Kurukshetra University, Kurukshetra

(Established by the State Legislature Act-XII of 1956)

("A+" Grade, NAAC Accredited)

SCHEME/STRUCTURE and SYLLABUS

of

Master of Science in Mathematics

CBCS LOCF

With Effect From Academic Session 2020-21

DEPARTMENT OF MATHEMATICS

KURUKSHETRA UNIVERSITY, KURUKSHETRA -136119

HARYANA, INDIA

1. **Program Outcomes (POs)**

PO1	Knowledge	Capable of demonstrating comprehensive disciplinary knowledge gained during course of study
PO2	Research Aptitude	Capability to ask relevant/appropriate questions for identifying, formulating and analyzing the research problems and to draw conclusion from the analysis
PO3	Communication	Ability to communicate effectively on general and scientific topics with the scientific community and with society at large
PO4	Problem Solving	Capability of applying knowledge to solve scientific and other problems
PO5	Individual and Team Work	Capable to learn and work effectively as an individual, and as a member or leader in diverse teams, in multidisciplinary settings.
PO6	Investigation of Problems	Ability of critical thinking, analytical reasoning and research based knowledge including design of experiments, analysis and interpretation of data to provide conclusions
PO7	Modern Tool usage	Ability to use and learn techniques, skills and modern tools for scientific practices
PO8	Science and Society	Ability to apply reasoning to assess the different issues related to society and the consequent responsibilities relevant to the professional scientific practices
PO9	Life-Long Learning	Aptitude to apply knowledge and skills that are necessary for participating in learning activities throughout life
PO10	Ethics	Capability to identify and apply ethical issues related to one’s work, avoid unethical behaviour such as fabrication of data, committing plagiarism and unbiased truthful actions in all aspects of work
PO11	Project Management	Ability to demonstrate knowledge and understanding of the scientific principles and apply these to manage projects

2. **Program Specific Outcomes (PSOs)**
   After successful completion of the programme, a student will be able to:

PSO1	Have deep understanding and knowledge in the core areas of Mathematics and demonstrate understanding and application of the concepts/theories/principles/ methods/ techniques in different areas of pure and applied Mathematics.
PSO2	Have capability to read and understand mathematical texts, demonstrate and communicate mathematical knowledge effectively and unambiguously through oral and/or written expressions and attain skills of computing/programming/using software tools/formulating models.
PSO3	Attain abilities of critical thinking, logical reasoning, investigating problems, analysis, problem solving, application of mathematical methods/techniques, disciplinary knowledge so as to develop skills to solve mathematical problems having applications in other disciplines and/or in the real world.
PSO4	Have strong foundation in basic and applied aspects of Mathematics so as to venture into research in different areas of mathematical sciences, jobs in scientific and various industrial sectors and/or teaching career in Mathematics.

3. **Programme Scheme/ Structure:**

The M.Sc. Mathematics programme is a two-year programme divided into foursemesters. A student is required to complete at least 116 credits for the completion of the course and the award of degree. Of these, 82 credits have to be earned from Core Courses, 30 from Elective coursesand 4 credits from open elective courses.

	SEMESTER	**SEMESTER**
PART-I (FIRST YEAR)	Semester I	Semester II
PART-II (SECOND YEAR)	Semester III	Semester IV

This Scheme will be effective in phased manner from the session 2020-21 initially for University Teaching Department of Mathematics.

4. **4.1 Course Credit Scheme:**

Semester	Core Courses			Elective Courses			Open Elective Courses			Total Credits
	No. of Courses	Credits (L+T+P+S)	Total Credits	No. of Courses	Credits (L+T)	Total Credits	No. of Courses	Credits (L+T)	Total Credits	
I	7	20+5+2+2	29	Nil	Nil	Nil	Nil		Nil	**29**
II	6	20+5+2+0	27	Nil	Nil	Nil	1	2+0	2	**29**
III	3	8+2+2+0	12	03	12+3	15	1	2+0	2	**29**
IV	4	8+2+2+2	14	03	12+3	15	Nil		Nil	**29**
Maximum Credits including Open Elective offered by the other departments			**82**			**30**			**4***	**116**
							***4 Credits are to be earned from open electives of other Departments or from MOOCs courses**			
Minimum Credits Required			**82**			**30**			**4***	**116**

4.2 Contact hours per weeks for M.Sc. Mathematics CBCS LOCF Programme

	Core Courses (CC)	Elective Courses	Open Elective Courses	Total hours
Theory	56	24	4	84
Tutorial	14	6	-	20
Practical	16	-	-	16
Seminar	4		-	4
Total	90	30	4	**124**

4.3 Duration of Examination Hours

Duration of End Term Theory Examination	3 Hours
Duration of End Term Practical Examination	4 Hours

5. **Structure/Scheme of Examination for M.Sc. Mathematics CBCS LOCF Programme**

Semester	Core Courses	Elective Courses	Open Elective Courses
I	Core Course 1 Abstract Algebra Core Course 2 Complex Analysis Core Course 3 Ordinary Differential Equations Core Course 4 Real Analysis Core Course 5 Topology Core Course 6 Practical-I Core Course 7 Seminar-I		
II	Core Course 8 Advanced Abstract Algebra Core Course 9 Computer Programming with MATLAB Core Course 10 Differential Equations Core Course 11 Measure and Integration Core Course 12 Mechanics of Solids Core Course 13 Practical-II		Open Elective 1 Basic Mathematics-I
III	Core Course 14 Fluid Mechanics Core Course 15 Functional Analysis Core Course 16 Practical-III	Elective 1 Elective 2 Elective 3	Open Elective 2 Basic Mathematics-II
IV	Core Course 17 Mechanics and Calculus of Variations Core Course 18 Partial Differential Equations Core Course 19 Practical-IV Core Course 20 Seminar-II	Elective 4 Elective 5 Elective 6	
Note: **Open Elective Course :**In each of the Semester II and Semester III, one open Elective course is to be opted out of the list of such courses offered at the University/Institute/College level OR one can choose a MOOC course of minimum credit 2 offered at SWAYAM Portal in that semester.			
Note: The open elective courses, Basic Mathematics-I and Basic Mathematics-II, will be offered to the students other than students of M.Sc. Mathematics Programme.			

