course Details:

Unit-I: Java Basics: History of Java, Java buzzwords, comments, data types, variables, constants, scope and life time of variables, operators, operator hierarchy, expressions, type conversion and casting, enumerated types, control flow-block scope, conditional statements, loops, break and continue statements, simple java program, arrays, input and output, formatting output.

Unit-II: Inheritance: Inheritance concept, benefits of inheritance, Super classes and Sub classes, Member access rules, Inheritance hierarchies, super uses, preventing inheritance: final classes and methods, casting, polymorphism- dynamic binding, method overriding, abstract classes and methods, the Object class and its methods. **Interfaces:** Interfaces vs. Abstract classes, defining an interface, implementing interfaces, accessing implementations through interface references, extending interface.

Unit-III: Files: Files – streams- byte streams, character streams, text Input/output, binary input/output, random access file operations, File management using File class, Using java.io. Networking: Networking in Java – Introduction, Manipulating URLs, Ex. Client/Server Interaction with Stream Socket Connections, Connectionless Client/Server Interaction with Datagrams, Using java.net.

Unit-IV: Exception handling: Dealing with errors, benefits of exception handling, the classification of exceptions- exception hierarchy, checked exceptions and unchecked exceptions, usage of try, catch, throw, throws and finally, rethrowing exceptions, exception specification, built in exceptions, creating own exception sub classes, Guide lines for proper use of exceptions.

Course References:

1. Core Java, Volume 1-Fundamentals, Cay S. Horstmann and G. Cornell, Pearson, 2013, Ninth Edition.

2. Java: the complete reference, H. Schildt, McGraw Hill, 2011, Seventh Edition.

3. Java for Programmers, P.J. Deitel and H.M.Deitel, Pearson, 2009, Second Edition.

4. Java Programming, D.S. Malik, Cengage Learning, 2009 and Edition.

5. An introduction to Java programming and object-oriented application development, R.A. Johnson, Cengage Learning, 2007.

Semester-VI

Course Code: UMATC60304	Title of the Course: Operations Research
L-T-P: 3-1-0	Credits: 4
Semester: VI	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: Formulate the LPP and understand the graphical solution. Also, understand optimization models and apply them to real life problems.
CLO-2: Determine the solution of an LPP by simplex methods.
CLO-3: Apply the post optimality analysis and determine the solution of transportation and assignment problems.
CLO-4: Find the characteristics of a queuing model.
CLO-5: Make decision in certainty, uncertainty and under risk.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	3	3	2	2	2	3	3	2
CLO2	2	3	1	3	2	2	3	2	3	2
CLO3	1	3	2	3	2	2	2	3	3	2
CLO4	1	3	1	3	2	2	1	2	3	1
CLO5	2	3	1	3	2	2	1	2	3	2

Course Details:

Unit-I: Linear Programming: Lines and hyperplanes, convex sets, convex hull, Formulation of a Linear Programming Problem, Theorems dealing with vertices of feasible regions and optimality, Graphical solution, Simplex method (including Big M method and two-phase method) – Dual problem, duality theory, dual simplex method, sensitivity analysis, revised simplex method, parametric programming.

Unit-II: Transportation problem, existence of solution, degeneracy, MODI method (including the theory). Assignment problem, travelling salesman problem.

Unit-III: Queuing theory: Characteristics of queueing systems - the birth and death process - steady state solutions – single server model (finite and infinite capacities) - single server model (with SIRO) - models with state dependent arrival and service rates-waiting time distributions.

Unit-IV: Decision Analysis and Games: Decision making under certainty, Decision making under risk, Decision making under risk, Game Theory: optimal solution for two-person zero sum game, Solution for mixed strategy games.

Course References:

1. H. A. Taha (2014), *Operations Research, An Introduction*, PHI, New Delhi.
2. N. S. Kambo (1991), *Mathematical Programming Techniques*, East-West Pub., Delhi.
3. Kanti Swarup, P. K. Gupta and Man Mohan (2010), *Operations Research*, Sultan Chand and Co, New Delhi.
4. J. C. Pant (2012), *Introduction to Operations Research*, Jain Brothers, New Delhi.
5. H. M. Wagner (2010), *Principles of Operations Research*, PHI, Delhi.
6. J. C. Pant (2015), *Introduction to Optimization: Operations Research*, Jain Brothers, Delhi.
7. H. Paul Williams (2013), Model Building in Mathematical Programming, Wiley Publishers.

Course Code: UMATC60305	Title of the Course: Complex Analysis
L-T-P: 3-0-0	Credits: 3
Semester: VI	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Understand how complex numbers provide a satisfying extension of the real numbers.

CLO-2: Know analytic function as a mapping on the plane, Mobius transformation, branch of logarithm and learn the techniques of complex analysis.

CLO-3: Apply Cauchy's theorems and integral formulas on open subsets of the plane.

CLO-4: Count the number of zeros of analytic function giving rise to open mapping theorem. Also, evaluate the improper/definite integrals using residue theorem.

CLO-5: Extend their knowledge of complex variable theory for further exploration of the subject for going into research.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2					
CLO2			1	3	2					
CLO3			1	2	2					
CLO4	2	3		2	2	1	1	1	2	
CLO5	1	3		2	2	1	1	2	1	

Course Details:

Unit-I: Introduction: Extended complex numbers, Riemann sphere, stereographic projection, lines, circles. Limit, continuity, analytic functions, harmonic conjugates, elementary functions, conformal mapping, Mobius transformations.

Unit-II: Series, uniform convergence, power series, radius of convergence, power series representation of analytic function, relation between power series and analytic function. Maximum modulus theorem, index of a closed curve, simple connectedness.

Unit-III: Cauchy's theorem for triangle, rectangle, in a disk, Goursat's theorem and Cauchy's integral formula, Liouville's theorem, fundamental theorem of algebra, counting zeros and open mapping theorem, classification of singularities, poles, Taylor's series, Laurent series.

Unit-IV: Residues, contour integration, evaluation of definite integrals, argument principle, Rouche's theorem, maximum principles, Schwarz's lemma.

Course References:

1. L.V. Ahlfors (2017), Complex Analysis, Mc Graw Hill Co., Indian Edition.
2. J.B. Conway (1996), Functions of One Complex Variable, Second Edition, Narosa Publications, New Delhi.
3. T.W. Gamelin (2001), Complex Analysis, Springer.
4. R.V. Churchill, Brown (1974), Complex Variables and Applications. McGraw Hill.
5. D.C. Ullrich (2008), Complex Made Simple, American Mathematical Society.
6. S. Ponnaswamy (2019), Functions of Complex variable, Narosa Publications.
7. R. Nevanlinna (1970), Analytic functions, Springer.
8. E. Hille (1959), Analytic Theory, Vol. I, Ginn.
9. Narasimhan, Raghavan and Nievergelt, Yves (2001), Complex Analysis in One Variable, 2nd edition, Birkhauser Boston, Inc., MA.

Course Code: UMATC60306	**Title of the Course: Computational Topology and Data Analysis**
L-T-P: 3-0-0	**Credits: 3**
Semester: VI	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Understand and apply fundamental concepts of topology, including definitions, metric spaces, compactness, and connectedness.
CLO-2: Analyze topological persistence, utilizing space and simplicial filtrations, persistence diagrams, and efficient implementation algorithms.
CLO-3: Apply computational geometric topology techniques, such as curve and surface reconstruction, to graphs and 2-dimensional manifolds.
CLO-4: Perform topological analysis of point clouds, using persistence for Rips and Cech filtrations, and infer homology from point cloud data and scalar fields.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1		1		2		3		1		
CLO2	3			2					2	3
CLO3		2	1		2		1	2		
CLO4	1			3			2		1	
CLO5		2				2		2	1	

Course Details:

Unit-I: Fundamentals of Topology: Definition and Examples, Base and Subbase for a Topology, Continuous Functions, Homeomorphisms, Metric Spaces, Metrizability of a Topological Space, Topology on the Cartesian Product of Sets, Compactness, Connectedness. Basic Algebraic Topology and Manifold Theory.

Unit-II: Topological Persistence: Space Filtration, Simplicial Filtrations and Persistence, Persistence Diagram, Matrix Reduction Algorithm, Efficient Implementation, Persistence Modules, Persistence for PL-Functions.

Unit-III: Computational Geometric Topology

Graphs: Connected Components, Curves in the Plane, Knots and Links, Planar Graphs, Curve Reconstruction.

Surfaces: 2-Dimensional Manifolds, Searching a Triangulation, Self-intersections, Surface Reconstruction.

Unit-IV: Topological Analysis of Point Clouds: Persistence for Rips and Cech Filtrations, Approximation via Data Sparsification, Homology Inference from Point Cloud Data, Homology Inference for Scalar Fields.

Course References:

1. J. R. Munkres (2014), Topology, Second Edition, Pearson Education Limited, Harlow, UK.

URL: http://www.alefenu.com/libri/topologymunkres.pdf

2. J. R. Munkres (1984), Elements of Algebraic Topology, Addison-Wesley Publishing Company, California, USA. URL: https://people.dm.unipi.it/benedett/MUNKRES-ETA.pdf

3. A. Hatcher (2001), Algebraic Topology, Cambridge University Press, Cambridge, UK. URL:

https://pi.math.cornell.edu/~hatcher/AT/AT.pdf

4. T. K. Dey (2006), Curve and Surface Reconstruction: Algorithms with Mathematical Analysis, Cambridge University Press, Cambridge, UK. DOI: 10.1017/CBO9780511546860

5. H. Edelsbrunner and J. L. Harer (2009), Computational Topology: An Introduction, American Mathematical Society, USA. URL: https://www.maths.ed.ac.uk/~v1ranick/papers/edelcomp.pdf

6. T. K. Dey and Y. Wang (2022), Computational Topology for Data Analysis, Cambridge University Press, Cambridge, UK. DOI: 10.1017/9781009099950, URL: https://www.cs.purdue.edu/homes/tamaldey/book/CTDAbook/CTDAbook.pdf

Course Code: UMACC60300	**Title of the Course: Computational Graph Theory**
L-T-P: 2-0-2	**Credits: 3**
Semester: VI	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

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

CLO-1: Know vector space of graphs and variety of matrices associated to graphs.

CLO-2: Find factors, matching, independent sets in graphs and to construct chromatic polynomial and find chromatics number.

CLO-3: Identify incidence matrix, circuit matrix and cut set matrix of a graph and relate them all.

CLO-4: Count number of trees on ‘n’ number of vertices using Polya’s enumeration theorem.

CLO-5: Use graph as modelling tools in various problems of networks and operations research and finding shortest path between two nodes.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	2	1	1	2	1	2	2	2
CLO2	3	3	2	1	1	2	1	2	2	3
CLO3	3	3	2	1	1	2	1	2	2	3
CLO4	3	3	3	1	1	2	1	2	2	3
CLO5	3	2	3	1	1	3	1	2	2	3

Recap: All basic concepts of graph theory.

Course Details:

Unit-I: Graphs and Vector Spaces: Vector Space Associated with a Graph, Basis Vectors of a Graph, Circuit and Cut-Set Subspaces, Orthogonal Vectors and Spaces, Intersection and Join of *W* and *Ws,* examples: Cycle and Cocycle Spaces and related problems. Matrix representation of graphs: Incidence Matrix, Submatrices of *A*(*G*), Circuit Matrix, Fundamental Circuit Matrix and Rank of *B,* An Application to a Switching Network, Cut-Set Matrix*,* Path Matrix, Adjacency Matrix, Laplacian Matrix, Distance Matrix.

Unit-II: Coloring, covering, and partitioning: Chromatic Number, Chromatic Partitioning, Chromatic Polynomial, Matching, factorization, Coverings, The Four Color theorem, Perfect Matching, Augmenting Paths, Maximum Matching, Hall's theorem for Bipartite Graphs, the Personnel Assignment problem, Matching algorithm for bipartite graphs, Factorizations, 1-factorization, 2-factorization. Partitions-degree Sequence, Havel's-Hakimi algorithms and graphical degree sequence related problems.

Unit-III: Directed graphs: Types of Digraphs, Digraphs and Binary Relations, Directed Paths and Connectedness, Euler Digraphs, Trees with Directed Edges, Fundamental Circuits in Digraphs, Matrices A, B, and C of Digraphs, Adjacency Matrix of a Digraph, Paired Comparisons and Tournaments, Acyclic digraphs and Decyclization.

Unit-IV: Enumeration of graphs: Types of Enumeration, Counting Labeled trees, Counting Unlabeled Trees, Pólya's Counting Theorem, Graph Enumeration with Pólya's Theorem, Problems. Applications of graphs in switching, coding, electric circuits, operations research, game theory. Drawing some standard graphs using Sage math software, Displaying a 2D or 3D graph with specified vertices, edges, and directions. Using Python "dictionary" formatting to specify vertices and edges. Naming edges using dict () as dictionary to specify vertices and edges. Drawing a digraph .Functions to analyze graphs. Printing vertices and edges. Degree of a vertex. Neighbors of a vertex. Listing all the paths between pairs of vertices. A shortest path from one vertex to another. Adjacency and Incidence Matrices.

Course References:

1. F. Harary: Graph Theory, Addison -Wesley,1969
2. N. Deo: Graph Theory: Prentice Hall of India Pvt. Ltd. New Delhi – 1990.
3. R. B. Bapat, Graphs and Matrices, Hindustan Book Agency, Springer
4. J. A. Bondy and V. S. R. Murthy, Graph Theory with Applications, Macmillan, London, Book Agency

5. D. B. West, Introduction to Graph Theory, Pearson Education Asia, 2nd Edition, 2002.
6. Charatrand and L. Lesnaik-Foster: Graph and Digraphs, CRC Press (Third Edition), 2010.

Course Code: UMAPC60301	Title of the Course: Optimization Lab
L-T-P: 0-0-2	Credits: 1
Semester: VI	Type of the Course: Practical

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Understand the logic involved in the program to solve an LPP by simplex method.

CLO-2: Write the programs to solve an LPP by Big-M, two-phase and revised simplex method.

CLO-3: Expertize in executing the programs to solve transportation and assignment problems.

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Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1		1		2		3		1		
CLO2	3			2					2	3
CLO3		2	1		2		1	2		
CLO4	1			3			2		1	
CLO5		2				2		2	1	

Course Details:

Simple programs dealing with fundamentals of C/C++/Python/Matlab/Mathematica etc. language for

1. Simplex method
2. Big-M method
3. Two phase method
4. Revised simplex method
5. Dual simplex method
6. Solution of a transportation problem by north west corner rule
7. Initial basic feasible solution for a transportation problem by Vogel's approximation method
8. Assignment problem, Queuing Models, etc.

Course References:

1. Hamdy A. Taha, Operations Research, Pearson Education © 2017.
2. Kanti Swarup, Operations Research, S. Chand Publication,2022
3. S.D. Sharma, Operations Research.

Semester-VII

Course Code: UMATC70400	Title of the Course: Functional Analysis
L-T-P: 3-0-0	Credits: 3
Semester: VII	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Understand the concepts of norm, relation between compactness and dimension of a space, etc.

CLO-2: Distinguish between Banach and Hilbert spaces.

CLO-3: Apply uniform boundedness, open mapping and closed graph theorems.

CLO-4: Compute the spectrum of operators and classify the set into subclasses.

CLO-5: Find the expansion of resolvent operator.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					
CLO2	2	2	1	2	3					
CLO3	2	1	1	2	3					
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3					

Course Details:

Unit-I: Normed spaces, Holder's inequality, Minkowski's inequality, Banach spaces, Finite dimensional normed spaces and subspaces, Compactness and finite dimension, Bounded and continuous linear operators, Linear operators and functionals on finite dimensional spaces, Normed spaces of operators, Dual spaces.

Unit-II: Hilbert spaces, projections on a Hilbert space, invariant subspace, Orthogonality of projections. Orthogonal complements and direct sums, Bessel's inequality, total orthonormal sets and sequences, Representation of functionals on Hilbert spaces, Hilbert adjoint operators, Self-adjoint, unitary and normal operators.

Unit-III: Hahn Banach theorems for real and complex normed spaces, Adjoint operator, Reflexive spaces, Uniform boundedness theorem strong and weak convergence,

Convergence of sequences of operators and functionals, Open mapping theorem, Closed graph theorem.

Unit-IV: Spectrum of an operator, Spectral properties of bounded linear operators, Non-emptiness of the spectrum.

Course References:

1. G. Bachman and L. Narici (2000), Functional Analysis, Dover Publications.
2. R. Bhatia (2009), Notes on Functional Analysis, Hindustan Book Agency, India.
3. E. Kreyszig (2006), Introductory Functional Analysis with Applications, John Wiley & Sons, India. 4. M. Schechter (2001), Principles of Functional Analysis, Second Edition, American Mathematical Society.
4. M. Schechter (2001), Principles of Functional Analysis, Second Edition, American Mathematical Society.
5. G. F. Simmons (1998), Introduction to Topology and Modern Analysis, McGraw-Hill.
6. B. V. Limaye (1998), Functional Analysis, Wiley Eastern.
7. S. Kesavan, (2009), Functional Analysis, Trim series, Hindustan Book Agency.
8. I.J. Maddox (1992), Elements of Functional Analysis, Cambridge Univ. Press, New Delhi.
9. J. B. Conway (1985), A Course in Functional Analysis, GTM, Vol. 96, Springer.
10. A. E. Taylor (1958), Introduction to Functional Analysis, Wiley, New York.

Course Code: UMATC70401	**Title of the Course: Cryptography**
L-T-P: 3-0-0	**Credits: 3**
Semester: VII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Analyze number theoretic concepts.

CLO-2: Understand encryption algorithms.

CLO-3: Explore key management issues and solutions.

CLO-4: Apply cryptographic algorithms to build secure protocols.

CLO-5: Evaluate security mechanisms using rigorous approaches by key ciphers and Hash functions.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	1	1	1	3	
CLO2	1	3	1	3	2			1	1	
CLO3	1	3	1	2	2			1	1	
CLO4	2	3		2	2			1	2	
CLO5	1	3		2	2	1	1	2	1	3

Course Details:

Unit-I: Basic number theoretic & Algebraic concepts – Time Estimates of doing arithmetic, Divisibility, Euclidean & Extended Euclidean Algorithm, Congruences, Chinese Remainder Theorem, Euler's & Fermat's theorems, Finite fields, Quadratic Residues and reciprocity.