with effect from the Session 2020-21 in phased manner

Elective 1- A student will opt for one of the following courses:

i.	MMATH21-304	Advanced Topology
ii.	MMATH21-305	Commutative Algebra
iii.	MMATH21-306	Differential Geometry
iv.	MMATH21-307	Elasticity

Elective 2- A student will opt for one of the following courses:

i.	MMATH21-308	Advanced Numerical Analysis
ii.	MMATH21-309	Fuzzy Sets and Applications
iii.	MMATH21-310	Mathematical Statistics
iv.	MMATH21-311	Number Theory

Elective 3- A student will opt for one of the following courses:

i.	MMATH21-312	Algebraic Coding Theory
ii.	MMATH21-313	Financial Mathematics
iii.	MMATH21-314	Integral Equations
iv.	MMATH21-315	Mathematical Modeling

Elective 4 - A student will opt for one of the following courses:

i.	MMATH21-405	Advanced Complex Analysis
ii.	MMATH21-406	Algebraic Number Theory
iii.	MMATH21-407	General Measure and Integration Theory
iv.	MMATH21-408	Mathematical Aspects of Seismology

Elective 5 - A student will opt for one of the following courses:

i.	MMATH21-409	Advanced Discrete Mathematics
ii.	MMATH21-410	Advanced Functional Analysis
iii.	MMATH21-411	Advanced Fluid Mechanics
	MMATH21-412	Boundary Value Problems

Elective 6 - A student will opt for one of the following courses:

	MMATH21-413	Bio-Mathematics
	MMATH21-414	Fourier and Wavelet Analysis
	MMATH21-415	Linear Programming
	MMATH21-416	Non-Commutative Rings

Choice of Elective Courses:

Under each Elective course a student may choose one course from a given basket of four options or amongst the courses actually offered by the Department/Institute/College. In case a particular course is over-subscribed, merit in the previous semester(s) examination(s) or the number of preferencesor the availability of teacher(s) or feasibility of the option will be taken into account to determine course allocations. The decision of the Department/Institute/College shall be final in this regard.

Scheme / Structure of M.Sc. Mathematics CBCS LOCF Programme with effect from the Session 2020-21 in phased manner

Semester - I

Course Code	Course Type	Nomenclature	Teaching Hours			Credits	Maximum Marks		
			L	**P**	**T/S**		**Ext**	**Int**	**Total**
MMATH20-101	Core	Abstract Algebra	4	0	1	5	80	20	100
MMATH20-102	Core	Complex Analysis	4	0	1	5	80	20	100
MMATH20-103	Core	Ordinary Differential Equations	4	0	1	5	80	20	100
MMATH20-104	Core	Real Analysis	4	0	1	5	80	20	100
MMATH20-105	Core	Topology	4	0	1	5	80	20	100
MMATH20-106	Core	Practical-I	0	4	0	2	40	10	50
MMATH20-107	Core	Seminar-I	0	0	2	2	0	50	50
		Total	**20**	**4**	**7**	**29**	**440**	**160**	**600**

Each End Term Theory Examination will be of three hours duration and End Term Practical Examination will be of four hours duration.

Semester – II

Course Code	Course Type	Nomenclature	Teaching Hours per week			Credits	Maximum Marks		
			L	**P**	**T/S**		**Ext**	**Int**	**Total**
MMATH20-201	Core	Advanced Abstract Algebra	4	0	1	5	80	20	100
MMATH20-202	Core	Computer Programming with MATLAB	4	0	1	5	80	20	100
MMATH20-203	Core	Differential Equations	4	0	1	5	80	20	100
MMATH20-204	Core	Measure and Integration	4	0	1	5	80	20	100
MMATH20-205	Core	Mechanics of Solids	4	0	1	5	80	20	100
MMATH20-206	Core	Practical-II	0	4	0	2	40	10	50
	Open Elective	Open Elective 1 #	-	-	-	2	40	10	50
		# One Open Elective course is to be opted out of the list of such courses offered at the University/Institute level OR A MOOC course offered at SWAYAM Portal in an even semester.							
OEM20-207	Open Elective	Basic Mathematics-I	2	0	0	2*	40*	10*	50*
		(*This open elective course will be offered and credited to the students other than students of M.Sc. Mathematics)							
		Total	**22**	**4**	**5**	**29**	**480**	**120**	**600**

Each End Term Theory Examination will be of three hours duration and End Term Practical Examination will be of four hours duration.

Semester – III

Course Code	Course Type	Nomenclature	Teaching Hours per week			Credits	Maximum Marks		
			L	P	T/S		Ext	Int	Total
Core Papers									
MMATH21 -301	Core	Fluid Mechanics	4	0	1	5	80	20	100
MMATH21 -302	Core	Functional Analysis	4	0	1	5	80	20	100
MMATH21 -303	Core	Practical-III	0	4	0	2	40	10	50
Elective 1		**Any One of the following:**							
MMATH21 -304	Elective	Advanced Topology	4	0	1	5	80	20	100
MMATH21 -305	Elective	Commutative Algebra	4	0	1	5	80	20	100
MMATH21 -306	Elective	Differential Geometry	4	0	1	5	80	20	100
MMATH21 -307	Elective	Elasticity	4	0	1	5	80	20	100
Elective 2		**Elective**							
MMATH21 -308	Elective	Advanced Numerical Analysis	4	0	1	5	80	20	100
MMATH21 -309	Elective	Fuzzy Sets and Applications	4	0	1	5	80	20	100
MMATH21 -310	Elective	Mathematical Statistics	4	0	1	5	80	20	100
MMATH21 -311	Elective	Number Theory	4	0	1	5	80	20	100
Elective 3		**Elective**							
MMATH21 -312	Elective	Algebraic Coding Theory	4	0	1	5	80	20	100

MMATH21-313	Elective	Financial Mathematics	4	0	1	5	80	20	100
MMATH21-314	Elective	Integral Equations	4	0	1	5	80	20	100
MMATH21-315	Elective	Mathematical Modeling	4	0	1	5	80	20	100
	Open Elective	Open Elective 2#	-	-	-	2	40	10	50
		# One Open Elective course is to be opted out of the list of such courses offered at the University/Institute level OR A MOOC course offered at SWAYAM Portal in an odd semester.							
OEM21-316	Open Elective	Basic Mathematics-II *	2	0	0	2*	40*	10*	50*
		(*This open elective paper will be offered and credited to the students other than students of M.Sc. Mathematics)							
		Total	**22**	**4**	**5**	**29**	**480**	**120**	**600**

Each End Term Theory Examination will be of three hours duration and End Term Practical Examination will be of four hours duration.