Unit-II: Classical Cryptography – some simple cryptosystems and their cryptanalysis; Secret Key Cryptosystems – Block ciphers, DES & AES; Hash Functions; Stream ciphers.

Unit-III: Public Key Cryptosystems – RSA Cryptosystem, Primality testing, Factoring algorithms; Rabin Cryptosystem; Di·e-Hellman Key exchange protocol; Discrete-log problem; ElGamal Cryptosystems.

Unit-IV: Elliptic curves – basic facts; elliptic-curve cryptosystem; Digital Signature schemes; Zero knowledge protocols, one-way functions; Advanced protocols for different applications, e.g. echeque, ecash etc.; Copyright protection; Current trends in Cryptography.

Course References:

1. Douglas R. Stinson, Cryptography: Theory and Practice, Chapman & Hall/CRC, 3 Edition, 2006
2. Neal Koblitz, A Course in Number Theory and Cryptography, Springer, 1994
3. Bruce Schneier, Applied Cryptography: Protocols, Algorithms and Source Code In C, John Wiley, 2002.
4. Ranjan Bose, "Information Theory, Coding and Cryptography", Tata McGraw-Hill Publishing, 2002.

Course Code: UMATC70402	Title of the Course: Advanced Scientific Computing for Engineers
L-T-P: 3-0-0	Credits: 3
Semester: VII	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: Obtain numerical solutions of algebraic and transcendental equations.

CLO-2: Find numerical solutions of system of linear equations and to check the accuracy of the solutions.

CLO-3: Learn about various interpolating and extrapolating methods to find numerical solutions.

CLO-4: Solve initial and boundary value problems in differential equations using numerical methods.

CLO-5: Apply various numerical methods in real life problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					
CLO2	2	2	1	2	3					
CLO3	2	1	1	2	3					
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3					

Course Details:

Unit-I: Chebyshev's and Muller's methods, Birge-Vita method, Bairstow method, Grafees's Root squaring method for solving an algebraic and Transcendental equations. Solution of system of nonlinear equations. Successive over-relaxation (SOR) method.

Unit-II: Bounds on eigenvalues (Gerschgorin, Brauers theorem). Jacobi, Givens and House holder's methods for symmetric matrices, Ratishauser method for arbitrary matrices. Power and Inverse Power method for eigenvalues and eigenvectors.

Unit-III: Bessel and Stirling's, Laplace Everett's interpolation, Hermite interpolation. Curve fitting and cubic spline interpolation. Bivariate interpolation. Romberg integration, Gaussian quadrature rule and its error analysis.

Unit-IV: Multi-step methods (Predictors-Corrector methods): Adams-Bashforth-Moulton, Milnes-Simpsons, Nystrom methods for initial value problems, Shooting method for boundary value problems.

Course References:

1. Brian Bradie (2006), A Friendly Introduction to Numerical Analysis. Pearson.
2. C. F. Gerald and P. O. Wheatley (2008). Applied Numerical Analysis (7th edition), Pearson Education, India.
3. M.K. Jain, S. R. K. Iyengar and R. K. Jain (2012). Numerical Methods for Scientific and Engineering Computation (6th edition). New Age International Publishers.
4. Robert J. Schilling and Sandra L. Harris (1999). Applied Numerical Methods for Engineers Using MATLAB and C. Thomson-Brooks/Cole.
5. M.K. Jain, Numerical Solution of Differential Equations, New Age International Publishers.

Course Code: UMAPC70400	**Title of the Course: Lab on Advanced Scientific Computing**
L-T-P: 0-0-2	**Credits: 1**
Semester: VII	**Type of the Course: Practical**

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the logic in the programming to get numerical solutions of system of an algebraic and transcendental equations.
CLO-2: Write the programs on Hermite and spline interpolation, curve fitting.
CLO-3: Implement and execute the numerical codes on initial and boundary value problems in differential equations.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					
CLO2	2	2	1	2	3					
CLO3	2	1	1	2	3					
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3					

Course Details:

Unit-I: Programs on Chebyshev's and Muller's methods, Solution of system of nonlinear equations (NRM), Successive over-relaxation (SOR) method, QR decomposition method. Also on Power and Inverse Power method for eigenvalues and eigenvectors using Python/Matlab/Mathematica etc.

Unit-II: Programs on Bessel and Stirling's, Laplace Everett's interpolation, Hermite interpolation. Curve fitting and cubic spline interpolation. Bivariate interpolation. Romberg integration, Gussain quadrature rule, Adams-Bashforth-Moulton, Milnes-Simpsons, Nystrom, Shooting method using Python/Matlab/Mathematica etc.

Course References:

1. Brian Bradie (2006), A Friendly Introduction to Numerical Analysis. Pearson.
2. C. F. Gerald and P. O. Wheatley (2008). Applied Numerical Analysis (7th edition), Pearson Education, India.
3. M.K. Jain, S. R. K. Iyengar and R. K. Jain (2012). Numerical Methods for Scientific and Engineering Computation (6th edition). New Age International Publishers.
4. Robert J. Schilling and Sandra L. Harris (1999). Applied Numerical Methods for Engineers Using MATLAB and C. Thomson-Brooks/Cole.
5. M.K. Jain, Numerical Solution of Differential Equations, New Age International Publishers.

List of Departmental Electives (V Semester)

Departmental Elective I (Mathematics)

Course Code: UMATL50300	Title of the Course: Advanced Algebra
L-T-P: 3-0-0	Credits: 3
Semester: V	Type of the Course: Theory

Prerequisite course/knowledge: Rings, Some special classes of rings (Integral domain, division ring, field, maximal and prime ideals).

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the concepts of Gauss lemma, Einstein's irreducibility criterion, separable extensions etc.

CLO-2: Create, select and apply appropriate algebraic structures such as Galois extensions, auto morphisms of groups and fixed fields, fundamental theorem.

CLO-3: Comprehend the important concepts and results of rings and ideals and apply standard theorems on homeomorphisms to algebraic problems.

CLO-4: Prove deep theorems on different kinds of ideals.

CLO-5: learn advanced concepts such as Artinian and Noetherian modules.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	1	1	1	3	
CLO2	1	3	1	3	2	1	1	1	1	
CLO3	1	3	1	2	2	1	1	1	1	
CLO4	2	3		2	2	1	1	1	2	
CLO5	1	3		2	2	1	1	2	1	

Course Details:

Unit-I: Extension fields, Finite and Algebraic extensions. Degree of extension, Algebraic elements and algebraic extensions, Adjunction of an element of a field. Roots of a polynomial, Splitting fields, Construction with straight edge and compass more about roots, Simple and separable extensions, Finite fields.

Unit-II: Elements of Galois Theory, Fixed fields, Normal extension, Galois groups over the rationales.

Unit-III: The prime spectrum of a ring, the nil radical and Jacobson, radical, operation on ideals, extension and contraction. Modules - Modules and modules homomorphism's, submodules and quotient modules, Direct sums, Free modules Finitely generated modules, Nakayama Lemma, Simple modules, Exact sequences of modules.

Unit-IV: Modules with chain conditions - Artinian and Noetherian modules, modules of finite length, Artnian rings, Noetherian rings, Hilbert basis theorem.

Course References:

1. M. F. Atiyah and I. G. Macdonald – Introduction to Commutative Algebra, Addison-Wesley. (Part A)

2. I. N. Herstein: Topics in Algebra, 2nd Edition, Vikas Publishing House, 1976. (Part B)

3. C. Musili: Introduction to Rings and Modules, Narosa Publishing House, 1997.

4. Miles Reid – Under-graduate Commutative Algebra, Cambridge University Press, 1996.

5. M. Artin: Algebra, Prentice Hall of India, 1991.

6. N. Jacobson: Basic Algebra-I, HPC, 1984. 7. J. B. Fraleigh: A first courses in Algebra, 3rd edition, Narosa 1996.

Course Code: UMATL50301	**Title of the Course: Mathematical Theory of Control**
L-T-P: 3-0-0	**Credits: 3**
Semester: V	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Understand the stability of linear systems using matrix exponentials, Jordan form, and Lyapunov theory.

CLO-2: Evaluate the controllability of linear time-invariant systems using criteria such as Kalman's rank condition and the PBH controllability test.

CLO-3: Assess the observability of systems through Kalman's rank criterion, duality, and the PBH observability test.

CLO-4: Design stabilizing feedbacks for controllable systems and understand the limitations of eigenvalue placement for stabilization.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1		1		2		3		1		
CLO2	3			2					2	3
CLO3		2	1		2		1	2		
CLO4	1			3			2		1	
CLO5		2				2		2	1	

Course Details:

Unit-I: Linear Systems and Stability: The Matrix Exponential, The Primary Decomposition and Solutions of LTI-systems, Jordan Form and Matrix Exponentials: Two-Dimensional and Generalization to n-Dimensional, Cayley-Hamilton theorem, Linear Time-Varying Systems: Existence and Uniqueness of Solutions, Stability Definition: Motivating Examples, Lyapunov Theory for Linear Systems. Numerous Examples on Each Concept.

Unit-II: Controllability of Linear Time-Invariant Systems: Introduction, Linear Equivalence of Linear Systems, Controllability with Scalar Input, Eigenvalue Placement with Single Input, Controllability with Vector Input: Kalman's Rank Criteria, Eigenvalue Placement with Vector Input, The PBH Controllability Test, Linear Time Varying Systems, Extensive Examples**.**

Unit-III: Observability and Duality: Observability, Kalman's Rank Criteria, Duality, Normal Form, Lyapunov Equations and Hurwitz Matrices, The PBH Observability.

Unit-IV: Stabilizability of LTI Systems: Stabilizing Feedbacks for Controllable Systems, Limitations of Eigenvalue Placement, The PBH Stabilizability Test, Examples.

Course References:

Text Books:

1. S. Barnett and R. G. Cameron. Introduction to Mathematical Control Theory. Clarendon Press, Oxford, Second Edition, 1985.

2. C. T. Chen. Linear Systems: Theory and Design. Oxford University Press, Oxford, Third Edition, 1999.

3. J. Klamka. Controllability of Dynamical Systems. Polish Scientific Publishers, Warsaw, 1991.

4. W. J. Terrell. An Introduction: Stability and Stabilization. Princeton University Press, Princeton, 2009.

Reference Books:

1. R. W. Brockett. Finite Dimensional Linear Systems. John Wiley, New York, 1970.

2. J. J. Distefano III, A. R. Stubberud, and I. J. Williams. Schaum's Outlines: Control Systems, Special Indian Edition. McGraw Hill Education, Chennai, 2010.

3. R. E. Kalman, P. L. Falb, and M. A. Arbib. Topics in Mathematical Control Theory. McGraw-Hill, New York, 1969.

4. E. D. Sontag. Mathematical Control Theory: Deterministic Finite Dimensional Systems, Second Edition. Springer, New York, 1998.

5. J. Zabczyk. Mathematical Control Theory: An Introduction. Birkh¨auser, Boston, 1992.

Course Code: UMATL50302	**Title of the Course: Mathematical Modelling**
L-T-P: 3-0-0	**Credits: 3**
Semester: V	**Type of the Course: Theory**

Prerequisite: Knowledge of Calculus and Linear Algebra

Course Learning Outcomes (CLOs)

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

CLO-1: Understand physical phenomena in order to create a mathematical model.

CLO-2: Learn the statistical data analysis and modeling.

CLO-3: Analyze the difference between various models.

CLO-4: Develop network and population models.

CLO-5: Apply numerical methods to solve ordinary and partial differential equations.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	1				
CLO2	1	3	1	3	2	1				
CLO3	1	3	1	2	2	1				
CLO4	2	3		2	2	1				
CLO5	1	3		2	2	1	1	2		

Course Details:

Unit-I: Introduction to mathematical modeling, Discrete change in financial and biological population systems, Difference equations and discrete dynamical systems, solutions and stability.

Model fitting, Errors, Chebychev's criterion, least squares criterion, linear regression, and data transformation.

Unit-II: Network models, Graphs and networks, network flows, assignment problems, graph coloring, vertex covers, local search algorithms, Discrete probabilistic models, Finite discrete time Markov chains and stationary distribution, component and system reliability.

Unit-III: Population models, Ordinary differential equations, equilibria, phase diagrams and solutions fields, competing species and predator-prey models, Dynamical systems, Euler's method, solving linear dynamical systems.

Unit-IV: Numerical Methods to solve Ordinary Differential Equations and Partial Differential Equations.

Course References:

1. R. Aris, Mathematical Modelling Techniques, Dover, 1994.
2. C. L. Dym and E. S. Ivey, Principles of Mathematical Modelling, Academic Press, 1980.
3. M. S. Klamkin, Mathematical Modelling: Classroom Notes in Applied Mathematics, SIAM, 1986.
4. A. Friedman and W. Littman, Industrial Mathematics for Undergraduates, SIAM, 1994.
5. Y. C. Fung, A First Course in Continuum Mechanics, Prentice Hall, 1969.
6. E. N. Lightfoot, Transport Phenomenon and Living Systems, Wiley, 1974.
7. M. Braun, C. S. Coleman and D. A. Drew, Differential Equation Models, Modules in Applied Mathematics, Volume1, Springer Verlag, 1978.
8. Giordano, Fox, Horton, A First Course in Mathematical Modeling, 5th edition, Cengage, 2013.

9. Functions, Data, and Models, Gordon and Gordon, The Mathematical Association of America, 2010 (ISBN-10: 0-8838-5767-7; ISBN-13 978-0-88385-767-0).

Course Code: UMATL50303	Title of the Course: Advanced Differential Equations
L-T-P: 3-0-0	Credits: 3
Semester: V	Type of the Course: Theory

Prerequisite Course / Knowledge (If any): Differential Equations

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the allied theory of higher order ordinary differential equations.

CLO-2: Recognize the difference between various types of higher order ordinary differential equations.

CLO-3: Gain the knowledge of stability analysis.

CLO-4: Solve the higher order ordinary and partial differential equations.

CLO-5: Apply different methods to solve ordinary and partial differential equations.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		3				2		
CLO2	3	3		3						
CLO3	3	2		2						
CLO4	3	3		3	2	1				
CLO5	3	3		2	2	1		2		

Course Details:

Unit I: Existence and Uniqueness for the Cauchy Problem on Ordinary Differential Equations: Existence and Uniqueness for First-Order ODEs; Existence and Uniqueness for Systems of First-Order ODEs; Existence and Uniqueness for Higher Order ODEs (Picard-Lindelö-Lipschitz-Cauchy's theorem), Cauchy-Peano's Existence Theorem, Caratèodary's Existence Theorem, Global Existence and Uniqueness, Continuous Dependence on Initial Conditions and Parameters, Differential Inclusions.

Unit II: Systems of Linear Ordinary Differential Equations: Notation and Some General Results, Homogeneous Systems of Linear Ordinary Differential Equations, Nonhomogeneous Systems of Linear Ordinary Differential Equations, Higher Order Linear Ordinary Differential Equations, The Harmonic Oscillator, Differentiability in Initial Data, Distribution Solutions of Linear Ordinary Differential Equations.

Unit III: Stability Theory: The Concept of Stability, Stability of Linear Ordinary Differential Equations, Stability of Perturbed Linear Ordinary Differential Equations, The Lyapunov Function Technique, Stability of Control Systems, Stability of Dissipative Systems.

Unit IV: Partial Differential Equations: Overview of Second-Order PDEs: Classification, Energy Estimates, Separation of Variables; Laplace Equations: Fundamental Solutions, Mean-Value Properties, The Maximum Principle, Poisson Equations; Heat Equations: Fourier Transforms, Fundamental Solutions, The Maximum Principle; Wave Equations: One-Dimensional Wave Equations, Higher-Dimensional Wave Equations.

Course References:

1. V. Barbu. Differential Equations. Springer Undergraduate Mathematics Series, Switzerland, 2016.
2. E. A. Coddington and N. Levinson. Theory of Ordinary Differential Equations. Tata McGraw-Hill, New Delhi, 1987.
3. Q. Han. A Basic Course in Partial Differential Equations. American Mathematical Society, Providence, 2011.
4. I. N. Sneddon. Elements of Partial Differential Equations. Dover Publications, New York, 2006.
5. R. P. Agarwal and D. O’Regan. An Introduction to Ordinary Differential Equations. Springer Science + Business Media, New York, 2008.
6. E. A. Coddington and R. Carlson. Linear Ordinary Differential Equations. SIAM, Philadelphia, 1997.
7. S. J. Farlow. Partial Differential Equations for Scientists and Engineers. Dover Publications, New York, 1993.
8. G. F. Simmons. Differential Equations with Applications and Historical Notes, Second Edition. McGraw-Hill, USA, 1991.
9. I. P. Stavroulakis and S. A. Tersian. Partial Differential Equations: An Introduction with Mathematica and Maple, Second Edition. World Scientific, Singapore, 2004.

Course Code: UMATL50304	Title of the Course: Tensor Analysis & Differential Geometry
L-T-P: 3-0-0	Credits: 3
Semester: V	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the difference between vector and tensor.

CLO-2: Learn about tensor quantities and algebra of tensor addition and multiplication, differentiation of tensors fields.

CLO-3: Know the regular curves, arc length, and natural parametrization, Serret-Fernet apparatus.

CLO-4: Understand that Simple surfaces, tangent vectors and tangent spaces, and first and second fundamental forms.

CLO-5: Determine areas and various curvatures of surfaces. Also, understand normal and geodesic curvatures, Weingarten map, principal curvatures, Gaussian and mean curvatures, Equations of Gauss and geodesics.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					
CLO2	2	2	1	2	3					
CLO3	2	1	1	2	3					
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3					

Course Details:

Unit I: Transformation of coordinates, properties of admissible transformation of coordinates, transformation by invariance, transformation by covariance and contravariance. Tensor concept, contravariant and covariant tensors. Algebra of tensors, quotient laws, symmetric and anti-symmetric tensors, relative tensors, metric tensor. Fundamental and associated tensors. Christoffel symbols and transformation.

Unit II: Covariant differentiation of tensors, formulas for covariant differentiation of tensors. Tensor form of differential operators. Ricci Theorem, Riemann-Christoffel tensor and its properties. Ricci Tensor, Bianchi identities, Einstein tensor. Existence theorem. Some applications to analytical mechanics.

Unit III: Vectors in R3; tangent vectors; tangent spaces; tangent vector fields; derivative mappings; translations; affine transformations and rigid motions (isometries); exterior derivatives. Space curves; arc length; tangent vectors and vector fields on a curve; curvature and torsion; Serret-Frenet formulas; osculating plane; osculating circle; osculating sphere; fundamental theorem of local theory of space curves (existence and uniqueness theorems).

Unit IV: Surfaces and their (local) parametrization on coordinate systems; change of parameters; parametrized surfaces; curves on surfaces; tangent and normal vectors; tangent and normal vector fields on a surface; first, second and third fundamental forms of a surface at a point; Gauss mapping. Normal sections and normal curvature of a surface at a point; Meusnier's theorem; elliptic, hyperbolic, parabolic and planar points; Dupin indicatrix; principal directions; principal curvatures of a surface at a point; Mean curvature and Gaussian curvature of a surface at a point. Line of curvature; asymptotic curves; conjugate directions; fundamental equations of the local theory of surfaces; statement of Bonnet's fundamental theorem of local theory of surfaces.

Course References:

1. I. S. Sokolnikoff, Tensor Analysis, Wiley edition, 1951.
2. J.R. Ruz-Tolosa and E. Castill, From vectors to tensors, Springer 2005.
3. Hsiung, C. C., A first Course in Differential Geometry, International Press, University of Michigan, 1997.
4. Eissenhart, P., A Treatise on the Differential Geometry of Curves and Surfaces, Dover Publications, Inc., New York, 1960.
5. Weatherburn, C. R. Differential Geometry of Three Dimensions, The English Language Book Society and Cambridge University Press, 1964.
6. Willmore, T. S., An Introduction to Differential Geometry, Clarendon Press, Oxford, 1979.
7. Klingenberg, V., A Course in Differential Geometry, Graduate Texts in Mathematics 51, Springer-Verlag, 1978.
8. Pressley, A., Elementary Differential Geometry, Springer International Edition, 2005.

Course Code: UMATL50305	Title of the Course: Computational Linear Algebra
L-T-P: 3-0-0	Credits: 3
Semester: V	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: Apply QR- decomposition for solving system of equations.

CLO-2: Know the dual spaces and higher order dual spaces.

CLO-3: Understand the annihilator, apply this concept in different decompositions.

CLO-4: Write a matrix in different canonical forms.

CLO-5: Apply techniques of constrained optimization and singular value decomposition for problems arising in control system analysis, signals and systems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					
CLO2	2	2	1	2	3					
CLO3	2	1	1	2	3					
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3					

Course Details:

Unit I: Systems of linear equations, Block matrices, LU decomposition, QR- decomposition.

Unit II: Linear Functional, Dual bases, dual space, Double dual spaces, Reflexivity, Annihilators. Direct sum decomposition, invariant direct sums, the primary decomposition theorem, bilinear and quadratic forms, Canonical forms, Jordan canonical forms, rational canonical forms.

Unit III: Projections, Algebra of Projections, Projections and Invariance. Orthogonal projections and the spectral theorem, Generalized g-inverse of a matrix, The Singular value decomposition, Linear models and least-squares problems.

Course References:

1. Gel'fand I.M. Lectures on linear algebra, Courier Corporation, 1989.

2. Kenneth Hoffman & Ray Kunze, Linear Algebra, 2nd edition, Prentice-Hall, 2015.
3. David C. Lay, "Linear Algebra and its Applications", Cambridge University Press, 3rd Edition, 2017.
4. Seymour Lipshutz and Marc Lipson, Schaum's outlines "Linear Algebra" 3rd Edition, Mc Graw Hill Education, 2012.
5. Gilbert Strang, "Introduction to Linear Algebra", Wellesley-Cambridge Press 5th Edition, 2016.
6. Kenneth Hoffman and Ray Kunze, "Linear Algebra", Pearson Education (Asia) Pte. Ltd, 2004. 2nd Edition, 2004.

Departmental Elective II (Computing)

Course Code: UMACL50300	**Title of the Course: Deep Learning**
L-T-P: 2-0-2	**Credits: 3**
Semester: V	**Type of the Course: Theory Cum Practical**

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the fundamentals of deep learning and the main research activities in this field.

CLO-2: Demonstrate the basics of deep learning for a given context.

CLO-3: Remember architectures and optimization methods for deep neural network training.

CLO-4: Implement, apply and test various deep learning models for the given problem.

CLO-5: Evaluate the given deep learning application and enhance by applying latest techniques.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	1	1			
CLO2	1	3	1		2	1				
CLO3	1	3	1		2					
CLO4	2	3			2					
CLO5	1	3		2	2	1	1			

Course Details:

Unit-I: Introduction to Neural Networks and Deep learning: History of Deep Learning, Basics of Artificial Neurons, introduction to cost functions, activation functions and optimization strategies, Network architectures, Multilayer Perceptrons (MLPs), Feed Forward Neural Networks and Back propagation.

Unit-II: Auto-encoders and Regularization: Auto encoders, Regularization in auto encoders, Denoising auto encoders, Sparse auto encoders, Regularization: Bias Variance Tradeoff, L2 regularization, Early stopping, Dataset augmentation, Encoder Decoder Models, Batch Normalization.

Unit-III: Deep Learning Models: Introduction to CNNs, Architecture, Convolution/pooling layers, CNN Applications, Transfer learning and pre-trained models. Introduction to RNNs, Back propagation through time (BPTT), Vanishing and Exploding Gradients, RNN Applications, Long Short-Term Memory (LSTM) and Gated Recurrent Units (GRU)

Unit-IV: Deep Learning Applications: Image Processing, Natural Language Processing, Speech recognition, Video Analytics.

Laboratory/Practical's:

Introduction to Tensor flow and Keras libraries, Practice the programs on Perceptron learning, Multilayer Neural networks, Hyper parameter tuning, CNN implementation, transfer learning of pre trained models, RNN implementation, Text generation using LSTM, Denoising using Autoencoders.

Course References:

1. Ian Goodfellow, Yoshua Bengio, Aaron Courville. Deep Learning, the MIT press, 2016.
2. Bengio, Yoshua. " Learning deep architectures for AI." Foundations and trends in Machine Learning 2.1, Now Publishers, 2009.
3. Deep Learning, Rajiv Chopra, Khanna Book Publishing, Delhi 2020.
4. Deng & Yu, Deep Learning: Methods and Applications, Now Publishers,2013.
5. https://nptel.ac.in/courses/106/106/106106184/

Course Code: UMACL50301	Title of the Course: Big Data Analytics
L-T-P: 2-0-2	Credits: 3
Semester: V	Type of the Course: Theory Cum Practical

Course Learning Outcomes (CLOs)

After completing this course successfully, the students will be able to:

CLO-1: Understand fundamentals of Big Data analytics.

CLO-2: Investigate Hadoop framework and Hadoop Distributed File system.

CLO-3: Demonstrate the MapReduce programming model to process the big data along with Hadoop tools.

CLO-4: Explain NoSQL big data management.

CLO-5: Use Machine Learning algorithms for real world big data.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	1				
CLO2	1	2	1	3	2					
CLO3	1	2	1	2	2					
CLO4	2	3		2	2	1				
CLO5	1	3		3	3	1				

Course Details:

Unit-I: Introduction to Big Data Analytics: Understanding Big data: What is big data – why big data – convergence of key trends – unstructured data – industry examples of big data, Scalability and Parallel Processing, Designing Data Architecture, Data Sources, Quality, Pre-Processing and Storing, Data Storage and Analysis, Big Data Analytics Applications and case studies.

Unit-II: Introduction to Hadoop: Introduction to Hadoop: Introduction, Hadoop and its Ecosystem, Hadoop Distributed File System, MapReduce Framework and Programming Model, Hadoop Yarn, Hadoop Ecosystem Tools. Hadoop Distributed File System Basics: HDFS Design Features, Components, HDFS User Commands. Essential Hadoop Tools: Using Apache Pig, Hive, Sqoop, Flume, Oozie, HBase.

Unit-III: Introduction to NoSQL Big Data Management, MapReduce, Hive and Pig: NoSQL Big Data Management: Introduction, NoSQL Data Store, NoSQL Data Architecture Patterns, NoSQL to Manage Big Data, MongoDB. MapReduce, Hive and Pig: Introduction, MapReduce Map Tasks, Reduce Tasks and MapReduce Execution, Composing MapReduce for Calculations and Algorithms, Hive, HiveQL, Pig.

Unit-IV: Machine Learning Algorithms for Big Data Analytics: Introduction, Estimating the relationships, Outliers, Variances, Probability Distributions, and Correlations, Regression analysis, Finding Similar Items, Similarity of Sets and Collaborative Filtering, Frequent Item sets and Association Rule Mining. Big data graph analytics.

Laboratory/Practical's:

1. Describe big data and use cases from selected business domains.
2. Explain NoSQL big data management.
3. Install, configure, and run Hadoop and HDFS.
4. Perform map-reduce analytics using Hadoop.

Course References:

1. Anand Rajaraman and Jeffrey David Ullman, Mining of Massive Datasets, Cambridge University Press, 2011.
2. Raj Kamal and Preeti Saxena, "Big Data Analytics Introduction to Hadoop, Spark, and Machine-Learning", McGraw Hill Education, 2018 ISBN: 9789353164966, 9353164966
3. Ron Bekkerman, Mikhail Bilenko and John Langford, Scaling up Machine Learning: Parallel and Distributed Approaches, Cambridge University Press, 2011.
4. Tom White, Hadoop: The Definitive Guide, O"Reilly Media, Third Edition, 2012.
5. Bill Franks, Taming The Big Data Tidal Wave: Finding Opportunities in Huge Data Streams Analytics, Wiley, 2012.
6. Douglas Eadline, " Hadoop 2 Quick-Start Guide: Learn the Essentials of Big Data Computing in the Apache Hadoop 2 Ecosystem", 1 stEdition, Pearson Education, 2016. ISBN13: 978-9332570351
7. Eric Sammer, "Hadoop Operations: A Guide for Developers and Administrators",1 st Edition, O'Reilly Media, 2012.ISBN-13: 978-9350239261
8. Arshdeep Bahga, Vijay Madisetti, " Big Data Analytics: A Hands-On Approach", 1st Edition, VPT Publications, 2018. ISBN-13: 978-0996025577

Course Code: UMACL50302	Title of the Course: Signal Processing
L-T-P: 3-0-0	Credits: 3
Semester: V	Type of the Course: Theory

Pre-requisites: Signals and Systems

Course Learning Outcomes (CLOs)

After completing this course successfully, the students will be able to:

CLO-1: Analyze the discrete time signals in the frequency domain

CLO-2: Design FIR and IIR digital filters.

CLO-3: Identify various filter structures and evaluate the finite word length and the coefficient quantization effects

CLO-4: Understand the concepts of sample rate conversion techniques and its applications

CLO-5: Comprehend the architectural features of digital signal processors.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	1	1			
CLO2	1	3		3	2	1				
CLO3	1	3		2	2	1				
CLO4	2	3		2	2	1		1		
CLO5	1	3		3	2	1		2		

Course Details:

Review of signals and Systems:

Discrete Fourier Transform (DFT): The DFT & its properties; Inverse DFT, Linear filtering methods based on DFT - Use of DFT in linear filtering, filtering of long data sequences, Efficient computation of DFT algorithms-Radix2 (DIT & DIF), Radix4, Split radix algorithms. Linear filtering approach to computation of DFT-Goertzel algorithm, Chirp z transform, Quantization effects in the computation of DFT - Direct & FFT method.

Digital Filters: Linear phase FIR filter, characteristic response, location of zeros, Design of FIR filter-Windowing, Frequency sampling, Design of IIR filters from Analog filters-Impulse in variance, Bilinear transformation, Matched z-transform. Quantization of filter coefficients - Sensitivity to Quantization of filter coefficients, Quantization of coefficients in FIR filters, Roundoff effects in digital filters - Limit cycle, scaling to prevent overflow.

Digital Filter Structures: FIR filters - Direct form, Cascade form, Frequency sampling, Lattice IIR filter - Direct form I, Direct form II cascade form parallel form Lattice & Lattice loader,

Multirate Digital Signal Processing: Decimation by a factor D, Interpolation by a factor I, Sampling rate conversion by a rational factor I/D, cascade equivalence, Filter design & Implementation for sampling rate conversion, Applications: Phase Shifters, Digital Filter Banks, Sub band Coding of Speech Signals, Quadrature Mirror Filters, Trans multiplexers, Over Sampling A/D and D/A Conversion.

DSP Processors: TMS C6xxx, Features, Architecture and Applications. Harvard Architecture, pipelining, Multiplier-Accumulator (MAC) Hardware. Architectures of Fixed and Floating point DSP processors. Addressing modes, functional modes. Memory architecture, on-chip peripherals of a DSP processor.

Course References:

1. J. G. PROAKIS & D. G. MANOLAKIS, Digital Signal Processing - Principles, algorithms & Applications, PHI, 2000.
2. B. Venkataramani, M. Bhaskar, "Digital Signal Processors, Architecture, Programming and Application", Tata McGraw Hill, New Delhi, 2003
3. A.V. Oppenheim and Ronald W. Schafer, Discrete Time Signal Processing, 2nd Edition, PHI, 2000.
4. S.K.MITRA, Digital Signal Processing – A computer Based Approach, 4th Edition, MGH, 2010.
5. Multi Rate Systems and Filter Banks – P. P. Vaidyanathan – Pearson Education.
6. Fundamentals of Digital Signal Processing using Matlab – Robert J. Schilling, Sandra L. Harris, Thomson, 2nd Edition, 2010.

Course Code: UMATL50306	**Title of the Course: Computer Architecture**
L-T-P: 3-0-0	**Credits: 3**
Semester: V	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Explain the organization and architecture of computer systems with machine instructions and programs

CLO-2: Analyze the input/output devices communicating with computer system

CLO-3: Demonstrate the functions of different types of memory devices

CLO-4: Apply different data types on simple arithmetic and logical unit

CLO-5: Analyze the functions of basic processing unit, Parallel processing and pipelining

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2			1	3	
CLO2	1	3	1	3	2			1	1	
CLO3	1	3	1	2	2	1		1	1	
CLO4	2	3		2	2	1		1	2	
CLO5	1	3		2	2	1		2	1	

Course Details:

Unit-I: Basic Structure of Computers: Basic Operational Concepts, Bus Structures, Performance – Processor Clock, Basic Performance Equation, Clock Rate, Performance Measurement.

Machine Instructions and Programs: Memory Location and Addresses, Memory Operations,

Instructions and Instruction Sequencing, Addressing Modes

Unit-II: Input/Output Organization: Accessing I/O Devices, Interrupts – Interrupt Hardware, Direct Memory Access, Buses, Interface Circuits

Unit-III: Register transfer and macro-operations, Register Transfer Languages (RTL). Arithmetic, Logic and Shift Macro-operations, Sequencing, Micro-program sequences.

Memory & Storage: Processor Vs. Memory speed: Cache memory. Associative memory, Virtual memory and Memory management

Unit-IV: Pipeline and Vector Processing: Parallel Processing, Pipelining, Arithmetic Pipeline, Instruction Pipeline, Vector Processing, Array Processors

Text Books:

1. Carl Hamacher, Zvonko Vranesic, Safwat Zaky, Computer Organization, 5th Edition, Tata McGraw Hill
2. M. Morris Mano, Computer System Architecture, PHI, 3rd Edition

References:

1. William Stallings: Computer Organization & Architecture, 9th Edition, Pearson
2. Hayes J. P., Computer Architecture & Organisation, McGraw Hill

Course Code: UMATL50307	Title of the Course: Fuzzy Sets and Fuzzy Logic
L-T-P: 3-0-0	Credits: 3
Semester: V	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: Understand basic knowledge of the Fuzzy sets, operations and their properties.

CLO-2: Know the fundamental concepts of Fuzzy functions and Fuzzy logic.

CLO-3: Determine the maximum and minimum of fuzzy functions.

CLO-4: Learn the concepts of classical logic, multi-valued logics, Fuzzy quantifiers, linguistic hedges.

CLO-5: Apply the concepts of Fuzzy sets in image processing, Pattern reorganization and decision making.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	3	3	2	2	1	3	1	3
CLO2	3	3	1	3	2	2	1	2	1	3
CLO3	3	3	2	3	2	2	2	3	1	3
CLO4	3	3	1	3	2	2	1	2	1	3
CLO5	2	3	1	3	2	2	3	2	3	2

Course Details:

Unit I: Basic concepts of fuzzy set, t-norm, t-conorms, membership function, α-cut, Algebra of fuzzy sets, distance between fuzzy sets, fuzzy relation. Fuzzy numbers, Arithmetic operations of fuzzy numbers, Extension principle, Interval arithmetic, De-fuzzification.

Unit II: Fuzzy valued functions, fuzzy equations, fuzzy inequalities, system of fuzzy. Linear equations, maximum and minimum of fuzzy functions.

Unit III: Classical Logic – Multi-valued Logics – Fuzzy Propositions – Fuzzy Quantifiers – Linguistic hedges – Inference from conditional Fuzzy proposition.

Unit IV: Fuzzy sets in Decision making, Optimization in Fuzzy environment, Fuzzy set application in image processing, Fuzzy set application in Pattern reorganization.

Course References:

1. George J. Klir and Bu Yuan, Fuzzy sets and Fuzzy logic Theory and applications, Prentice Hall of India, New Delhi.
2. Didier Bubois and Henri Prade, Fuzzy sets and systems, Academic Press.
3. James J Buckley, Esfandiar Eslami, An Introduction to Fuzzy logic and Fuzzy sets, Springer.
4. J. C. Pant (2012), Introduction to Operations Research, Jain Brothers, New Delhi.
5. H. J. Zimmernman, Fuzzy set theory and application (Allied Publication in Association with KLUWER).

Course Code: UMATL50308	**Title of the Course: Financial Mathematics**
L-T-P: 3-0-0	**Credits: 3**
Semester: V	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the basic concepts in discrete time models.

CLO-2: Demonstrate the concepts relating to continuous time models.

CLO-3: Employ methods related to the concepts in a variety of financial applications.

CLO-4: Use appropriate techniques to aid problem solving.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	2		2		3		2		
CLO2	2	2		2		2		2		
CLO3	2	2		2		2		2		
CLO4	2	1		2		2		1		
CLO5	3			3		2		3		

Course Details:

Unit I: Basic concepts of hedging and pricing by arbitrage in discrete time models, Setting of binomial tree models. Concepts of conditional expectation, martingale, change of measure, and representation.