Semester – IV

Course Code	Course Type	Nomenclature	Teaching Hours per week			Credits	Maximum Marks		
			L	P	T/S		Ext	Int	Total
Core Papers									
MMATH21-401	Core	Mechanics and Calculus of Variations	4	0	1	5	80	20	100
MMATH21-402	Core	Partial Differential Equations	4	0	1	5	80	20	100
MMATH21-403	Core	Practical – IV	0	4	0	2	40	10	50
MMATH21-404	Core	Seminar-II	0	0	2	2	0	50	50
Elective 4		**Any One of the following:**							
MMATH21-405	Elective	Advanced Complex Analysis	4	0	1	5	80	20	100
MMATH21-406	Elective	Algebraic Number Theory	4	0	1	5	80	20	100
MMATH21-407	Elective	General Measure and Integration Theory	4	0	1	5	80	20	100
MMATH21-408	Elective	Mathematical Aspects of Seismology	4	0	1	5	80	20	100
Elective 5		**Any One of the following:**							
MMATH21-409	Elective	Advanced Discrete Mathematics	4	0	1	5	80	20	100
MMATH21-410	Elective	Advanced Functional Analysis	4	0	1	5	80	20	100

MMATH21-411	Elective	Advanced Fluid Mechanics	4	0	1	5	80	20	100
MMATH21-412	Elective	Boundary Value Problems	4	0	1	5	80	20	100
Elective 6		**Any One of the following:**							
MMATH21-413	Elective	Bio-Mathematics	4	0	1	5	80	20	100
MMATH21-414	Elective	Fourier and Wavelet Analysis	4	0	1	5	80	20	100
MMATH21-415	Elective	Linear Programming	4	0	1	5	80	20	100
MMATH21-416	Elective	Non-Commutative Rings	4	0	1	5	80	20	100
		Total	**20**	**4**	**7**	**29**	**440**	**160**	**600**

Each End Term Theory Examination will be of three hours duration and End Term Practical Examination will be of four hours duration.

CO-PSO matrix for the course MMATH20-101 (Abstract Algebra)

COs	PSO1	PSO2	PSO3	PSO4
MMATH20-101.1	3	2	2	2
MMATH20-101.2	3	2	2	3
MMATH20-101.3	3	2	2	2
MMATH20-101.4	3	2	3	3
Average	**3**	**2**	**2.25**	**2.5**

CO-PO matrix for the course MMATH20-101 (Abstract Algebra)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH 20-101.1	3	3	2	3	-	2	2	-	2	-	2
MMATH 20-101.2	3	3	2	3	-	2	2	-	2	-	2
MMATH 20-101.3	3	3	2	3	-	2	2	-	2	-	2
MMATH 20-101.4	3	3	2	3	-	2	2	-	2	-	2
Average	**3**	**3**	**2**	**3**	**-**	**2**	**2**	**-**	**2**	**-**	**2**

CO-PSO matrix for the course MMATH20-102 (COMPLEX ANALYSIS)

COs	PSO1	PSO2	PSO3	PSO4
MMATH20-102.1	3	3	2	3
MMATH20-102.2	3	2	3	3
MMATH20-102.3	2	3	3	3
MMATH20-102.4	2	3	3	3
Average	**2.5**	**2.75**	**2.75**	**3**

CO-PO matrix for the course MMATH20-102 (COMPLEX ANALYSIS)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-102.1	3	2	3	3	2	2	3	2	3	--	--
MMATH20-102.2	3	2	3	3	2	2	3	2	3	--	--
MMATH20-102.3	3	2	3	3	2	2	3	2	3	--	2
MMATH20-102.4	3	2	3	3	2	2	3	2	3	--	2
Average	**3**	**2**	**3**	**3**	**2**	**2**	**3**	**2**	**3**	**--**	**2**

CO-PSO matrix for the course MMATH20-103 (Ordinary Differential Equations)

	PSO1	PSO2	PSO3	PSO4
MMATH20-103.1	3	3	3	3
MMATH20-103.2	3	3	3	3
MMATH20-103.3	3	3	3	3
MMATH20-103.4	3	2	2	3
Average	**3**	**2.75**	**2.75**	**3**

CO-PO matrix for the course MMATH20-103 (Ordinary Differential Equations)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-103.1	3	3	3	3	2	2	2	2	3	-	2
MMATH20-103.2	3	3	3	3	3	3	3	3	3	-	3
MMATH20-103.3	3	3	3	3	3	3	3	3	3	--	3
MMATH20-103.4	3	3	3	3	2	2	2	3	3	-	2
Average	**3**	**3**	**3**	**3**	**2.5**	**2.5**	**2.5**	**2.75**	**3**	**-**	**2.5**

CO-PSO matrix for the course MMATH20-104 (Real Analysis)

COs	PSO1	PSO2	PSO3	PSO4
MMATH20-104 .1	3	3	3	3
MMATH20-104 .2	3	2	2	3
MM20-104 .3	3	3	3	3
MM20-104 .4	3	3	3	3
Average	**3**	**2.75**	**2.75**	**3**

CO-PO matrix for the course MMATH20-104 (Real Analysis)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-104 .1	3	3	3	3	3	3	3	3	3	-	2
MMATH20-104 .2	3	3	2	3	2	3	2	2	3	-	-
MMATH20-104 .3	3	3	2	3	2	3	2	2	3	--	-
MMATH20-104 .4	3	3	3	3	3	3	3	3	3	-	3
Average	**3**	**3**	**2.5**	**3**	**2.5**	**3**	**2.5**	**2.5**	**3**	**-**	**2.5**

CO-PSO matrix for the course MMATH20-105 (Topology)

COs	PSO1	PSO2	PSO3	PSO4
MMATH20-105 .1	3	3	3	3
MMATH20-105 .2	3	2	2	3
MMATH20-105 .3	3	2	3	3
MMATH20-105 .4	3	3	2	3
Average	**3**	**2.5**	**2.5**	**3**

CO-PO matrix for the course MMATH20-105 (Topology)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-105 .1	3	3	2	3	2	3	3	3	3	-	2
MMATH20-105 .2	3	3	2	3	2	3	2	2	3	-	-
MMATH20-105 .3	3	3	2	3	2	3	2	2	3	--	-
MMATH20-105 .4	3	3	2	3	2	3	2	2	3	-	2
Average	**3**	**3**	**2**	**3**	**2**	**3**	**2.25**	**2.25**	**3**	**-**	**2**

CO-PSO matrix for the course MMATH20-106 (PRACTICAL-I)

COs	PSO1	PSO2	PSO3	PSO4
MMATH20-106.1	3	3	3	2
MMATH20-106.2	3	3	3	3
MMATH20-106.3	2	3	3	3
MMATH20-106.4	2	3	3	3
Average	**2.25**	**3**	**3**	**2.75**

CO-PO matrix for the course MMATH20-106 (PRACTICAL-I)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-106.1	3	3	2	3	3	3	3	--	3	--	3
MMATH20-106.2	3	3	2	3	3	3	3	--	3	--	3
MMATH20-106.3	3	3	2	3	3	3	3	3	3	--	3
MMATH20-106.4	3	3	2	3	3	3	3	3	3	--	3
Average	**3**	**3**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**--**	**3**

CO-PSO matrix for the course MMATH20-107 (SEMINAR-I)

COs	PSO1	PSO2	PSO3	PSO4
MMATH20-107.1	3	3	2	3
MMATH20-107.2	3	3	3	3
MMATH20-107.3	3	3	3	3
MMATH20-107.4	3	3	2	3
Average	**3**	**3**	**2.5**	**3**

CO-PO matrix for the course MMATH20-107 (SEMINAR-I)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-107.1	3	3	2	2	3	3	2	3	3	1	3
MMATH20-107.2	3	3	2	3	2	3	2	3	3	1	3
MMATH20-107.3	3	2	3	3	3	2	2	2	3	1	3
MMATH20-107.4	3	2	3	3	3	3	2	2	3	1	3
Average	**3**	**2.5**	**2.5**	**2.75**	**2.75**	**2.75**	**2**	**2.5**	**3**	**1**	**3**

CO-PSO matrix for the course MMATH20-201 (Advanced Abstract Algebra)

COs	PSO1	PSO2	PSO3	PSO4
MMATH20-201.1	3	2	2	2
MMATH20-201.2	3	2	2	2
MMATH20-201.3	3	2	2	2
MMATH20-201.4	3	2	3	3
Average	**3**	**2**	**2.25**	**2.25**

CO-PO matrix for the course MMATH20-201 (Advanced Abstract Algebra)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH 20-201.1	3	3	2	3	-	2	2	-	2	-	2
MMATH 20-201.2	3	3	2	3	-	2	2	-	2	-	2
MMATH 20-201.3	3	3	2	3	-	2	2	-	2	--	2
MMATH 20-201.4	3	3	2	3	-	2	2	-	2	-	2
Average	**3**	**3**	**2**	**3**	**-**	**2**	**2**	**-**	**2**	**-**	**2**

CO-PSO matrix for the course MMATH20-202 (COMPUTER PROGRAMMING with MATLAB)

COs	PSO1	PSO2	PSO3	PSO4
MMATH20-202.1	2	2	3	3
MMATH20-202.2	3	3	3	3
MMATH20-202.3	2	2	3	3
MMATH20-202.4	3	3	3	3
Average	**2.5**	**2.5**	**3**	**3**

CO-PO matrix for the course MMATH20-202 (COMPUTER PROGRAMMING with MATLAB)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-202.1	3	2	2	2	3	3	3	3	3	--	3
MMATH20-202.2	3	3	3	3	3	3	3	3	3	--	3
MMATH20-202.3	3	3	3	3	3	2	3	3	3	--	3
MMATH20-202.4	3	3	2	3	3	3	3	3	3	--	3
Average	**3**	**2.75**	**2.5**	**2.75**	**3**	**2.75**	**3**	**3**	**3**	**--**	**3**

CO-PSO matrix for the course MMATH20-203 (Differential Equations)

	PSO1	PSO2	PSO3	PSO4
MMATH20-203.1	3	3	3	3
MMATH20-203.2	3	3	3	3
MMATH20-203.3	3	3	3	3
MMATH20-203.4	3	2	3	3
Average	**3**	**2.75**	**3**	**3**

CO-PO matrix for the course MMATH20-203 (Differential Equations)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-203.1	3	2	3	3	3	2	3	3	3	-	3
MMATH20-203.2	3	3	3	3	2	3	3	3	3	-	3
MMATH20-203.3	3	3	3	3	3	3	3	3	3	--	2
MMATH20-203.4	3	3	3	3	3	3	2	2	3	-	2
Average	**3**	**2.75**	**3**	**3**	**2.75**	**2.75**	**2.75**	**2.75**	**3**	**-**	**2.5**

CO-PSO matrix for the course MMATH20-204 (Measure and Integration)