Unit II: Mathematical models for the development and analysis of continuous time models. Brownian motion, stochastic calculus, change of measure, martingale representation theorem.
Unit III: Black-Scholes option pricing formula. Models for the interest rate in the national and international markets. Mathematical models of bond and stock prices, other derivative securities; Markowitz portfolio optimization theory and the Capital Asset Pricing Model; and interest rates and their term structures. Case studies

Course References:

1. RJ Williams, Introduction to Mathematics of Finance, AMS, 2006.

2. Marek Capiński, Tomasz Zastawniak, Mathematics for Finance: An Introduction to Financial Engineering, Springer, 2003.

List of Departmental Electives (VI Semester)

Departmental Elective III (Mathematics)

Course Code: UMATL60309	**Title of the Course: Measure and Integration**
L-T-P: 3-0-0	**Credits: 3**
Semester: VI	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Know the Lebesgue measure can be viewed as a natural generalization of length to sets that are more complicated than intervals or finite unions of intervals.

CLO-2: Understand the construction of the Lebesgue integral and know its key properties.

CLO-3: Verify whether a given subset of R or a real valued function is measurable.

CLO-4: Understanding that Lebesgue integration can solve certain problems for which Riemann integration does not provide adequate answers.

CLO-5: Prove the basic results of measure theory and integration theory.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					
CLO2	2	2	1	2	3					
CLO3	2	1	1	2	3					
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3					

Course Details:

Unit-I: Algebra of sets, sigma algebras of sets, Borel subsets of R, F_σ and G_δ sets, Lebesgue outer measure and its properties, algebra of measurable sets in R, Existence of a non-measurable set, Measurability of Cantor set, Lebesgue measure and its properties.

Unit-II: Lebesgue Measurable functions and their properties, Convergence pointwise and convergence in measures of a sequence of measurable functions, Littlewood's three principles and Egoroff's Theorem, Characteristic function of a set, simple function.

Unit-III: Lebesgue integral of simple functions, Lebesgue integral of bounded functions, Bounded convergence theorem, Comparison of Riemann and Lebesgue integral. Lebesgue integral of nonnegative functions, Fatou's Lemma, Monotone convergence theorem, Lebesgue general integral, Lebesgue dominated convergence theorem.

Unit-IV: Differentiation of Monotone functions, Vitali covering lemma, Differentiability of an integral, Absolute continuity and indefinite integrals, L^p spaces, Holder and Minkowski inequalities, Convergence and completeness, Riesz – Fischer Theorem, Bounded linear functionals, Riesz representation theorem and illustrative examples, Measure spaces, Signed measures, the Radon Nikodyn theorem.

Course References:

1. H.L. Royden (1995), Real Analysis, 3rd Edition, Prentice-Hall of India.

2. G. de Barra (2014), Measure and Integration, 2nd Edition, New Age International (P) Ltd., New Delhi.

3. Inder K Rana (2005), An Introduction to Measure and Integration, Narosa Publishing House India.

4. P.R. Halmos (1962), Measure Theory, East West Press.

5. W. Rudin (1966), Real & Complex Analysis, McGraw Hill.

Course Code: UMATL60310	Title of the Course: Coordinate Geometry
L-T-P: 3-0-0	Credits: 3
Semester: VI	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: understand geometry and its applications in the real world.

CLO-2: know how to communicate geometric ideas in the language of the mathematician.

CLO-3: analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.

CLO-4: apply transformations and use symmetry to analyze mathematical situations.

CLO-5: apply appropriate techniques, tools, and formulas to determine measurements.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2			2						
CLO2	2			2						
CLO3	2			2	3					
CLO4	2	2	1	2	3		1			
CLO5	2	2	1	2	3			2		

Course Details:

Preliminaries: Rectangular coordinates- Distance between two points- Division of a line joining two points in a given ratio - Angle between two lines- Direction cosines and ratios of a straight line- Condition for parallelism and perpendicularity of two lines- Projection of a line segment on another line. The plane- The general equation of the first degree in three variables always represents a plane Surface-Direction cosine of the normal to a plane- Equation of a plane in intercept form- The form $lx + my + nz = p$ - Angle between two planes- Pair of planes- Image of a point in a plane - Length of perpendicular from a point to a plane.

The equation to a straight line- Symmetrical form- Parametric coordinates of any point on a line Transformation from un-symmetrical form to the symmetric form- Condition for a line to be parallel to a plane- Angle between a line and a plane- Coplanar Lines, intersecting two lines –Skew lines – Shortest distance between two lines. The sphere- The equation of a sphere with given center and radius- The equation of a sphere on the line joining two given points as diameter- Plane section of a sphere- Equation of a sphere passing through a given circle- The intersection of two spheres- The equation of a tangent plane to a sphere- Length of tangent to a sphere- Orthogonal spheres. Hyperbolic functions- Inverse hyperbolic functions- Separation into real and imaginary parts.

Course References:

1. S. L. Loney, The Elements of Coordinate Geometry, Macmillan India, 2010.
2. R. J. T. Bill, Elementary Treatise on Coordinate Geometry of Three Dimensions, Macmillan India, 1918.

Course Code: UMATL60311	**Title of the Course: Special Functions**
L-T-P: 3-0-0	**Credits: 3**
Semester: VI	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the importance of Heine's transformation and Jackson transformation formula.

CLO-2: Explain the application of Jacobi's triple product identity and Quintuple product identity.

CLO-3: Learn the importance of Ramanujan ${}_1\Psi_1$ summation formula.

CLO-4: Learn some theta function identities mentioned in the Chapter 16 of Ramanujan's notebook III.

CLO-5: Work effectively as part of a group to solve challenging problems in Number Theory.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2			2						
CLO2	2									
CLO3	2				3					
CLO4	2	2	1	2	3		2			
CLO5	2	2	1	2	3			2		

Course Details:

Unit I: Hypergeometric series: Definition- convergence- Solution of second order ordinary differential: equation or Gauss equation- Confluent hypergeometric series- Binomial theorem, Integral Representation- Gauss's Summation formula- Chu-Vandermonde's Summation formula- Pfaff-Kummer Transformation Formula- Euler's transformation formula.

Unit II: Basic-hypergeometric series: Definition- Convergence- q-binomial theorem- Heines transformation formula and its q-analogue- Jackson transformation formula- Jacobi's triple product identity and its applications - Quintuple product identity - Ramanujan's 1 ψ1 summation formula and its applications- A new identity for $(q; q)10$ with an application to Ramanujan partition congruence modulo 11- Ramanujan theta-function identities involving Lambert series.

Unit III: q-series and Theta-functions: Ramanujan's general theta-function and special cases- Entries 18, 21, 23, 24, 25, 27, 29, 30 and 31 of Ramanujan's Second note book (as in text book reference 4).

Unit IV: Partitions: Definition of partition of a +ve integer- Graphical representation- Conjugate- Self conjugate- Generating function of $p(n)$- other generating functions- A theorem of JacobiTheorems 353 and 354- applications of theorem 353- Congruence properties of $p\,(n)$- $p\,(5n + 4) \equiv 0\,(mod\,5)$ and $p\,(7n + 4) \equiv 0\,(mod\,7)$- Two theorems of Euler-Rogers-Ramanujan Identitiescombinatorial proofs of Euler's identity, Euler's pentagonal number theorem. Franklin combinatorial proof. Restricted partitions- Gaussian.

Course References:

1. C. Adiga, B. C. Berndt, S. Bhargava and G. N. Watson, Chapter 16 of Ramanujan's second notebook: Theta-function and q-series, Mem. Amer. Math. Soc., 53, No.315, Amer. Math. Soc., Providence, 1985.
2. T. M. Apostol: Introduction to Analytical number theory, Oxford University Press, 2000.
3. G. E. Andrews, The theory of Partition, Cambridge University Press, 1984.
4. B. C. Berndt, Ramanujan's notebooks, Part-III, Springer-Verlag, New York, 1991.
5. B. C. Berndt, Ramanujan's notebooks, Part-IV, Springer-Verlag, New York, 1994.
6. B. C. Berndt, Ramanujan's notebooks, Part-V, Springer-Verlag, New York, 1998
7. George Gasper and Mizan Rahman, Basic hyper-geometric series, Cambridge University Press, 1990.
8. G. H. Hardy and E. M. Wright, An Introduction of the Theory of Numbers, Oxford University Press, 1996.

Course Code: UMATL60312	Title of the Course: Mathematics for Biology
L-T-P: 3-0-0	Credits: 3
Semester: VI	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: formulate discrete and differential equation models that represent a range of biological problems.
CLO-2: apply computational tools to perform parameter estimation and to solve discrete models.
CLO-3: interpret model and data output in terms of the original biological problem.
CLO-4: perform appropriate data manipulations, and graphically display model output.
CLO-5: apply the mathematical knowledge to understand the biological structure.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1								
CLO2	1	1						1		
CLO3	2	1	1							
CLO4	3	2	2	2	3		1	3		
CLO5	2	2	2		2		2	3		

Course Details:

Unit-I: Concepts of Population biology, physiology and in the biomedical sciences including single and competing species ecological models, enzyme reaction kinetics, molecular motors, epidemiology, and infectious diseases.
Unit-II: Mathematical modeling techniques of formulation, implementation, validation, and analysis.

Course References:

1. Mathematical Models in Biology, Leah Edelstein-Keshet, 1988

Course Code: UMATL60313	Title of the Course: Introduction to Modular Forms
L-T-P:3-0-0	Credits: 3
Semester: VI	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: Get good exposure to highly complicated unimodular functions.

CLO-2: Learn Mobius transformation and its application to Picard's theorem.

CLO-3: Work on Dedekind's functional equation and its rich structure.

CLO-4: Prove deep theorems on Congruence's for the coefficients of the modular function j.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1								
CLO2	1	1								
CLO3	2	1	1					2		
CLO4	3	2	2	2	3			3		

Course Details:

Unit I. Elliptic Functions Introduction, Doubly periodic functions, Fundamental pairs of periods, Elliptic functions, Construction of elliptic functions, The Weierstrass $\wp$function, The Laurent expansion of$\wp$near the origin, Differential equation satisfied by $\wp$, The Eisenstein series and the invariants $g2$ and $g3$,The numbers $e1$, $e2$, $e3$, The discriminant Δ, Klein's modular function $J(\tau)$, Invariance of J under unimodular transformations, The Fourier expansions of $g2$ (τ) and $g3$ (τ), The Fourier expansions of $\Delta(r)$ and $J(\tau)$.

Unit II. The Modular group and modular functions Mobius transformations, The modular group Γ, Fundamental regions, Modular functions, Special values of J, Modular functions as rational functions of J, Mapping properties of J, Application to the inversion problem for Eisenstein series, Application to Picard's theorem.

Unit III. The Dedekind eta function Introduction, Siegel's proof of Theorem 3.1, Infinite product representation for $\Delta(\tau)$, The general functional equation for $\eta(\tau)$ transformation formula, Deduction of Dedekind's functional equation from Iseki's Formula, Properties of Dedekind sums, The reciprocity law for Dedekind sums, Congruence properties of Dedekind sums, The Eisenstein series $G2$ (τ).

Course References:

1. Tom M. Apostol, Modular Functions and Dirichlet Series in Number Theory, Springer - Verlag, 1976.
2. 2. Gunning, R. C. Lectures on Modular Forms, Annals of Mathematics Studies, No. 48. Princeton Univ. Press, Princeton, New Jersey, 1962. MR 24 # A2664.

Course Code: **UMATL60314**	Title of the Course: **Continuum Mechanics**
L-T-P: **3-0-0**	Credits: **3**
Semester: **VI**	Type of the Course: **Theory**

Prerequisite Course / Knowledge (If any): Basic knowledge in physics

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the concept of components of a tensor, Transpose of a tensor, Symmetric & Anti-symmetric tensor, Principal values, and directions.

CLO-2: Know the Principal Stresses, Equations of motion, and Boundary conditions.

CLO-3: Gain the concepts of Isotropic solids and Equations of infinitesimal theory.

CLO-4: Solve the examples of electrodynamics and electrostatics.

CLO-5: Apply the concepts of rate of deformation, Conservation of mass and Compatibility conditions.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	3		1						
CLO2	2	3		2						
CLO3	3			2						
CLO4	3	3	1	3	2			2		
CLO5	3	3	2	2	2			2		

Course Details:

Unit I: Tensors: Summation Convention, Components of a tensor, Transpose of a tensor, Symmetric & anti-symmetric tensor, Principal values and directions, Scalar invariants.

Unit II: Kinematics of a Continuum: Material and Spatial descriptions, Material derivative, Deformation, Principal Strain, Rate of deformation, Conservation of mass, Compatibility conditions.

Unit III: Stress: Stress vector and tensor, Components of a stress tensor, Symmetry, Principal Stresses, Equations of motion, Boundary conditions.

Unit IV: Linear Elastic Solid: Isotropic solid, Equations of infinitesimal theory, Examples of electrodynamics and electrostatics.

Course References:

1. W.M. Lai, Rubin D. and Krempel E. (1974), Introduction to Continuum Mechanics, Pergamon Unified Engineering Series,
2. S.C. Hunter (1983), Mechanics of Continuous Media, Ellis Harwood Series.
3. T.J. Chung (1988), Continuum Mechanic, Prentice Hall.
4. D.S. Chandrasekhraiah and Loknath Debnath (1995), Continuum Mechanics, Academic Press.

Departmental Elective IV (Computing)

Course Code: UMATL60315	**Title of the Course: Design & Analysis of Algorithms**
L-T-P: 3-0-0	**Credits: 3**
Semester: VI	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the basic concepts of algorithms and analysis.
CLO-2: Analyze time and space complexity.
CLO-3: Understand algorithm design methodology.
CLO-4: Apply important algorithm methodology to solve problems.
CLO-5: Understand the difference between P and NP classes of problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	1	2	1	1	1	1	3	1
CLO2	1	3		2	1	1	2	2	3	2
CLO3	1	3	1	3	2	2	1	1	3	2
CLO4	2	3		2	2	1	1	1	3	2
CLO5	1	2	2	2	1	3	1	2	3	1

Course Details:

Unit -I: Analyzing Algorithms: Concepts in Algorithms Analysis – asymptotic complexity of algorithms –Growth functions Recurrences. Master Theorem.

Divide and Conquer Method: Binary Search, Quick Sort, Expected Running Time of Randomized Quick Sort, Merge Sort, Strassen's Matrix Multiplication Algorithm.

Unit-II: Data Structures for Set manipulation problems: Binary tree traversal algorithms, disjoint-set union algorithms.

Graph Algorithms: Representations of graphs – Breadth-first search – Depth-first search – Minimum spanning tree – The algorithms of Kruskal and Prim – Shortest paths – Dijkstra's algorithm.

Unit-III: Greedy Method: Activity Selection Problem, Knapsack Problem, single source shortest path problem.

Dynamic Programming: Solution to 0-1 Knapsack Problem, multistage graphs, TSP using Dynamic Programming Backtracking: Basic examples, N-Queen's Problem, sum of subsets problem.

Unit-IV: Complexity Classes: Example NP-complete problems

Course References:

1. Cormen T.H., Leiserson C.E., Rivest R.L. and C. Stein, Introduction to Algorithms, 3rd Edition, PHI, New Delhi, 2004.
2. Horowitz E., Sahni S. and Rajasekaran S., Fundamentals of Computer Algorithms, Second Edition, Universities Press, 2011.
3. Aho A V, Hopcroft J E, and Ullman J.D., The Design and Analysis of Computer Algorithms, Pearson, 10 th Impression, New Delhi, 2012.
4. Baase S. and Gelder A.V., Computer Algorithms: Introduction to Design and Analysis, 3rd Edition, Addison and Wesley, 2000.
5. Levitin A., Introduction to the Design and Analysis of Algorithms, 2nd Impression, Pearson Education, New Delhi, 2009.

Course Code: UMACL60303	Title of the Course: Internet of Things
L-T-P: 2-0-2	Credits: 3
Semester: VI	Type of the Course: Theory cum Practical

Prerequisite Course / Knowledge (If any): Basic knowledge in physics

Course Learning Outcomes (CLOs)

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

CLO-1: Interpret the impact and challenges posed by IoT networks leading to new architectural models.

CLO-2: Appraise the role of IoT protocols for efficient network communication.

CLO-3: Design the advanced hardware and software for IoT system.

CLO-4: Incorporate long lifetime of IoT network using energy harvesting technologies.

CLO-5: Employ advanced level knowledge, techniques, skills and modern tools in the development of the IoT system.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		1	2			1	3	
CLO2	3	3	2	2	2		2	2	3	
CLO3	3	3		3						
CLO4	3	3		2						
CLO5				2	2		2	2		

Course Details:

Unit I: Introduction to Internet of Things: Definition IoT, History of IoT, Basic Architecture and working of IoT. Challenges, Applications, Current Status and Future Prospect of IoT. Sensing, Actuation, Machine-to- machine (M2M) Communications.

Unit II: Introduction to Arduino Programming: Integration of Sensors and Actuators with Arduino. Introduction to Cloud Computing, Sensor-Cloud, Fog Computing, Smart Cities and Smart Homes, Connected Vehicles, Smart Grid.

Unit III: IoT System Design: Power supply, Processor, Memory Sensor Interface, Wireless Interface- LAN, BLE, Wi-Fi, RFID, LP WA-LORA, LTE-M, Sigfox, NB-IoT, Power Supply Design- LDOs, Swithing regulators-BuckBoost.

Unit IV: IOT Function Protocols: Data protocols (MQTT, COAP, AMQP), Communication/transport protocols (WIFI, BLUETOOTH, LPWAN), Connectivity protocols (6LOW PAN).

Course References:

Textbooks

1. Arshdeep Bahga, and Vijay Madisetti, "Internet of Things (A Hands-on-Approach)", 1 st Edition, VPT, 2014.
2. Getting Started with Raspberry Pi, Matt Richardson & Shawn Wallace, O'Reilly (SPD), 2014, ISBN: 9789350239759

Reference books

1. Francis da Costa, "Rethinking the Internet of Things: A Scalable Approach to Connecting Everything", 1st Edition, A press Publications, 2013.
2. Cuno Pfister, Getting Started with the Internet of Things, O"Reilly Media, 2011, ISBN: 978-1- 4493-9357-1.