Cos	PSO1	PSO2	PSO3	PSO4
MMATH20-204 .1	3	3	3	3
MMATH20-204 .2	3	2	3	3
MMATH20-204 .3	3	2	3	3
MMATH20-204 .4	3	3	2	3
Average	**3**	**2.5**	**2.75**	**3**

CO-PO matrix for the course MMATH20-204 (Measure and Integration)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-204 .1	3	3	3	3	2	3	3	3	3	-	2
MMATH20-204 .2	3	3	2	3	2	3	2	3	2	-	2
MMATH20-204 .3	3	3	3	3	2	3	3	3	3	--	2
MMATH20-204 .4	3	3	2	3	2	3	2	3	2	-	2
Average	**3**	**3**	**2.5**	**3**	**2**	**3**	**2.5**	**3**	**2.5**	**-**	**2**

CO-PSO matrix for the course MMATH20-205 (Mechanics of Solids)

	PSO1	PSO2	PSO3	PSO4
MMATH20-205.1	3	3	3	3
MMATH20-205.2	3	3	3	3
MMATH20-205.3	3	2	3	3
MMATH20-205.4	3	3	3	3
Average	**3**	**2.75**	**3**	**3**

CO-PO matrix for the course MMATH20-205 (Mechanics of Solids)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-205.1	3	3	3	3	3	3	3	2	3	-	3
MMATH20-205.2	3	3	3	3	3	3	2	3	3	-	3
MMATH20-205.3	3	3	3	3	3	2	2	3	3	--	3
MMATH20-205.4	3	3	3	3	3	3	3	3	3	-	2
Average	**3**	**3**	**3**	**3**	**3**	**2.75**	**2.5**	**2.75**	**3**	**-**	**2.75**

CO-PSO matrix for the course MMATH20-206 (PRACTICAL-II)

COs	PSO1	PSO2	PSO3	PSO4
MMATH20-206.1	3	3	3	2
MMATH20-206.2	3	3	3	3
MMATH20-206.3	2	3	3	3
MMATH20-206.4	2	3	3	3
Average	**2.5**	**3**	**3**	**2.75**

CO-PO matrix for the course MMATH20-206 (PRACTICAL-II)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-206.1	3	3	2	3	3	3	3	--	3	--	3
MMATH20-206.2	3	3	2	3	3	3	3	3	3	--	3
MMATH20-206.3	3	3	2	3	3	3	3	3	3	--	3
MMATH20-206.4	3	3	2	3	3	3	3	3	3	--	3
Average	**3**	**3**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**--**	**3**

CO-PSO matrix for the course OEM20-207 (Basic Mathematics-I)

	PSO1	PSO2	PSO3	PSO4
OEM20-207.1	3	2	2	3
OEM20-207.2	3	3	3	3
OEM20-207.3	3	3	3	3
OEM20-207.4	3	3	3	3
Average	**3**	**2.75**	**2.75**	**3**

CO-PO matrix for the course OEM20-207 (Basic Mathematics-I)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
OEM20-207.1	3	3	2	3	-	2	2	-	3	-	3
OEM20-207.2	3	3	2	3	-	2	3	-	3	-	3
OEM20-207.3	3	3	3	3	-	3	3	-	3	--	3
OEM20-207.4	3	3	3	3	-	3	3	-	3	-	3
Average	**3**	**3**	**2.5**	**3**	**-**	**2.5**	**2.75**	**-**	**3**	**-**	**3**

CO-PSO matrix for the course MMATH21-301 (Fluid Mechanics)

CO	PSO1	PSO2	PSO3	PSO4
MMATH21-301.1	3	3	3	3
MMATH21-301.2	3	3	3	3
MMATH21-301.3	3	2	3	3
MMATH21-301.4	3	3	3	3
Average	**3**	**2.75**	**3**	**3**

CO-PO matrix for the course MMATH21-301 (Fluid Mechanics)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-301.1	3	2	3	3	3	3	3	3	3	-	3
MMATH21-301.2	3	3	3	3	3	3	2	3	3	-	2
MMATH21-301.3	3	3	3	3	2	2	3	3	3	--	3
MMATH21-301.4	3	3	3	3	2	2	2	3	3	-	2
Average	**3**	**2.75**	**3**	**3**	**2.5**	**2.5**	**2.5**	**3**	**3**	**-**	**2.5**

CO-PSO matrix for the course MMATH21-302 (Functional Analysis)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-302 .1	3	3	3	3
MMATH21-302 .2	3	3	3	3
MMATH21-302 .3	3	3	3	3
MMATH21-302 .4	3	2	2	3
Average	**3**	**2.75**	**2.75**	**3**

CO-PO matrix for the course MMATH21-302 (Functional Analysis)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-302 .1	3	3	3	3	3	3	3	3	3	-	2
MMATH21-302 .2	3	3	2	3	2	3	3	2	3	-	3
MMATH21-302 .3	3	3	3	3	3	3	3	2	3	--	3
MMATH21-302 .4	3	3	3	3	2	3	3	3	3	-	2
Average	**3**	**3**	**2.75**	**3**	**2.5**	**3**	**3**	**2.5**	**3**	**-**	**2.5**

CO-PSO matrix for the course MMATH21-303 (PRACTICAL-III)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-303.1	3	3	3	3
MMATH21-303.2	3	3	3	3
MMATH21-303.3	2	3	3	2
MMATH21-303.4	2	3	3	3
Average	**2.5**	**3**	**3**	**2.75**

CO-PO matrix for the course MMATH21-303 (PRACTICAL-III)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-303.1	3	3	2	3	3	2	3	3	3	--	3
MMATH21-303.2	3	3	2	3	3	2	3	2	3	--	3
MMATH21-303.3	3	3	2	3	3	3	3	3	3	--	3
MMATH21-303.4	3	3	2	3	3	3	3	3	3	--	3
Average	**3**	**3**	**2**	**3**	**3**	**2.5**	**3**	**2.75**	**3**	**--**	**3**

CO-PSO matrix for the course MMATH21-304 (Advanced Topology)