Online Resources

1. https://nptel.ac.in/noc/courses/noc19/SEM1/noc19-cs31/
2. https://nptel.ac.in/courses/108/108/108108098/

Course Code: UMATL60316	Title of the Course: Finite Difference Methods
L-T-P: 3-0-0	Credits: 3
Semester: VI	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: solve the linear and non-linear initial value problems in ordinary differential equations using the shooting method.

CLO-2: solve the linear and non-linear initial value problems in ordinary differential equations using the explicit and implicit multistep methods.

CLO-3: solve the heat equation, wave equation and the Laplace equation in one dimensional and 2- dimensional space using the finite difference methods.

CLO-4: find the stability, convergence and the error analysis of the finite difference methods.
CLO-5: extend their knowledge of finite difference techniques for further exploration of the subject for going into research.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		1	2		2	1		2
CLO2	3	3		2	2		2	2	1	2
CLO3	3	3		3	3		2	2		3
CLO4	3	3		2	2		2	1		3
CLO5				2	2		2	2	3	2

Course Details:

Unit 1: Multistep (Explicit and Implicit) methods for Initial value problems, stability and convergence analysis, linear and nonlinear boundary value problems, shooting methods.
Unit 2: Finite difference approximations for ordinary derivatives and finite difference scheme for ordinary differential equations with explicit boundary conditions, implicit boundary conditions, error analysis, stability analysis, convergence analysis.
Unit 3: Finite difference approximations for partial derivatives and finite difference schemes for Parabolic equations: Schmidt's two level, multilevel explicit methods, Crank-Nicolson's two level, multilevel implicit methods, Dirichlet's problem, Neumann problem, mixed boundary value problem.
Unit 4: Hyperbolic Equations: Explicit methods, implicit methods, one space dimension, two space dimensions, ADI methods. Elliptic equations: Laplace equation, Poisson equation, iterative schemes, Dirichlet's problem, Neumann problem, mixed boundary value problem, ADI methods.

Course Reference:

1. M.K. Jain (1985), Numerical Solution of Differential Equations, Wiley Eastern, Delhi.
2. G.D. Smith (2004), Numerical Solution of Partial Differential Equations, Oxford University Press.
3. M.K. Jain, S.R.K. Iyengar and R.K. Jain (2002), Computational Methods for Partial Differential Equations, Wiley Eastern.
4. J. D. Lambert (1991), Numerical methods for Ordinary Differential equations, John Wiley & Sons.

5. P. Henrici (1962), Discrete Variable Methods in Ordinary Differential Equations, John Wiley & Sons, New York.
6. Richard K. Miller (1991), Introduction to Differential Equations, Prentice Hall, New Jersey.
7. J. D. Hoffman (2000), Numerical methods for Engineers and Scientists, Mc-Graw Hill.

Course Code: UMACL60304	**Title of the Course: Image Processing**
L-T-P: 2-0-2	**Credits: 3**
Semester: VI	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

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

CLO-1: Implement basic image processing operations.
CLO-2: Apply and develop new techniques in the areas of image enhancement and restoration.
CLO-3: Understand the image segmentation algorithms.
CLO-4: Apply descriptors for boundary detection, pattern classification and develop computer vision application that uses different concepts of image processing.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		1	2		2			
CLO2	3			2	2		2			
CLO3	3			3	3		2			
CLO4	3	3		2	2		2			

Course Details:

Unit I: Fundamentals of Image Processing: Introduction, applications of image processing, steps in image processing applications, digital imaging system, pixel connectivity.
Case Study: Study of image processing toolbox and basic image processing operations.

Unit II: Image Enhancement: Spatial Domain: Some Basic Intensity Transformation Functions, Histogram Processing, Fundamentals of Spatial Filtering, Smoothing Spatial Filters, Sharpening Spatial Filters.
Case Study: Understand enhancement techniques using Matlab.

Unit III: Image Resoration: Noise models, Restoration in the presence of noise only using spatial filtering and frequency domain filtering, linear, position invariant degradation, estimating the degradation function, inverse filtering.
Case Study: Study of different image restoration operations.

Unit IV: Image Segmentation and Feature Extraction: Image segmentation - Detection of discontinuities, edge operators, edge linking and boundary detection, thresholding.
Case Study: Design of edge detection algorithm of any one mask.

Course Reference:

Textbooks:

1. R. Gonzalez and E. Rechard, “Digital Image Processing”, 4th Edition, Pearson Education, 2018.
2. K. Jain, “Fundamentals of Digital Image Processing”, PHI, 2011.

Reference books:

3. M. Sonka, Vaclav Hlavac, Roger Boyle, “Image Processing Analysis and Machine Vision.

Online sources:

1. https://nptel.ac.in/courses/117105079

Course Code: UMATL60317	**Title of the Course: Data Mining**
L-T-P: 3-0-0	**Credits: 3**
Semester: VI	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the basics of data mining.
CLO-2: Learn the bayes Classifier, K nearest neighbor, etc.
CLO-3: Apply Sequence mining.
CLO-4: Evaluate visualize the data.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		1	2		2	1		
CLO2	3	3		2	2		2	2		
CLO3	3	3		3	3		2	2		
CLO4	3	3		2	2		2	1		

Course Details:

Unit I: Introduction, Data Preprocessing, Association Rule Mining, Classification Basics

Unit II: Decision Tree, Bayes Classifier, K nearest neighbor, Support Vector Machine, Kernel Machine

Unit III: Clustering, Outlier detection, Sequence mining

Unit IV: Evaluation, Visualization, Case studies

Course Reference:

1. Introduction to Data Mining, Tan, Steinbach and Vipin Kumar, Pearson Education, 2016
2. Data Mining: Concepts and Techniques, Pei, Han and Kamber, Elsevier, 2011

Online sources:

1. https://onlinecourses.nptel.ac.in/noc21_cs06/preview

Course Code: UMACL60305	**Title of the course: Web Technologies**
L-T-P: 2-0-2	**Credits: 3**
Semester: VI	**Type of the Course: Theory Cum Practical**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Understand, analyze and build dynamic and interactive web sites.

CLO-2: Understand current and evolving Web languages for integrating media and user interaction in both front end and back end elements of a Web site.

CLO-3: Analysis and reporting of web data using web analytics.

CLO-4: Solve initial and boundary value problems in differential equations using numerical methods.

CLO-5: Applying different testing and debugging techniques and analyzing the web site effectiveness.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					
CLO2	2	2	1	2	3			2	3	
CLO3	2	1	1	2	3	3	2			1
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3			2		

Course Details:

Unit-I: Introduction to XHTML: Editing XHTML, First XHTML Example, W3C XHTML Validation Service, Headers, Linking, Images, Special Characters and More Line Breaks, Unordered Lists, Nested and Ordered Lists, Internet and World Wide Web Resources.

Unit-II: Dynamic HTML: Object Model and Collections- Introduction, Object Referencing, Collections all and children, Dynamic Styles, Dynamic Positioning, Using the frames Collection, navigator Object, Summary of the DHTML Object Model; Event Model- vent on click, Event on load, Error Handling with on error, Tracking the Mouse with Event on mouse move, Rollovers with on mouse over and on mouse out; Form Processing- Form Processing with on focus and on blur, More Form Processing with on submit and on reset, Event Bubbling, More DHTML Events; Filters and transitions; Data binding with tabular data control, Structured graphics and active X control.

Unit-III: JavaScript: Functions; Program Modules in JavaScript, Programmer Defined Functions, Function Definitions, Random-Number Generation, Duration of Identifiers, Scope Rules, JavaScript Global Functions, Recursion, JavaScript arrays, JavaScript objects.

Unit-IV: XML: Structuring Data, XML Namespaces, Document Type Definitions (DTDs) and Schemas, Document Type Definitions, W3C XML Schema Documents, XML Vocabularies, Chemical Markup Language (CML), Other Markup Languages, Document Object Model (DOM), DOM Methods, Simple API for XML (SAX), Extensible Style sheet Language (XSL), Simple Object Access Protocol (SOAP); Web Servers: HTTP Request Types, System Architecture, Client-Side Scripting versus Server-Side Scripting, Accessing Web Servers, Microsoft Internet Information Services (IIS), Microsoft Personal Web.

Unit-V: Server-side Scripting: Introduction to PHP, String Processing and Regular Expressions, Form processing and Business logic, Dynamic content, Database connectivity, Applets and Servlets, JDBC connectivity, JSP and Web Development Frameworks.

Course References:

Text Books / Reference Books / Online Resources:

1. Deitel, Deitel and Nieto, "Internet and Worldwide Web - How to Program", 5th Edition, PHI, 2011.

2. Bai and Ekedhi, "The Web Warrior Guide to Web Programming", 3rd Edition, Thomson, 2008.

List of Departmental Electives (VII Semester)

Departmental Elective V (Mathematics)

Course Code: UMATL70400	**Title of the Course: Algebraic Topology**
L-T-P: 3-0-0	**Credits: 3**
Semester: VII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Explain the fundamental concepts of algebraic topology and their role in modern mathematics and applied contexts.

CLO-2: Demonstrate accurate and efficient use of algebraic topology techniques.

CLO-3: Demonstrate capacity for mathematical reasoning through analyzing, proving and explaining concepts from algebraic topology.

CLO-4: Apply problem-solving using algebraic topology techniques applied to diverse situations in physics, engineering and other mathematical contexts.

CLO-5: Provide an elementary example illustrating specified behavior in relation to a given combination of basic definitions and key theorems across the course.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	1	1	1	2	2	1		1
CLO2	3	2	1	2	1	2	2	1		1
CLO3	3	2	1	1	2	2	2	1		1
CLO4	3	2	1	1	2	2	2	1		1
CLO5	3	2	1	1	2	2	2	1		1

Course Details:

Unit-I: Paths and homotopy, homotopy equivalence, contractibility, deformation retracts. Basic constructions: cones, mapping cones,mapping cylinders, suspension. Cell complexes, subcomplexes, CW pairs. Fundamental groups. Examples (including the fundamental group of the circle) and applications (including Fundamental Theorem of Algebra, Brouwer Fixed Point Theorem and Borsuk-Ulam Theorem, both in dimension two). Van Kampen's Theorem, covering spaces, lifting properties, deck transformations. universal coverings (existence theorem optional).

Unit-II: Simplicial complexes, barycentric subdivision, stars and links, simplicial approximation. Simplicial Homology. Singular Homology. Mayer-Vietoris Sequences. Long exact sequence of pairs and triples. Homotopy invariance and excision (without proof).

Unit-III: Degree. Cellular Homology. Applications of homology: Jordan-Brouwer separation theorem, Invariance of dimension, Hopf's Theorem for commutative division algebras with identity, Borsuk-Ulam Theorem, Lefschetz Fixed Point Theorem.

Unit-IV: Outline of the theory of: cohomology groups, cup products, Kunneth formulas, Poincare duality.

Course References:

1. M. J. Greenberg and J. R. Harper, Algebraic Topology, Benjamin, 1981.
2. W. Fulton, Algebraic topology: A First Course, Springer-Verlag, 1995.
3. A. Hatcher, Algebraic Topology, Cambridge Univ. Press, Cambridge, 2002.
4. W. Massey, A Basic Course in Algebraic Topology, Springer-Verlag, Berlin, 1991.
5. J.R. Munkres, Elements of Algebraic Topology, Addison Wesley, 1984.
6. J.J. Rotman, An Introduction to Algebraic Topology, Springer (India), 2004.
7. H. Seifert and W. Threlfall, A Textbook of Topology, translated by M. A. Goldman, Academic Press, 1980.
8. J.W. Vick, Homology Theory, Springer-Verlag, 1994.

Course Code: UMATL70401	Title of the Course: Classical Mechanics
L-T-P: 3-0-0	Credits: 3
Semester: VII	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: Understanding the basic concepts of Mechanics to develop the equations of motion for a system of particles.

CLO-2: Analyse the motion of a rigid body under translation.

CLO-3: Analyse the motion of a rigid body under rotation about a fixed point.

CLO-4: Develop Euler's and Lagrange's equations of motion.

CLO-5: Develop Hamiltonian equation of motion.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	1	1	1	3	1
CLO2	1	3	1	3	2	1	1	1	3	1
CLO3	1	3	1	2	2	1	1	1	3	2
CLO4	2	3		2	2	1	1	1	3	2
CLO5	1	3		2	2	1	1	2	3	1

Course Details:

Unit-I: Generalized coordinates, the principle of least action, Galileo's relativity principle, the Lagrangian for a free particle, Lagrangian for a system of particle, energy, momentum, centre of mass, angular momentum, motion in one dimension, determination of the potential energy from the period of oscillation, the reduced mass, motion in a central field.

Unit-II: Free oscillation in one-dimension, angular velocity, the inertia tensor, angular momentum of a rigid body, the equation of motion of a rigid body, Eulerian angle, Euler's equation.

Unit-III: The Hamilton's equation, the Routhian, Poisson brackets, the action as a function of the coordinates, Maupertui's principle.

Unit-IV: The Canonical transformation, Liouville's theorem, the Hamiltonian – Jacobi equation, separation of the variables, adiabatic invariants, canonical Variables.

Course References:

1. F. Chorlton (1985), Textbook on Dynamics, CBS Pubs, New Delhi.
2. L. D. Landau and E. M. Lifshitz (1984) - Mechanics, (Third Edition), Butter worth – Heinenann.
3. J. L. Synge and B. A. Griffith (1987), Principles of Mechanics, McGraw Hill.
4. G. R. Fowles and G. L. Cassiday (2004), Analytical Mechanics, Cengage.
5. Herbert Goldstein, Classical mechanics, Narosa.
6. K. C. Gupta, Classical mechanics of particles and Rigid Bodies, Wiley Eastern.
7. M. G. Calkin, Lagrangian and Hamiltonian Mechanics, World Scientific.

Course Code: UMATL70402	Title of the Course: Advanced Operations Research
L-T-P: 3-0-0	Credits: 3
Semester: VII	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: Solve the LPP and integer programming problem.

CLO-2: Solve network flow problems including shortest path, maximum flow, minimum cost flow using appropriate algorithms.

CLO-3: Develop and solve models for the travelling salesman problem, vehicle routing, and the Chinese postman problem using both exact and heuristic methods.

CLO-4: Apply game theory, the critical path method, quadratic programming, and benders partitioning algorithm for solving advanced optimization problems.

CLO-5: Formulate and solve goal programming models and evaluate the computational complexity of various optimization algorithms.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	3	2	1	3	2	2	1	3
CLO2	3	3	3	2	1	3	2	2	1	3
CLO3	3	3	3	2	1	3	3	2	1	3
CLO4	3	3	3	2	1	3	3	3	1	3
CLO5	3	3	3	2	1	3	3	3	1	3

Course Details:

Unit-I: Recap of Linear Programming problems, Revised Simplex Algorithm, Simplex Method for Bounded Variables, One Dimensional Cutting Stock Problem, Dantzig-Wolfe Decomposition Algorithm, Primal-Dual Algorithm, Goal Programming-Formulation and solutions, Complexity of Simplex Algorithm.

Unit-II: Integer Programming-Formulations, Zero-One Problems, Branch and Bond Algorithm for Integer Programming, Cutting Plane Algorithm, All Integer Primal Algorithm, All Integer Dual Algorithm.

Unit-III: Network Models, Shortest Path Problem, Successive Shortest Path Problem, Maximum Flow Problem, Minimum Cost Flow Problem.

Unit-IV: Travelling Salesman problem and extensions, Traveling Salesman Problem (TSP), Branch and Bound Algorithms for TSP, Heuristics for TSP, Chinese Postman Problem, Vehicle Routing Problem. Game Theory, Critical Path Method, Quadratic Programming All Integer Dual Algorithm, Mixed Integer Linear Programming, Benders Partitioning Algorithm.

Course References:

1. Operations Research Applications and Algorithms, Wayne L. Winston, Duxbury Press, 1994.
2. H. A. Taha (2014), *Operations Research, An Introduction*, PHI, New Delhi.
3. N. S. Kambo (1991), *Mathematical Programming Techniques*, East-West Pub., Delhi.
4. Kanti Swarup, P. K. Gupta and Man Mohan (2010), *Operations Research*, Sultan Chand and Co, New Delhi.
5. J. C. Pant (2012), *Introduction to Operations Research*, Jain Brothers, New Delhi.
6. H. M. Wagner (2010), *Principles of Operations Research*, PHI, Delhi.

Course Code: UMATL70403	**Title of the Course: Theory of Partitions**
L-T-P: 3-0-0	**Credits: 3**
Semester: VII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Explain the applications and the usefulness of Jacobi's triple product identity.

CLO-2: Understand how to count the number of partitions via Euler's Pentagonal Theorem.

CLO-3: Learn the work of Ramanujan on partition function and get motivated towards the research.

CLO-4: Prove combinatorically Euler's beautiful identity on pentagonal numbers.

CLO-5: Work effectively as part of a group to solve challenging problems in Number Theory.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	1	1	1		
CLO2	1	3		3	2		1			
CLO3	1	3		2	2		1			
CLO4	2	3		2	2		1	1		
CLO5	1	3		2	2		1	2		

Course Details:

Unit I: Introduction to basic hyper geometric series, q-binomial theorem, Heine's transformation and Gaussian Polynomial, two theorems of Euler, Jacobi's triple product identity and its applications, bilateral series and its applications, theta functions.

Unit II: Partitions, Graphical representation, Conjugate and self-conjugate, Generating function of p(n), recurrence relation for p(n), other generating functions, Euler theorem for partition.

Unit III: Congruence properties of partition function, the Rogers - Ramanujan Identities.

Unit IV: Rank and crank of partitions and restricted partitions.

Course References:

1. G. H. Hardy and E. M. Wright (1979), An Introduction to Theory of Numbers, Oxford University Press, 5th Ed.
2. Bruce C. Berndt, Number Theory in the Spirit of Ramanujan, AMS.
3. Bruce C. Berndt, Ramanujan's Note Books Volumes-1 to 5.
4. G. E. Andrews (1976), The Theory of Partitions, Addison Wesley.
5. Gasper and Rahman (1990), Basic hypergeometric Series, Cambridge University Press.

Course Code: UMATL70404	**Title of the Course: Lie Group Theory and Applications**
L-T-P: 3-0-0	**Credits: 3**
Semester: VII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: understand basic knowledge of group, group of transformations.

CLO-2: understand the fundamental concepts Lie group, infinitesimal generators, invariant functions, canonical coordinates.

CLO-3: understand the fundamental invariance curves, invariant surfaces, invariant point, mapping of curves and surfaces, canonical coordinates.

CLO-4: determination of first order ordinary differential equations invariant under a given group.

CLO-5: determination of higher order ordinary differential equations invariant under a given group.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	1	3	2	1	1	2		1
CLO2	3	3	1	3	2	1	1	2		1
CLO3	3	3	1	3	2	1	2	3		1
CLO4	2	3	1	3	2	2	3	3		3
CLO5	2	3	1	3	2	2	3	3		3

Course Details:

Unit 1: Basic concepts of group, group of transformations, one-parameter Lie groups of transformations. Fundamental theorems of Lie group, infinitesimal generators, invariant functions, canonical coordinates.

Unit 2: Extended group of point transformations, extended infinitesimal transformations for one independent variable and one dependence variable, n independent variable and one dependence variable, n independent variable and n dependence variable; multi point Lie group of transformations, Lie algebras, solvable lie algebras.

Unit 3: Invariance curves, invariant surfaces, invariant point, mapping of curves and surfaces, canonical coordinates, determining equation for symmetries of a first order ODE, Invariance of an first ODE under a given group.

Unit 4: Reduction of order of the second and higher order ODEs through canonical coordinates and differential invariants, Determine the second and higher order ODEs invariant under lie group, multiparameter lie group. Invariance of overdetermined system of ODEs under an mutliparameter lie group with solvable Lie algebra.

Course References:

1. Bluman, G. W. and Kumei, S.(1989), Symmetries and Differential Equations, Springer Verlag, Heidelberg, Berlin,.
2. Bluman, G. W. and Cole, J. D.(1974) , Similarity Methods for Differential Equations,
3. Applied Mathematical Sciences, Vol. 13. Springer-Verlag, New York-Heidelberg,
4. Hydon, P.E. (2000), Symmetry methods for differential equations: a beginner's guide, Cambridge University Press.
5. P. Olver(1993), Application of lie Groups to Differential Equations, Springer, NY.
6. H. Stephani(1989), Differential Equations: Their Solutions Using Symmetries, Cambridge Univ. Press, NY.
7. Bluman, G. W., Cheviakov, A. F. and Anco, S. C.(2010), Applications of Symmetry Methods to Partial Differential Equations, Applied Mathematical Sciences, 168, Springer.

Course Code: UMATL70405	**Title of the Course: Boundary Layer Theory**
L-T-P: 3-0-0	**Credits: 3**
Semester: VII	**Type of the Course: Theory**

Prerequisite Course / Knowledge (If any): Fluid Dynamics

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the concept of boundary layer theory.

CLO-2: Know the boundary layer model and different analytic methods.

CLO-3: Familiarize flow instability and transition from laminar flow to turbulence.

CLO-4: Acquire the knowledge of boundary layer separation.

CLO-5: Apply the boundary layer concepts to understand the real-world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2		3	3			3		
CLO2	2	3		2	2					
CLO3	2			3	2					
CLO4	3			2	3					
CLO5	2	2		3	2			3		

Course Details:

Unit I: Introduction to boundary layer, Laminar Boundary Layers, Boundary Layer assumptions and equations, Similarity solutions for steady, 2-D flow, Free shear flows, Other analytic 2-D solutions, Simple viscous solutions of Navier-Stokes equations, for example: Couette flow, Poiseuille flow, and plane stagnation flow.

Unit II: Boundary layer separation, flow past a cylinder, plane fee jet, circular jet, Prandtl-Mises Transformation, axially symmetric boundary layers on bodies at rest/revolution, Mangler's transformation.

Unit III: Three-dimensional boundary layers, growth of 3-D boundary layer on various geometries, unsteady boundary layers, method of successive approximation, boundary layer for periodic flow.

Unit IV: Approximate methods for solution of boundary layer equations, Karman momentum and integral equations, Karman-Pohlhausen method and its applications, Thermal Boundary Layer, derivation of 2-D thermal boundary layer equation for flow over a plane wall.

Course References:

1. Boundary Layer Analysis, Joseph A. Schetz, Prentice Hall, 1993.
2. Boundary-Layer Theory, 8th Ed., H. Schlichting, K. Gersten, Springer Verlag, 2003.
3. Ronald L. Panton's Incompressible Flow (4th Edition)
4. An Introduction to Fluid Dynamics, G. K. Batchelor, Cambridge University Press, 2010
5. Viscous Fluid Flow, F. M. White, McGraw Hill, USA, 1974.
6. Fluid Mechanics, F. M. White, , McGraw Hill, USA, 1979
7. Fundamentals of Aerodynamics, John D. Anderson, McGraw Hill, USA, 2007.

Departmental Elective VI (Computing)

Course Code: UMATL70406	**Title of the Course: Finite Element Method**
L-T-P: 3-0-0	**Credits: 3**
Semester: VII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Determine an extremum by calculus of variations approach.

CLO-2: Formation of a variational problem for a boundary value problem.

CLO-3: Solve one and two-dimensional problems by rectangular and triangular elements.

CLO-4: Extend their knowledge of finite element techniques for further exploration of the subject for going into research.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					
CLO2	2	2	1	2	3					
CLO3	2	1	1	2	3					
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3					

Course Details:

Unit I: Introduction to calculus of variations, variation of a functional, Euler-Lagrange equation, Necessary and sufficient conditions for extrema, weak, strong minima and maxima.

Unit II: Variational formulation, Rayleigh-Ritz method, weighted residuals methods-Collocation method, least square method, Galerkin method, Petrov-Galerkin method for boundary value problems.

Unit III: Finite element analysis for one-dimension problems using linear, quadratic, cubic shape functions.

Unit IV: Finite element analysis for two-dimension problems using rectangle elements (linear, quadratic, cubic shape functions, serendipity) and triangular elements and it is implementation on steady state problems.

Course References:

1. J.N. Reddy (2005), An introduction to the Finite Element Method, McGraw Hill, NY.
2. I. J. Chung (1978), Finite element analysis in Fluid Dynamics, McGraw Hill Inc.
3. O.C. Zienkiewiez and K. Morgan, Finite Elements and approximation, John Wieley, 1983.
4. P.E. Lewis and J.P. Ward (1991), The Finite element method- Principles and applications, Addison Weley.
5. L.J. Segerlind (1984), Applied finite element analysis (2nd Edition), John Wiley.
6. A.S. Gupta (2003), Calculus of Variation, Prentice Hall of India Pvt. Ltd.
7. I.M. Gelfand and S. V. Francis (2000), Calculus of Variation, Prentice Hall, New Jersey.

Course Code: UMACL70400	Title of the Course: Computational Fluid Dynamics
L-T-P: 2-0-2	Credits: 3
Semester: VII	Type of the Course: Theory cum Practical

Prerequisite Course / Knowledge (If any): Fluid Dynamics

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the concept of governing equations of Incompressible viscous flows.

CLO-2: Apply the staggered grid, artificial compressibility, pressure correction and vortex methods.

CLO-3: Apprehend compressible inviscid flows, central schemes with combined and independent space time discretization.

CLO-4: Apply the concept of compressible viscous flows, Explicit, implicit and PISO methods.

CLO-5: Apply the Structured and unstructured grid generation methods.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	2	2					1	
CLO2	3	2		1					1	
CLO3	3	2		3	2			2		
CLO4	3	2		3	2			2		
CLO5	3	2		3	2			2		

Course Details:

Unit I: Review of the governing equations of Incompressible viscous flows, Stream function - vorticity approach.

Unit II: Upwind schemes, Primitive variables, Staggered grid, Artificial compressibility, pressure correction and vortex methods.

Unit III: Compressible inviscid flows, central schemes with combined and independent space time discretization, Compressible viscous flows, Explicit, implicit and PISO methods.

Unit IV: Grid generation: Structured and unstructured grid generation methods; Finite volume method: Finite volume method to convection-diffusion equations. Practice the programs on above concepts using CFD software.

Course References:

1. P Wessling (1991), Principles of Computational Fluid Dynamics, Springer.
2. John D Anderson, Jr. (1995), Computational Fluid Dynamics, The Basics with Applications, McGraw-Hill.
3. Ferziger, J. H. and Peric, M. (2003). Computational Methods for Fluid Dynamics. Third Edition, Springer Verlag, Berlin.
4. Versteeg, H.K. and Malalasekara, W. (2008). Introduction to Computational Fluid Dynamics: The Finite Volume Method. Second Edition (Indian Reprint) Pearson Education.
5. Anderson, D.A., Tannehill, J.C. and Pletcher, R.H. (1997). Computational Fluid Mechanics and Heat Transfer. Taylor & Francis.

Course Code: UMACL70401	**Title of the Course: Computer Graphics**
L-T-P: 2-0-2	**Credits: 3**
Semester: VII	**Type of the Course: Theory cum Practical**

Prerequisite Course / Knowledge (If any): Fluid Dynamics

Course Learning Outcomes (CLOs)

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

CLO-1: understand the structure of an interactive computer graphics system, and the separation of system components.

CLO-2: develop and analyses the algorithms for generation lines and polygons.

CLO-3: apply the geometrical transformations on objects.

CLO-4: implement the techniques for segmentation.

CLO-5: differentiate different techniques for windowing and clipping.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	3	1	2	1	1	1	1	3	1
CLO2	1	2		2	1	1	2	2	3	2
CLO3	1	3	1	3	2	2	1	1	3	2
CLO4	3	2		2	2	1	1	1	3	2
CLO5	1	3	2	2	1	3	1	2	3	1

Course Details:

Unit 1: Introduction: Pixels and frame buffers - Coordinate systems - vector generation - line drawing and circle generation - algorithms and initializing of lines - thick line segments - character generation -display file and its structure. Polygons: Polygon representation - inside test - filling of polygon. 2D Transformations: Matrices - coordinate transformations - rotation about an arbitrary point – other transformations and inverse transformations.

Unit 2: Segments: Segment table - operations on segments - image transformation and other display file structures. Windowing and Clipping: The viewing transformations - clipping - the cohen sutherland outcode algorithm - the sutherland Hodgman algorithm - clipping of polygons and multiple windowing.

Unit 3: 3D Transformations: Rotation about an arbitrary axis - parallel projection - respective projection -Clipping in three dimensions - clipping planes and 3D viewing transformations. Hidden surfaces and Lines: Back face algorithms, Z buffers - scan line algorithms - the painter's algorithms - warnock's algorithm - Franklin algorithm and hidden line methods.

Unit 4: Shading: Shading equations - smooth shading - Gouraud and phong shading methods - shadows. Curves and Fractals: Curve generation - interpolation - B-Splines - Benzier curves - fractal lines and fractal surfaces.

Course References:

1. S. Harrington, Computer Graphics - A Programming Approach, McGraw Hill, New York, 1983.
2. D.F.Rogers & J.A.Adams, Mathematical Elements of Computer Graphics, McGraw Hill, New York, 1990.

Course Code: UMACL70402	**Title of the Course: Cloud Computing**
L-T-P: 2-0-2	**Credits: 3**
Semester: VII	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the Cloud Computing Architecture.

CLO-2: Learn the Data Management in Cloud Computing

CLO-3: Apply Cloud Security.

CLO-4: Apply the Cloud Simulator.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3									
CLO2			2		2					
CLO3						2		1		
CLO4	2	3		2	2	1	1	1		
CLO5	1	3		2	2	1	1	2		

Course Details:

Unit I: Introduction to Cloud Computing, Cloud Computing Architecture.

Unit II: Service Management in Cloud Computing, Data Management in Cloud Computing.

Unit III: Resource Management in Cloud, Cloud Security.

Unit IV: Open Source and Commercial Clouds, Cloud Simulator, Research trend in Cloud Computing, Fog Computing.

Course References:

1. Cloud Computing: Principles and Paradigms, Editors: Rajkumar Buyya, James Broberg, Andrzej M. Goscinski, Wiley, 2011
2. Enterprise Cloud Computing - Technology, Architecture, Applications, Gautam Shroff, Cambridge University Press, 2010
3. Cloud Computing Bible, Barrie Sosinsky, Wiley-India, 2010
4. Cloud Security: A Comprehensive Guide to Secure Cloud Computing, Ronald L. Krutz, Russell Dean Vines, Wiley- India, 2010

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc21_cs14/preview

Course Code: UMACL70403	**Title of the Course: Elements of Data Science**
L-T-P: 2-0-2	**Credits: 3**
Semester: VII	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

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

CLO-1: Understand the data analysis tools.

CLO-2: Learn the data structures.

CLO-3: Learn the Statistical Models.

CLO-4: Apply the Statistical Models.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	1	1	2	2		3				
CLO2	3	1	2	2						
CLO3	1	2	1		2		1			
CLO4	3	3	2		3					
CLO5										

Course Details:

Unit I: Introduction to data analysis tools, Data structures.

Unit II: Linear Regression Analysis.

Unit III: Statistical Inference, Statistical Models.

Course References:

1. Allen B. Downey, Elements of Data Science, Green Tea Press
2. https://allendowney.github.io/ElementsOfDataScience/README.html

Course Code: UMACL70404	**Title of the Course: Computational Statistics**
L-T-P: 2-0-2	**Credits: 3**
Semester: VII	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

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

CLO-1: Use R-programming in statistical computations.

CLO-2: Do sampling of any given discrete data or continuous data applying inverse transform methods, Box Muller method and other sampling methods.

CLO-3: Learn characteristics of estimators and to find MLE.

CLO-4: Optimize likelihood parameters of a statistical model in varied cases using MM algorithm, EM algorithm, Gradient Descent algorithm etc.

CLO-5: To construct a multitude of simulated sample, and optimizing it.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	3	3	2	1	1	3	2	1	3
CLO2	3	3	3	2	1	1	3	2	1	3
CLO3	3	3	3	2	1	2	3	2	3	2
CLO4	3	3	3	2	1	2	3	2	3	3
CLO5	3	3	3	2	1	2	3	2	1	1

Course Details:

Unit-I: Introduction to R, Introduction to Monte Carlo, Pseudo random Number Generation. Sampling Discrete Random Variables: Inverse Transform Method. Accept-Reject Algorithm, Composition Method.

Unit-II: Sampling Continuous Random Variables: Inverse Transform Method. Box-Muller method. Ratio-of-Uniforms method, examples and code, miscellaneous methods in sampling. Sampling from multivariate distributions.

Unit-III: Simple Importance Sampling: Examples, bias, variance, consistency, Optimal proposals. Weighted importance sampling: Examples, Review of likelihood functions, MLE examples. Newton's optimization algorithm: examples and code, Gradient Descent algorithm, applications to logistic regression with code. MM algorithm, application to Bridge Regression, EM algorithm, Introduction to Gaussian Mixture Model. EM algorithm for GMM, Cross-validation with examples.

Unit-IV: Bootstrapping: examples and code. Application to bridge regression, stochastic gradient descent. Applications of SGD with code. Simulated annealing: examples, codes, and challenges.

Course References:

1. “Simulation” by Sheldon Ross, Elsevier, Fifth Edition

2. “Monte Carlo Statistical Methods” by Christian Robert and George Casella, Springer, 2004.

List of Departmental Electives (VIII Semester)

Departmental Elective VII (Mathematics/Computing)

Course Code: UMATL80407	Title of the Course: Finite Volume Method
L-T-P: 3-0-0	Credits: 3
Semester: VIII	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Derive the Conservation Equations.

CLO-2: Discretize linear partial differential equations (PDE).

CLO-3: Identify source terms in PDE and their linearization.

CLO-4: Solve diffusive problems: Steady and unsteady 1D, Steady 2D and 3D problems.

CLO-5: Solve convective problems using upwind, QUICK and hybrid schemes. Also, solve the velocity and pressure coupling using SIMPLE, SIMPLER, SIMPLEC algorithms.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1		1		2		3		1		
CLO2	3			2					2	3
CLO3		2	1		2		1	2		
CLO4	1			3			2		1	
CLO5		2				2		2	1	

Course Details:

Unit-I: Introduction - Obtaining the Integral Form from the Differential Form - Finite Volume Meshes - Discretizing the Semi-Integral Equation – Implementation.

Unit-II: Finite Volume Schemes - FVM on a Cartesian Mesh - Finite Volume Schemes in 1D and 3D – Time Step Calculation for a Finite Volume Scheme - Finite Volume FOU 2D Scheme – Boundary Conditions - Coding a Finite Volume Solver.

Unit-III: Derivation of Equations - Conservation Laws - Control Volume Approach - Deriving the Integral Form of the 2D Linear Advection Equation - Further Finite Volume Schemes -

Linear Interpolation - Quadratic Interpolation - Converting from Finite Difference to Finite Volume Systems of Equations.

Unit-IV: The Shallow Water Equations - General FVS for the SWE - FVS for the 2D SWE on a Structured Mesh - Heuristic Time Step for a 2D SWE FVS.

Course References:

1. D. M. Causon, C. G. Mingham, & L.Own (2009), Introductory Finite Volume Methods for Partial Differential Equations, Springer.

2. H. Versteeg & W. Malalasekera (2009), An introduction to CFD: The Finite Volume Method, Pearson.

Course Code: UMATL80408	Title of the Course: Ramanujan's Theta Functions & Applications to Number theory
L-T-P: 3-0-0	Credits: 3
Semester: VIII	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: Learn the applications and the usefulness of Ramanujan's work.

CLO-2: Understand Rogers-Ramanujan-type functions and their importance in physics.

CLO-3: Learn the work of Ramanujan on partition function and get motivated towards the research.

CLO-4: Work effectively as part of a group to solve challenging problems in Number Theory.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1		1		2		3		1		
CLO2	3			2					2	
CLO3		2	1		2		1	2		
CLO4	1			3			2		1	
CLO5		2				2		2	1	

Course Details:

Unit I: Ramanujan's general theta-function, special cases and their relations, q-series and infinite products, Jacobi triple product identity, Schröter's formulae and theta-function identities.

Unit II: Ramanujan's Modular equations, Class invariants, Evaluation of class invariants, Explicit values of theta-functions.

Unit III: Ramanujan's continued fractions and explicit values, Applications of theta-functions and modular equations to the theory of partitions.