	PSO1	PSO2	PSO3	PSO4
MMATH21-304 .1	3	2	3	3
MMATH21-304 .2	3	2	2	3
MMATH21-304 .3	3	2	3	3
MMATH21-304 .4	3	2	2	3
Average	**3**	**2**	**2.5**	**3**

CO-PO matrix for the course MMATH21-304 (Advanced Topology)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-304 .1	3	3	2	3	2	3	3	3	3	-	2
MMATH21-304 .2	3	3	2	3	2	3	2	2	3	-	2
MMATH21-304 .3	3	3	2	3	2	3	2	2	3	--	-
MMATH21-304 .4	3	3	2	3	2	3	2	2	3	-	-
Average	**3**	**3**	**2**	**3**	**2**	**3**	**2.25**	**2.25**	**3**	**-**	**2**

CO-PSO matrix for the course MMATH21-305 (Commutative Algebra)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-305.1	3	2	2	2
MMATH21-305.2	3	2	2	2
MMATH21-305.3	3	2	2	2
MMATH21-305.4	3	2	2	2
Average	**3**	**2**	**2**	**2**

CO-PO matrix for the course MMATH21-305 (Commutative Algebra)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH 21-305.1	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-305.2	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-305.3	3	3	2	3	-	2	2	-	2	--	2
MMATH 21-305.4	3	3	2	3	-	2	2	-	2	-	2
Average	**3**	**3**	**2**	**3**	**-**	**2**	**2**	**-**	**2**	**-**	**2**

CO-PSO matrix for the course MMATH21-306 (DIFFERENTIAL GEOMETRY)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-306.1	3	3	3	3
MMATH21-306.2	3	2	3	3
MMATH21-306.3	3	2	2	3
MMATH21-306.4	3	3	3	3
Average	**3**	**2.5**	**2.75**	**3**

CO-PO matrix for the course MMATH21-306 (DIFFERENTIAL GEOMETRY)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-306 .1	3	3	3	3	3	3	3	3	3	--	3
MMATH21-306 .2	3	3	3	3	3	3	3	3	3	--	3
MMATH21-306 .3	3	3	2	3	2	3	3	3	3	--	2
MMATH21-306 .4	3	3	3	3	2	2	2	3	3	--	2
Average	**3**	**3**	**2.75**	**3**	**2.5**	**2.75**	**2.75**	**3**	**3**	**--**	**2.5**

CO-PSO matrix for the course MMATH21-307 (ELASTICITY)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-307.1	3	3	2	3
MMATH21-307.2	3	2	3	3
MMATH21-307.3	3	3	3	3
MMATH21-307.4	3	3	3	3
Average	**3**	**2.75**	**2.75**	**3**

CO-PO matrix for the course MMATH21-307 (ELASTICITY)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-307.1	3	3	2	3	3	3	3	3	3	--	3
MMATH21-307.2	3	3	2	3	3	3	3	3	3	--	3
MMATH21-307.3	3	3	3	3	2	3	3	3	3	--	3
MMATH21-307.4	3	3	3	3	3	3	3	3	3	--	2
Average	**3**	**3**	**2.5**	**3**	**2.75**	**3**	**3**	**3**	**3**	**--**	**2.75**

CO-PSO matrix for the course MMATH21-308 (ADVANCED NUMERICAL ANALYSIS)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-308.1	3	3	2	3
MMATH21-308.2	3	3	3	3
MMATH21-308.3	3	3	3	3
MMATH21-308.4	3	3	3	3
Average	**3**	**3**	**2.75**	**3**

CO-PO matrix for the course MMATH21-308 (ADVANCED NUMERICAL ANALYSIS)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-308.1	3	3	3	3	2	3	3	3	3	--	3
MMATH21-308.2	3	3	2	3	2	3	3	2	3	--	3
MMATH21-308.3	3	3	3	3	3	3	3	2	3	--	3
MMATH21-308.4	3	3	3	3	3	3	3	3	3	--	3
Average	**3**	**3**	**2.75**	**3**	**2.5**	**3**	**3**	**2.5**	**3**	**--**	**3**

CO-PSO matrix for the course MMATH21-309 (Fuzzy Sets and Applications)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-309.1	3	3	2	3
MMATH21-309.2	3	2	3	3
MMATH21-309.3	3	2	3	3
MMATH21-309.4	3	3	3	3
Average	**3**	**2.5**	**2.75**	**3**

CO-PO matrix for the course MMATH21-309 (Fuzzy Sets and Applications)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-309.1	3	3	3	3	2	3	3	3	3	-	3
MMATH21-309.2	3	3	3	3	2	3	3	3	2	-	3
MMATH21-309.3	3	3	2	3	2	3	2	3	2	--	2
MMATH21-309.4	3	3	3	3	2	3	3	3	3	-	3
Average	**3**	**3**	**2.75**	**3**	**2**	**3**	**2.75**	**3**	**2.5**	**-**	**2.75**

CO-PSO matrix for the course MMATH21-310 (Mathematical Statistics)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-310.1	3	3	3	3
MMATH21-310.2	3	3	3	3
MMATH21-310.3	3	3	3	3
MMATH21-310.4	3	3	3	3
Average	**3**	**3**	**3**	**3**

CO-PO matrix for the course MMATH21-310 (Mathematical Statistics)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH 21-310.1	3	3	2	3	2	3	3	2	3	-	3
MMATH 21-310.2	3	3	2	3	2	3	3	3	3	-	2
MMATH 21-310.3	3	3	2	3	2	3	2	2	3	-	3
MMATH 21-310.4	3	3	2	3	2	3	3	2	3	-	3
Average	**3**	**3**	**2**	**3**	**2**	**3**	**2.75**	**2.25**	**3**	**-**	**2.75**

CO-PSO matrix for the course MMATH21-311 (Number Theory)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-311.1	3	2	2	2
MMATH21-311.2	3	2	2	3
MMATH21-311.3	3	2	2	2
MMATH21-311.4	3	2	2	3
Average	**3**	**2**	**2**	**2.5**

CO-PO matrix for the course MMATH21-311 (Number Theory)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH 21-311.1	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-311.2	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-311.3	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-311.4	3	3	2	3	-	2	2	-	2	-	2
Average	**3**	**3**	**2**	**3**	**-**	**2**	**2**	**-**	**2**	**-**	**2**

CO-PSO matrix for the course MMATH21-312 (Algebraic Coding Theory)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-312.1	3	2	3	3
MMATH21-312.2	3	2	3	3
MMATH21-312.3	3	2	3	3
MMATH21-312.4	3	2	3	3
Average	**3**	**2**	**3**	**3**

CO-PO matrix for the course MMATH21-312 (Algebraic Coding Theory)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH 21-312.1	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-312.2	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-312.3	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-312.4	3	3	2	3	-	2	2	-	2	-	2
Average	**3**	**3**	**2**	**3**	**-**	**2**	**2**	**-**	**2**	**-**	**2**

CO-PSO matrix for the course MMATH21-313 (FINANCIAL MATHEMATICS)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-313.1	3	3	2	2
MMATH21-313.2	3	2	3	3
MMATH21-313.3	3	3	3	3
MMATH21-313.4	3	3	3	3
Average	3	2.75	2.75	2.75

CO-PO matrix for the course MMATH21-313 (FINANCIAL MATHEMATICS)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-313.1	3	3	3	3	2	3	3	2	3	--	2
MMATH21-313.2	3	3	3	3	3	3	3	3	3	--	3
MMATH21-313.3	3	3	3	3	2	3	3	3	3	--	3
MMATH21-313.4	3	3	3	3	2	3	3	3	3	--	3
Average	3	3	3	3	2.25	3	3	3	3	--	2.75

CO-PSO matrix for the course MMATH21-314: (INTEGRAL EQUATIONS)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-314.1	3	3	2	3
MMATH21-314.2	3	2	3	3
MMATH21-314.3	3	3	2	3
MMATH21-314.4	3	3	3	3
Average	3	2.75	2.5	3

CO-PO matrix for the course MMATH21-314: (INTEGRAL EQUATIONS)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-314.1	3	3	3	3	2	2	2	3	3	--	3
MMATH21-314.2	3	3	3	3	2	3	3	3	3	--	2
MMATH21-314.3	3	3	3	3	2	2	2	2	3	--	2
MMATH21-314.4	3	3	3	3	2	3	3	3	3	--	3
Average	3	3	3	3	2	2.5	2.5	2.75	3	--	2.5

CO-PSO matrix for the course MMATH21-315 (MATHEMATICAL MODELING)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21- 315.1	3	3	2	2
MMATH21- 315.2	3	2	3	3
MMATH21- 315.3	3	3	3	3
MMATH21- 315.4	3	3	3	3
Average	**3**	**2.75**	**2.75**	**2.75**

CO-PO matrix for the course MMATH21-315 (MATHEMATICAL MODELING)

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21- 315.1	3	3	3	3	2	3	3	2	3	--	2
MMATH21- 315.2	3	3	3	3	3	3	3	3	3	--	3
MMATH21- 315.3	3	3	3	3	3	3	3	3	3	--	3
MMATH21- 315.4	3	3	3	3	3	3	3	3	3	--	3
Average	**3**	**3**	**3**	**3**	**2.75**	**3**	**3**	**3**	**3**	**--**	**2.75**

CO-PSO matrix for the course OEM21-316 (BASIC MATHEMATICS-II)

COs	PSO1	PSO2	PSO3	PSO4
OEM21-316.1	3	3	2	3
OEM21-316.2	3	2	2	3
OEM21-316.3	3	3	3	3
OEM21-316.4	3	3	3	3
Average	**3**	**2.75**	**2.5**	**3**

CO-PO matrix for the course OEM21-316 (BASIC MATHEMATICS-II)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
OEM21-316.1	3	3	2	3	2	2	2	2	3	--	3
OEM21-316.2	3	3	2	3	3	2	3	3	3	--	3
OEM21-316.3	3	3	3	3	3	2	3	3	3	--	3
OEM21-316.4	3	3	3	3	2	3	3	2	3	--	3
Average	**3**	**3**	**2.5**	**3**	**2.5**	**2.25**	**2.75**	**2.5**	**3**	**--**	**3**

CO-PSO matrix for the course MMATH21-401 (Mechanics and Calculus of Variations)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-401.1	3	3	3	3
MMATH21-401.2	3	3	3	3
MMATH21-401.3	3	2	3	3
MMATH21-401.4	3	3	3	3
Average	**3**	**2.75**	**3**	**3**

CO-PO matrix for the course MMATH21-401 (Mechanics and Calculus of Variations)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-401.1	3	3	3	3	3	3	3	3	3	-	3
MMATH21-401.2	3	3	3	3	2	3	2	3	3	-	3
MMATH21-401.3	3	3	3	3	3	3	2	3	3	--	3
MMATH21-401.4	3	3	2	3	3	3	3	3	3	-	3
Average	**3**	**3**	**2.75**	**3**	**2.75**	**3**	**2.5**	**3**	**3**	**-**	**3**

CO-PSO matrix for the course MMATH21-402 (PARTIAL DIFFERENTIAL EQUATIONS)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-402.1	3	3	3	3
MMATH21-402.2	3	3	3	3
MMATH21-402.3	3	3	3	3
MMATH21-402.4	3	3	3	3
Average	**3**	**3**	**3**	**3**

CO-PO matrix for the course MMATH21-402 (PARTIAL DIFFERENTIAL EQUATIONS)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-402.1	3	3	3	3	2	3	3	3	3	--	3
MMATH21-402.2	3	3	3	3	2	3	3	3	3	--	3
MMATH21-402.3	3	3	3	3	3	3	3	3	3	--	3
MMATH21-402.4	3	3	3	3	3	3	3	3	3	--	3
Average	**3**	**3**	**3**	**3**	**2.5**	**3**	**3**	**3**	**3**	**--**	**3**