Unit IV: Ramanujan's famous congruences for the partition function, Rogers-Ramanujan-type functions and partition theoretic interpretations.

Course References:

1. B.C. Berndt (2006), Number Theory in the Spirit of Ramanujan, American Mathematical Society.
2. Andrews, George E., The Theory of Partitions (Addition-Wesley, Reading, MA, 1976).
3. Berndt, Bruce C., Ramanujan's Notebooks, Part III, IV and V (Springer, 1991, 1994, 1998).
4. Whittaker, E. T. and Wilson, G. N., A Course in Modern Analysis (Cambridge University Press, Cambridge, 1966. Indian edition is published by Universal Book Stall, New Delhi, 1991).
5. Agarwal, R. P., Resonance of Ramanujan's Mathematics, Vol. I & II (New Age International (P) Limited, New Delhi, 1996).
6. Hardy, G. H., Ramanujan (AMS-Chelsea, New York 1999).

Course Code: UMATL80409	**Title of the Course: Spline Functions and their Applications**
L-T-P: 3-0-0	**Credits: 3**
Semester: VIII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Know the importance of piecewise interpolation, splines.

CLO-2: Understand the importance of B-splines and error estimate.

CLO-3: Interpolate of a function using M-spline, m-spline techniques, B-splines and error bounds.

CLO-4: Solve the ordinary differential equation using B-splines.

CLO-5: Approximate surface using B-splines. Usage of B-splines in mathematical modelling.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					
CLO2	2	2	1	2	3					
CLO3	2	1	1	2	3					
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3					

Course Details:

Unit-I: Interpolation, Piecewise interpolation, spline interpolation: linear, quadratic, cubic and higher order splines and its error analysis, Pade approximate.

Unit-II: Solution of Initial and boundary value problems using M-splines and m-splines. B-splines derivation, interpolation using the B-splines, minimal property of the smoothest interpolating natural spline, solution of differential equation using B-splines.

Unit-III: Application of B-spline in signal processing, image processing and mathematical modelling.

Course References:

1. M.K. Jain, S. R. K. Iyengar & R. K. Jain, Numerical Methods for Scientific and Engineering Computation (6th edition). New Age International Publishers, 2012.

2. F.B. Hildebrand, Introduction to Numerical Analysis, second edition, Dover Publications, Inc, New York,1974.
3. Prenter, P. M., Splines and Variational methods, John Wiley and Sons, 1975.

4. Carl de-boor, A Practical Guide to Splines, Springer-Verlag New York, 1978.

5. H. J. Ahlberg, The theory of splines and their applications, Academic Press, 2012.

Course Code: UMATL80410	Title of the Course: Optimal Control Theory
L-T-P: 3-0-0	Credits: 3
Semester: VIII	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Formulate and analyze optimal control problems using principles of calculus of variations and Euler–Lagrange equation.

CLO-2: Apply Pontryagin's Maximum Principle to derive and solve optimal control problems in both linear and nonlinear systems.

CLO-3: Implement dynamic programming techniques and solve Linear Quadratic Regulator (LQR) problems using Bellman's equation and the Riccati equation.

CLO-4: Utilize numerical methods and model predictive control (MPC) for solving optimal control problems and apply these techniques to practical scenarios in aerospace, robotics, economics, and energy systems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1		1		2		3		1		
CLO2	3			2					2	3
CLO3		2	1		2		1	2		
CLO4	1			3			2		1	
CLO5		2				2		2	1	

Course Details:

Unit-I: Introduction to Optimal Control and Calculus of Variations: Historical Background and Applications, Formulation of Optimal Control Problems, Performance Indices and Cost Functionals, Fundamentals of Calculus of Variations, Euler–Lagrange Equation, Necessary Conditions for Optimality, Applications to Control Problems.

Unit-II: Pontryagin's Maximum Principle: Statement and Interpretation of the Maximum Principle, Proof and Derivations, Application to Linear and Nonlinear Systems, Time-Optimal Control, Fuel-Optimal control, and Energy-Optimal Control.

Unit-III: Dynamic Programming and Linear Quadratic Regulator: Principle of Optimality, Bellman's Equation, Discrete-Time and Continuous-Time Dynamic Programming, Formulation of LQR Problems, Solution via Riccati Equation, Infinite Horizon LQR.

Unit-IV: Numerical Methods and Applications: Discretization Techniques, Numerical Solutions of Two-Point Boundary Value Problems, Gradient-based Methods, Direct Methods (Collocation and Shooting Methods), Model Predictive Control (MPC), Applications (Aerospace, Robotics, Economic systems, Energy Systems).

Course References:

1. E. Bryson and Y. C. Ho (1975), Revised Printing (First Edition), Applied Optimal Control: Optimization, Estimation, and Control, Taylor & Francis, New York. URL: https://doi.org/10.1201/9781315137667,eprint:http://e.guigon.free.fr/rsc/book/BrysonHo75.pdf
2. D. E. Kirk (2004), Optimal Control Theory: An Introduction, Dover Publications. URL: https://store.doverpublications.com/products/9780486434841
3. F. L. Lewis, D. Vrabie, and V. L. Syrmos (2012), Third Edition, Optimal Control, John Wiley & Sons, Inc., Hoboken. URL: https://doi.org/10.1002/9781118122631, eprint: https://lewisgroup.uta.edu/FL%20books/Lewis%20optimal%20control%203rd%20edition%202012.pdf
4. D. P. Bertsekas (2017), Vol. I (Fourth Edition), Dynamic Programming and Optimal Control, Athena Scientific, Belmont. URL: http://athenasc.com/dpbook.html.
5. R. F. Stengel (1994), Optimal Control and Estimation, Dover Publications. URL: https://store.doverpublications.com/products/9780486682006
6. E. B. Lee and L. Markus (1986), Reprint Edition, Foundations of Optimal Control Theory, Robert E. Krieger Publishing Company, Inc., Malabar.
7. C. K. Chui and G. Chen (1989), Linear Systems and Optimal Control, Springer Berlin, Heidelberg. URL: https://doi.org/10.1007/978-3-642-61312-8
8. L. C. Evans (2024), An Introduction to Mathematical Optimal Control Theory, eprint: https: //math.berkeley.edu/~evans/control.course.pdf

Course Code: UMATL80411	**Title of the Course: Advanced Functional Analysis**
L-T-P: 3-0-0	**Credits: 3**
Semester: VIII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: Apply the Picard-Banach Fixed Point Theorem to solve linear, differential, and integral equations.

CLO-2: Analyze spectral properties of bounded and compact linear operators in normed spaces using spectral theory and Banach algebras.

CLO-3: Understand and utilize spectral properties of bounded self-adjoint linear operators, including their spectral representation and positive operators.

CLO-4: Investigate and apply concepts related to unbounded linear operators in Hilbert spaces, including their spectral representation and properties of Hilbert-adjoint, symmetric, and self-adjoint operators.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1		1		2		3		1		
CLO2	3			2					2	3
CLO3		2	1		2		1	2		
CLO4	1			3			2		1	
CLO5		2				2		2	1	

Course Details:

Unit-I: Picard-Banach Fixed Point Theorem: Picard-Banach Fixed Point Theorem, Application of Picard-Banach Fixed Point Theorem to Linear Equations, Application of Picard-Banach Fixed Point Theorem to Differential Equations, Application of Picard-Banach Fixed Point Theorem to Integral Equations.

Unit-II: Spectral Theory of Linear Operators in Normed Spaces: Spectral Theory in Finite Dimensional Normed Spaces, Spectral Properties of Bounded Linear Operators, Properties of Resolvent and Spectrum, Use of Complex Analysis in Spectral Theory, Banach Algebras and their Properties. Compact Linear Operators on Normed Spaces and their Spectral Properties, Operator Equations Involving Compact Linear Operators.

Unit-III: Spectral Theory of Bounded Self-Adjoint Linear Operators: Spectral Properties of Bounded Self-Adjoint Linear Operators, Positive Operators, Square Roots of a Positive Operator, Projection Operators and their Properties, Spectral Family of a Bounded Self-Adjoint Linear Operator, Spectral Representation of Bounded Self-Adjoint Linear Operators, Extension of the Spectral Theorem to Continuous Functions, Properties of the Spectral Family of a Bounded Self-Adjoint Linear Operator.

Unit-IV: Unbounded Linear Operators in Hilbert Space: Unbounded Linear Operators and their Hilbert-Adjoint Operators, Hilbert-Adjoint Operators, Symmetric and Self-Adjoint Linear Operators, Closed Linear Operators and Closures, Spectral Properties of Self-Adjoint Linear

Operators, Spectral Representation of Unitary Operators, Spectral Representation of Self-Adjoint Linear Operators, Multiplication Operator and Differentiation Operator.

Course References:

Text Books:

1. G. Bachman and L. Narici. Functional Analysis. Academic Press, New York, 1972.

2. E. Kreyszig. Introductory Functional Analysis with Applications. John Wiley & Sons, USA, 1978.

3. B. V. Limaye. Functional Analysis, Third Edition. New Age International Publishers, New Delhi, 2014.

4. W. Rudin. Functional Analysis, Second Edition. McGraw-Hill, Singapore, 1991.

Reference Books:

1. A. V. Balakrishnan. Applied Functional Analysis, Second Edition. Springer-Verlag, New York, 1981.

Course Code: UMATL80412	**Title of the Course: Perturbation Methods**
L-T-P: 3-0-0	**Credits: 3**
Semester: VIII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Know asymptotic expansion and approximation of a function.

CLO-2: Learn regular and singular perturbations techniques for first and second-order ordinary differential equations.

CLO-3: Apply different types of techniques for two-point perturbation differential equations.

CLO-4: Understand perturbation methods for solving linear eigenvalue problems.

CLO-5: Apply perturbation methods for solving non-linear eigenvalue problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					

CLO2	2	2	1	2	3					
CLO3	2	1	1	2	3					
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3					

Course Details:

Unit I: Asymptotic expansion and approximation, asymptotic solution of algebraic and transcendental equations, regular and singular perturbations for first and second-order ordinary differential equations, physical examples, initial-value problems.

Unit II: Multiple scales, two-scale asymptotic approximation, averaging technique, composite asymptotic expansions, initial layers - matching by Van Dyke rules.

Unit-III: Two-point boundary-value problems: Boundary layers -exponential and cusp layers, matched asymptotic expansions, composite asymptotic expansions, WKB (Wentzel, Kramers, Brillouin) expansion method, conditions for validity of the WKB approximation, patched asymptotic approximations, WKB solution of inhomogeneous ordinary differential equations.

Unit IV: Perturbation methods for linear eigenvalue problems, Rayleigh-Schrodinger theory, singularity structure of eigenvalues as functions of complex perturbing parameter, level crossing. Nonlinear eigenvalue problems, direct error estimation, oscillatory phenomena - free conservative and free self-sustained oscillations, harmonic resonance, shock and transition layers.

Course References:

1. C.M. Bender, S.A. Orszag, Advanced Mathematical Methods for Scientists and Engineers, Springer, New York, 1999.
2. W. Eckhaus, Asymptotic Analysis of Singular Perturbations, North-Holland, Amsterdam, 1979.
3. J. Kevorkian, J.D. Cole, Perturbation Methods in Applied Mathematics, Springer- Verlag, New York, 1981.
4. P.A. Lagerstrom, Matched Asymptotic Expansions, Springer-Verlag, New York, 1988.
5. J. A. Murdock, Perturbations -Theory and Methods, SIAM -Classics in Applied Mathematics, Vol. 27, SIAM, Philadelphia, 1999.
6. A.H. Nayfeh, Introduction to Perturbation Techniques, John Wiley & Sons, New York, 1981.
7. R.E. O'Malley, Singular Perturbation Methods for Ordinary Differential Equations, Springer-Verlag, New York, 1991.

Course Code: UMATL80413	Title of the Course: Wavelets
L-T-P: 3-0-0	Credits: 3
Semester: VIII	Type of the Course: Theory

Course Learning Outcomes (CLOs)

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

CLO-1: Apply Fourier tools to analyse signal.

CLO-2: Gain knowledge about multiresolution and analyse the signal using the wavelet.

CLO-3: Learn about different types of wavelets and its importance.

CLO-4: Apply Haar wavelet transformation to solve boundary value problems.

CLO-5: Apply wavelet transformation for different signals and image processing applications.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	1	1	2	3					
CLO2	2	2	1	2	3					
CLO3	2	1	1	2	3					
CLO4	2	2	1	2	3					
CLO5	2	2	1	2	3					

Course Details:

Unit I: Vector spaces, Bases, Orthogonality, Orthonormality, Projection, Functions and function spaces Orthogonal functions, Orthonormal functions, Orthogonal basis functions, Fourier series, Orthogonality, Orthonormality and the method of finding the Fourier coefficients Complex Fourier series, Orthogonality of complex exponential bases, Mathematical preliminaries for continuous and discrete Fourier transform, limitations of Fourier domain signal processing. Signal representation with continuous and discrete STFT, concept of time-frequency resolution, Resolution problem associated with STFT, Heisenberg's Uncertainty principle and time frequency tiling, why wavelet transform.

Unit II: The origins of wavelets, Wavelets and other wavelet like transforms, History of wavelet from Morlet to Daubechies via Mallat, Different communities and family of wavelets, Different families of wavelets within wavelet communities. Wavelet transform-A first level introduction, Continuous time-frequency representation of signals, Properties of wavelets used in continuous wavelet transform, Continuous versus discrete wavelet transform.

Unit III: Haar scaling functions and function spaces, Translation and scaling of Orthogonality of translates of ϕ(t), Function space V0 , Finer Haar scaling functions, Concepts of nested vector spaces, Haar wavelet function, Scaled and translated Haar wavelet functions, Orthogonality of ϕ(t) and ψ(t), Normalization of Haar bases at different scales, Refinement relation with respect to normalized bases, Support of a wavelet system, Daubechies wavelets, Plotting the Daubechies wavelets, Bi-orthogonality in vector space, Introduction to Biorthogonal Wavelet Systems, Signal Representation Using Biorthogonal Wavelet System.

Course References:

1. S. Mallat, A Wavelet Tour of Signal Processing, 2nd edition, Academic Press, 1999.
2. M. Vetterli and J. Kovacevic, Wavelets and Sub band Coding, Prentice Hall, 1995.
3. Raghuveer rao and Ajit S. Bopardikar, Wavelet transforms: Introduction, Theory and applications, Pearson Education Asia, 2000.
4. J.C. Goswami and A.K. Chan, Fundamentals of Wavelets: Theory, Algorithms, and Applications, 2nd ed., Wiley, 2011.
5. Michel Misiti, Yves Misiti, Georges Oppenheim, JeanMichel Poggi, Wavelets and their Applications, John Wiley & Sons, 2010.
6. J S Walker, A premier on Wavelets and their scientific applications, CRC press, 2002.

Course Code: UMATL80414	**Title of the Course: Advanced Fluid Mechanics**
L-T-P: 3-0-0	**Credits: 3**
Semester: VIII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

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

CLO-1: Learn the concepts of finite difference and finite volume methods.

CLO-2: Solve the Navier-Stokes equations using semi analytical methods.

CLO-3: Apply the algorithms for various flow problems.

CLO-4: Analyze the different schemes to solve the nonlinear equations.

CLO-5: Transform the governing equations to one plane to another.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	1		1							
CLO2	1		2						2	
CLO3		3	3		1		2		2	
CLO4	3	2	3	2	3		2		2	
CLO5	3	2	3	2	2		2		2	

Course Details:

Unit-I: Introduction: Brief introduction of incompressible and compressible flows, finite difference and finite volume method, example of parabolic and hyperbolic systems and time discretization technique, explicit and implicit methods, upwind and central difference schemes, stability, dissipation and dispersion errors. Point iterative/block iterative methods, Gauss-Seidel iteration (concept of central coefficient and residue, SOR), CGS, matrix solvers, and different acceleration techniques.

Unit-II: Solution of NS equations: Solution of incompressible N-S equation (Explicit time stepping, Semi–explicit time stepping). SMAC method for staggered grid: Predictor - Corrector step, discretization of N-S and continuity equations, Pressure correction Poisson's equation, boundary conditions (no-slip, moving wall, slip boundary and inflow conditions), outflow (zero gradient/Orlanski) boundary conditions for unsteady flows, algorithm for the SMAC method, stability considerations for SMAC method. Semi–implicit method (SIMPLE): Comparison with the SMAC and fully – implicit methods, algorithm for semi–implicit method. Discretization of governing equations and boundary conditions in the FVM framework.

Unit-III: Compressible Flow: N-S and energy equations, properties of Euler equation, linearization. Solution of Euler equation: Explicit and implicit treatment such as Lax-Wendroff, MacCormark, Beam and Warming schemes, Upwind schemes for Euler equation: Steger and Warming, Van Leer's flux splitting, Roe's approximate Riemann solver, TVD schemes. Solution of N-S equations: MacCormack, Jameson algorithm in finite volume formulation and transformed coordinate system.

Unit-IV: FDE in complex geometries: Transformation of governing equation in ξ $\eta-$ plane, transformation of Laplace equation, introduction to geometrical parameters and the accuracy of the solution, basic facts about transformation, grid transformation on complex geometries. N-S equations in transformed plane, matrices and Jacobians.

Course References:

1. Computational Fluid Flow and Heat Transfer, Second Edition by K. Muralidhar, T. Sundararajan (Narosa), 2011.

2. Computational Fluid Dynamics by Chung T. J., Cambridge University Press, 2003.

3. Computational Fluid Dynamics by Tapan K. Sengupta, University Press, 2005.

4. Numerical Computation of Internal and External Flows by Hirch C., Elesvier 2007.

5. Numerical Heat Transfer and Fluid Flow by S. V. Patankar (Hemisphere Series on Computational Methods in Mechanics and Thermal Science)

6. Essential Computational Fluid Dynamics by Zikanov. O., Wiley 2010

Course Code: UMACL80405	**Title of the Course: Parallel Computing**
L-T-P: 2-0-2	**Credits: 3**
Semester: VIII	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Understand the fundamentals of parallel computing.

CLO-2: Analyze the parallel algorithms for solving linear system of equations.

CLO-3: Design parallel algorithms for eigenvalue problems.

CLO-4: Develop parallel algorithm code for iterative methods.

CLO-5: Apply parallel computing method for solving simple differential equations.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1		1		2		3		1		
CLO2	3			2					2	3
CLO3		2	1		2		1	2		
CLO4	1			3			2		1	
CLO5		2				2		2	1	

Course Details:

Unit-I: Introduction to parallel programming: Data parallelism, functional parallelism, pipelining, Flynn’s taxonomy, parallel algorithm design, task/channel model, Foster's design methodology, case studies: boundary value problem, finding the maximum, n-body problem, Speedup and efficiency, Amdahl's law, Gustafson-Barsis's Law, Karp-Flatt Metric, Iso-efficiency metric.

Unit-II: Shared Memory: Fundamentals of Shared Memory Programming, Basic OpenMP concepts, PARALLEL directive, Data scoping rules, Basic OpenMP constructs/directives/calls, Examples, parallelizing an existing code using OpenMP, More advanced OpenMP directives & functions, OpenMP Performance issues, Fundamentals of Distributed Memory Programming, MPI concepts - Point to Point Communications.

Unit-III: The message-passing model: the message-passing interface, MPI standard, basic concepts of MPI: MPI_Init, MPI_Comm_size, MPI_Comm_rank, MPI_Send, MPI_Recv, MPI_Finalize timing the MPI programs: MPI_Wtime, MPI_Wtick, collective communication: MPI_Reduce, MPI_Barrier, MPI_Bcast, MPI_Gather, MPI_Scatter, case studies: the sieve of Eratosthenes, Floyd's algorithm, Matrix-vector multiplication.

Unit-IV: Monte Carlo methods: parallel random number generators, case studies, Matrix multiplication, row wise block-stripped algorithm, Cannon's algorithm, solving linear systems, back substitution, Gaussian elimination. Sorting algorithms: quicksort, parallel quick sort, hyper quick sort, sorting by regular sampling, Fast Fourier transform, combinatorial search, divide and conquer, parallel backtrack search. Practice the programs on above concepts.

Course References:

1. Parallel Computing – Theory and Practice, M. J. Quinn, Tata McGraw-Hill Publishing Company Ltd., 2002, Second Edition.

2. Parallel Programming–Techniques and applications using networked workstations and parallel computers, B. Wilkinson and M. Allen, Pearson Education, 2005, Second Edition.

3. Parallel Programming in C with MPI and OpenMP, Michael J. Quinn, Tata McGraw-Hill Publishing Company Ltd., 2003.

Course Code: UMATL80415	**Title of the Course: Riemannian Geometry**
L-T-P: 3-0-0	**Credits: 3**
Semester: VIII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: define the various geometrical and algebraic concepts that are introduced in the course, and be able to use and interpret them in specific examples.

CLO-2: use and formulate central theorems in Riemannian geometry and Topology, and be able to give an account of their proofs.

CLO-3: understanding of Riemannian sub manifolds, Jacobi fields, completeness, and be able to prove and apply fundamental results in the subject.

CLO-4: use the theory, methods and techniques of the course to solve problems.

CLO-5: understand and work manifolds, tangent spaces and curvature.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	2	1	1	1	1	2	1	1
CLO2	3	2	2	1	1	1	1	1	1	1
CLO3	3	2	1	1	1	1	1	2	1	1
CLO4	3	2	2	1	1	1	1	2	1	1
CLO5	3	2	1	1	1	1	1	1	1	1

Course Details:

Unit 1: Differentiable manifolds: - Charts, Atlases, Differentiable structures, Topology induced by differentiable structures, equivalent atlases, complete atlases. Manifolds. Examples of manifolds. Properties of induced topology on manifolds.

Unit 2: Tangent and cotangent spaces to a manifold. Vector fields. Lie bracket of vector fields. Smooth maps and diffeomorphism. Derivative(Jacobi) of smooth maps and their matrix representation. Pull back functions. Tensor fields and their components. Transformation formula for components of tensors. Operations on tensors. Contraction, Covariant derivatives of tensor fields.

Unit 3: Riemannian Metric. Connections. Riemannian connections and their components, Parallel translation, Fundamental theorem of Riemannian Geometry. Curvature and torsion tensors. Bianchi identities, Curvature tensor of second kind. Sectional curvature. Space of constant curvature. Schur's theorem. Curves and geodesics in Riemannian manifold. Geodesic curvature, Frenet formula.

Unit 4: Hypersurfaces of Riemannian Manifolds Gauss formula, Gauss equation, Codazzi equation, Sectional curvature for a hyper surface of a Riemannian manifold, Gauss map, Weingartan map and Fundamental forms on hypersurface. Equations of Gauss and Codazzi. Gauss theorem egregium.

Course References:

1. Y. Matsushima: Differentiable manifolds. Marcel Dekker Inc. New, York,1972.

2. W.M. Boothby: An introduction to differentiable manifolds and Riemannian Geometry. Academic Press Inc. New York, 1975.
3. N.J. Hicks: Notes on differential Geometry D. Van Nostrand company Inc. Princeton, New Jersey, New York, London (Affiliated East-West Press Pvt. Ltd. New Delhi), 1998.

REFERENCE BOOKS

4. R.L. Bishop and Grittendo: Geometry of manifolds. Acamedic Press, New York, 1964.
5. L.P. Eisenhart: Riemannian Geometry. Princeton University Press, Princetion, New Jersey, 1949.
6. H. Flanders: Differential forms with applications to the physical science, Academic Press, New York, 1963.
7. R.L. Bishop and S.J. Goldberg: Tensor analysis on manifolds, Macmillan Co., 1968.
8. K. S. Amur, D.J. Shetty and C. S. Bagewadi, An introduction to differential Geometry, Narosa Pub. New Dehli, 2010.

Course Code: UMACL80406	**Title of the Course: Multi Objective Programming**
L-T-P: 2-0-2	**Credits: 3**
Semester: VIII	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: learn the concepts behind multi-objective optimization.

CLO-2: understand Optimization models and apply them to real life problems.

CLO-3: understand the applications to problems in project management and other areas of engineering.

CLO-4: understand the concept of Fuzzy programming.

CLO-5: understand the applications of multi-objective programming to some real-world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	3	3	2	2	2	3	3	2
CLO2	2	3	1	3	2	2	3	2	3	2
CLO3	1	3	2	3	2	2	2	3	3	2
CLO4	1	3	1	3	2	2	1	2	3	1
CLO5	2	3	1	3	2	2	1	2	3	2

Course Details:

Unit-I: Prerequisite: Operations Research Formulation of multi-objective (linear and non-linear programming) problems and related terms, dominated and non-dominated solutions. Mathematics courses including: multi-variable Calculus, linear algebra.

Unit-II: Goal programming - Graphical method, sequential goal programming method, multiphase simplex method.

Unit-III: Fuzzy programming, vector maximum and vector minimum problems, linear and non-linear membership functions, compromise solutions, utility function method, weighting method.

Unit-IV: Analytic hierarchy process, ranking method, surrogate worth trade off method, step method, e-constrained method, global criterion method, group decision making. Applications of multi-objective programming to some real-world problems.

Course References:

1. Multiple Criteria Optimization: Theory, Computation, and Application," Ralph E. Steuer, John Wiley & Sons, 1986.
2. Multi objective Programming and Planning, Jared L. Cohon, Academic Press, 1978.
3. Nonlinear Multi objective Optimization, Kaisa M. Miettinen, Kluwer Academic Press, 1999.
4. Operations Research Applications and Algorithms, Wayne L. Winston, Duxbury Press, 1994.
5. H. A. Taha (2014), Operations Research, An Introduction, PHI, New Delhi.
6. N. S. Kambo (1991), Mathematical Programming Techniques, East-West Pub., Delhi.
7. Kanti Swarup, P. K. Gupta and Man Mohan (2010), Operations Research, Sultan Chand and Co, New Delhi.
8. J. C. Pant (2012), Introduction to Operations Research, Jain Brothers, New Delhi.
9. H. M. Wagner (2010), Principles of Operations Research, PHI, Delhi.
10. J. C. Pant (2015), Introduction to Optimization: Operations Research, Jain Brothers, Delhi.

Course Code: UMATL80416	**Title of the Course: Bio-fluid Mechanics**
L-T-P: 3-0-0	**Credits: 3**
Semester: VIII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Estimate volumetric flow rate of blood in blood vessels.

CLO-2: Analyse pressure in stenotic regions in blood vessels.

CLO-3: Simplify governing equations for blood flow by taking small amplitude and long wave length.

CLO-4: Analyse filtration process of the blood flow in Renal tubes.

CLO-5: Apply the concepts to real world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2									
CLO2	2			2		2				
CLO3	1			1	3	2				
CLO4	2	2	1	2	3	2				
CLO5	2	2	1	3	3	2				

Course Details:

Unit I: Fundamental concepts of Biomechanics: Introduction

Unit II: Cardiovascular System: Basic concepts about blood, Blood vessels, Governing equations,

Models on blood flow, Flow in large blood vessels, Microcirculation, Pulsatile flow, Stenotic region flow.

Unit III: Peristalsis: Basic concepts, Governing equations, Peristaltic transport under long wave

length approximation, Peristaltic flow for small amplitudes and small Reynold's number.

Unit IV: Flow in Renal Tubules: Basic concepts, Governing equations, Ultra-filtration, Flow through proximal tubules, Flow through tubes with varying cross section.

Course References:

Text Books:

1. Mathematical Models in Biology and Medicine, J. N. Kapur, Affiliated East West Press, 1992
2. Biodynamics: Circulation, Y. C. Fung, Springer-Verlag New York, 2010, Second Edition

Reference Books:

1. Mechanics of Circulation, C. G. Caro, T. J. Pedley, R. C. Schroter, and W. A. Seed, Oxford University Press, 2011

Course Code: UMATL80417	Title of the Course: Cyber Security
L-T-P: 3-0-0	Credits: 3
Semester: VIII	Type of the Course: Theory

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Understand cyber security fundamentals

CLO-2: Analyze cyber security threats and vulnerabilities in Information Systems and apply security measures to real time scenarios

CLO-3: Design and implement appropriate security techniques and cyber policies to protect computers and digital information.

CLO-4: Demonstrate the use of standards and cyber laws to enhance information security in the development process and infrastructure protection

CLO-5: Apply Cyber Forensics and Laws for real world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2									
CLO2	2									
CLO3			1							
CLO4	2		3	3	1		2	2		
CLO5	2		3	3	3		2	2		

Course Details:

Unit I: Introduction to Cyber Security: Overview of Cyber Security, Internet Governance – Challenges and Constraints, Cyber Threats: - Cyber Warfare-Cyber Crime-Cyber terrorism-Cyber Espionage, need for a Comprehensive Cyber Security Policy, need for a Nodal Authority, Need for an International convention on Cyberspace.

Unit II: Cyber Security Vulnerabilities and Safeguards: Cyber Security Vulnerabilities-Overview, vulnerabilities in software, System administration, Complex Network Architectures, Open Access to Organizational Data, Weak Authentication, Unprotected Broadband communications, Poor Cyber Security Awareness. Cyber Security Safeguards- Overview, Access control, Audit, Authentication, Biometrics, Cryptography, Deception, Denial of Service Filters, Ethical Hacking, Firewalls, Intrusion Detection Systems, Response, Scanning, Security policy, Threat Management.

Unit III: Securing Web Application, Services and Servers: Introduction, Basic security for HTTP Applications and Services, Basic Security for SOAP Services, Identity Management and Web Services, Authorization Patterns, Security Considerations, Challenges.

Intrusion Detection and Prevention: Intrusion, Physical Theft, Abuse of Privileges, Unauthorized Access by Outsider, Malware infection, Intrusion detection and Prevention Techniques, Anti-Malware software, Network based Intrusion detection Systems, Network based Intrusion Prevention Systems, Host based Intrusion prevention Systems, Security Information Management, Network Session Analysis, System Integrity Validation.

Unit IV: Cyber Forensics and Laws: Introduction to Cyber Forensics, Handling Preliminary Investigations, controlling an Investigation, conducting disk-based analysis, Investigating Information-hiding, Scrutinizing E-mail, Validating E-mail header information, Tracing Internet access, Tracing memory in real-time. Cyberspace and the Law: Cyber Security Regulations, Roles of International Law, the state and Private Sector in Cyberspace, Cyber Security Standards. The INDIAN Cyberspace, National Cyber Security Policies

Course References:

1. James Graham, Richard Howard, Ryan Olson, "Cyber Security Essentials", CRC Press, 2016.
2. Nina Godbole and Sunit Belapure, "Cyber Security", Wiley India, 2012

Course Code: UMACL80410	**Title of the Course: Quantum Computing**
L-T-P: 2-0-2	**Credits: 3**
Semester: VIII	**Type of the Course: Theory cum Practical**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Understand the basics of quantum computing.

CLO-2: Learn Deutsch and Deutsch–Jozsa and Grover's Search algorithms.

CLO-3: Learn Spintronics and QED approaches

CLO-4: Apply Quantum Computing approaches.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	2								
CLO2	2									
CLO3	1		1	1	2		1	1		
CLO4	2		3	3	1	2	2	3		
CLO5										

Course Details:

Unit I: Quantum Measurements Density Matrices, Positive-Operator Valued Measure, Fragility of quantum information: Decoherence, Quantum Superposition and Entanglement, Quantum Gates and Circuits, No cloning theorem & Quantum Teleportation, Bell's inequality and its implications, Quantum Algorithms &Circuits.

Unit II: Deutsch and Deutsch–Jozsa algorithms, Grover's Search Algorithm, Quantum Fourier Transform Shore's Factorization Algorithm, Quantum Error Correction: Fault tolerance, Quantum Cryptography.

Unit III: Implementing Quantum Computing: issues of fidelity, Scalability in quantum computing NMR Quantum Computing, Spintronics and QED approaches, Linear Optical Approaches Nonlinear Optical Approaches, Limits of all the discussed approaches, How promising is the future?

Course References:

1. Michael A. Nielsen and Issac L. Chuang, "Quantum Computation and Information", Cambridge (2002).
2. Riley Tipton Perry, "Quantum Computing from the Ground Up", World Scientific Publishing Ltd (2012).
3. Scott Aaronson, "Quantum Computing since Democritus", Cambridge (2013).
4. P. Kok, B. Lovett, "Introduction to Optical Quantum Information Processing", Cambridge (2010).

Course Code: UMATL80418	**Title of the Course: Quantum Mechanics**
L-T-P: 3-0-0	**Credits: 3**
Semester: VIII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Understand the evolution of quantum mechanics.

CLO-2: Solve potential well problems using Schrödinger wave equation.

CLO-3: Analyze the commutation relations between spin and angular momentum.

CLO-4: Apply variational principle and perturbation theory to standard systems as appropriate.

CLO-5: Apply approximation methods.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	2								
CLO2	2									
CLO3	1		1	2	2		1	1		
CLO4	2		3	3	1		2	2		
CLO5	2		3	3	3		2	2		

Course Details:

Unit I: Origin of Quantum Mechanics and One-Dimensional Problems: The development of quantum physics, basic preliminaries, wave particle duality, one dimensional Schrodinger equation, the free particle problem in one dimension, wave packets and group velocity. One-dimensional problems: Potential well of infinite and finite depths/potentials and the linear harmonic oscillator.

Unit II: Three-Dimensional Problems: Angular momentum-I and rotation.

Unit III: Schrodinger equation: Particle in a box with applications to the free electron model, particle in a spherically symmetric potential problem and the hydrogen atom problem. Dirac's bra-ket algebra: Linear harmonic oscillator problem using bra-ket algebra, creation and annihilation operators, transition to the classical oscillator, coherent states.

Unit IV: The angular momentum-II: The angular momentum problem using bra-ket algebra, ladder operators, angular momentum and spin matrices. The Stern Gerlach and magnetic resonance experiments. Addition of angular Momenta and Clebsch Gordon coefficients. Approximation methods: Perturbation theory, the variational principle and their applications.

Course References:

Text Books:

1. Quantum Mechanics: Theory and Applications, A. Ghatak and S. Lokanathan, Trinity

Press, 6th edition, 2020.

2. Introduction to Quantum Mechanics, David J. Griffiths and D. F. Schroeter, Cambridge University Press, 3rd edition, 2018.

Reference Books:

1. Quantum Mechanics: Concepts and applications, Nouredine Zettilli, John Wiley & Sons, 2nd edition, 2009.
2. Quantum Mechanics, G. Aruldhas, PHI Learning Private Ltd, 2nd edition, 2009.

Online Resources:

1. http://www.nptelvideos.in/2012/11/quantum-mechanics-and-applications.html
2. https://nptel.ac.in/courses/122/106/122106034

Course Code: UMATL80419	**Title of the Course: Block Chain Technologies**
L-T-P: 3-0-0	**Credits: 3**
Semester: VIII	**Type of the Course: Theory**

Course Learning Outcomes (CLOs)

After studying this course, the student will be able to

CLO-1: Understand the concepts of Blockchain Technology and its Importance.

CLO-2: Learn the Elements of a Blockchain.

CLO-3: Apply Permissioned Models.

CLO-4: Use Decentralized Identity Management.

CLO-5: Analyze Blockchain Interoperability

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	2								
CLO2	2									
CLO3	1	1	2	2	2		1	1		
CLO4	2	1	3	3	3		2	2		
CLO5	2		3	3	3		2	2		

Course Details:

Unit I: Introduction to Blockchain Technology and its Importance, Basic Crypto Primitives I – Cryptographic Hash, Basic Crypto Primitives II – Digital Signature.

Unit II: Evolution of the Blockchain Technology, Elements of a Blockchain, Blockchain Consensus I – Permissionless Models.

Unit III: Blockchain Consensus II – Permissioned Models, Smart Contract Hands On I – Ethereum Smart Contracts (Permissionless Model), Smart Contract Hand On II – Hyperledger Fabric (Permissioned Model)

Unit IV: Decentralized Identity Management, Blockchain Interoperability, Blockchain Applications.

Course References:

1. Mastering Blockchain: A deep dive into distributed ledgers, consensus protocols, smart contracts, DApps, cryptocurrencies, Ethereum, and more, 3rd Edition, Imran Bashir, Packt Publishing, 2020, ISBN: 9781839213199, book website: https://www.packtpub.com/product/mastering-blockchain-third-edition/9781839213199
2. Hyperledger Tutorials - https://www.hyperledger.org/use/tutorials
3. Ethereum Development Resources - https://ethereum.org/en/developers