CO-PSO matrix for the course MMATH21-403 (PRACTICAL-IV)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-403.1	3	3	3	3
MMATH21-403.2	3	3	3	3
MMATH21-403.3	2	3	3	2
MMATH21-403.4	2	3	3	3
Average	**2.5**	**3**	**3**	**2.75**

CO-PO matrix for the course MMATH21-403 (PRACTICAL-IV)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-403.1	3	3	2	3	3	2	3	3	3	--	3
MMATH21-403.2	3	3	2	3	3	2	3	2	3	--	3
MMATH21-403.3	3	3	2	3	3	3	3	3	3	--	3
MMATH21-403.4	3	3	2	3	3	3	3	3	3	--	3
Average	**3**	**3**	**2**	**3**	**3**	**2.5**	**3**	**2.75**	**3**	**--**	**3**

CO-PSO matrix for the course MMATH21-404 (SEMINAR-II)

COs	PSO1	PSO2	PSO3	PSO4
MMATH20-404.1	3	3	2	3
MMATH20-404.2	3	3	3	3
MMATH20-404.3	3	3	3	3
MMATH20-404.4	3	3	2	3
Average	**3**	**3**	**2.5**	**3**

CO-PO matrix for the course MMATH21-404 (SEMINAR-II)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-404.1	3	3	2	2	3	3	2	3	3	1	3
MMATH20-404.2	3	3	2	3	2	3	2	3	3	1	3
MMATH20-404.3	3	2	3	3	3	2	2	2	3	1	3
MMATH20-404.4	3	2	3	3	3	3	2	2	3	1	3
Average	**3**	**2.5**	**2.5**	**2.75**	**2.75**	**2.75**	**2**	**2.5**	**3**	**1**	**3**

CO-PSO matrix for the course MMATH21-405 (Advanced Complex Analysis)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-405.1	3	3	3	3
MMATH21-405.2	3	2	2	3
MMATH21-405.3	3	3	3	3
MMATH21-405.4	3	2	2	3
Average	**3**	**2.5**	**2.5**	**3**

CO-PO matrix for the course MMATH21-405 (Advanced Complex Analysis)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-405.1	3	3	2	3	2	3	2	2	3	-	2
MMATH21-405.2	3	3	3	3	3	3	3	3	3	-	2
MMATH21-405.3	3	3	3	3	2	3	3	3	3	--	3
MMATH21-405.4	3	3	2	3	2	3	2	2	3	-	2
Average	**3**	**3**	**2.5**	**3**	**2.25**	**3**	**2.5**	**2.5**	**3**	**-**	**2.25**

CO-PSO matrix for the course MMATH 21-406 (Algebraic Number Theory)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-406.1	3	2	2	2
MMATH21-406.2	3	2	2	2
MMATH21-406.3	3	2	2	2
MMATH21-406.4	3	2	2	3
Average	**3**	**2**	**2**	**2.25**

CO-PO matrix for the course MMATH21-406 (Algebraic Number Theory)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH 21-406.1	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-406.2	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-406.3	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-406.4	3	3	2	3	-	2	2	-	2	-	2
Average	**3**	**3**	**2**	**3**	**-**	**2**	**2**	**-**	**2**	**-**	**2**

CO-PSO matrix for the course MMATH21- 407 (General Measure and Integration Theory)

Cos	PSO1	PSO2	PSO3	PSO4
MMATH21- 407.1	3	3	3	3
MMATH21- 407.2	3	2	2	3
MMATH21- 407.3	3	3	3	3
MMATH21- 407.3	3	2	2	3
Average	**3**	**2.5**	**2.5**	**3**

CO-PO matrix for the course MMATH21- 407 (General Measure and Integration Theory)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-407.1	3	3	2	3	2	3	2	2	3	-	2
MMATH21-407.2	3	3	2	3	2	3	2	2	3	-	2
MMATH21-407.3	3	3	2	3	2	3	2	2	3	--	2
MMATH21-407.4	3	3	3	3	2	3	3	2	3	-	2
Average	**3**	**3**	**2.25**	**3**	**2**	**3**	**2.25**	**2**	**3**	**-**	**2**

CO-PSO matrix for the course MMATH21-408 (Mathematical Aspects of Seismology)

	PSO1	PSO2	PSO3	PSO4
MMATH21-408.1	3	3	3	3
MMATH21-408.2	3	3	3	3
MMATH21-408.3	3	3	3	3
MMATH21-408.4	3	3	3	3
Average	**3**	**3**	**3**	**3**

CO-PO matrix for the course MMATH21-408 (Mathematical Aspects of Seismology)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-408.1	3	3	3	3	3	3	3	3	3	-	3
MMATH21-408.2	3	3	3	3	2	2	3	3	3	-	2
MMATH21-408.3	3	3	3	3	3	3	3	3	3	--	3
MMATH21-408.4	3	3	3	3	3	3	3	3	3	-	3
Average	**3**	**3**	**3**	**3**	**2.75**	**2.75**	**3**	**3**	**3**	**-**	**2.75**

CO-PSO matrix for the course MMATH21-409 (Advanced Discrete Mathematics)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-409.1	3	3	2	3
MMATH21-409.2	3	3	2	3
MMATH21-409.3	3	2	2	2
MMATH21-409.4	3	2	2	2
Average	**3**	**2.5**	**2**	**2.5**

CO-PO matrix for the course MMATH21-409 (Advanced Discrete Mathematics)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH 21-409.1	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-409.2	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-409.3	3	3	2	3	-	2	2	-	2	-	2
MMATH 21-409.4	3	3	2	3	-	2	2	-	2	-	2
Average	**3**	**3**	**2**	**3**	**-**	**2**	**2**	**-**	**2**	**-**	**2**

CO-PSO matrix for the course MMATH21-410 (Advanced Functional Analysis)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-410.1	3	3	3	3
MMATH21-410.2	3	2	3	3
MMATH21-410.3	3	2	2	3
MMATH21-410.4	3	3	3	3
Average	**3**	**2.5**	**2.75**	**3**

CO-PO matrix for the course MM21-410 (Advanced Functional Analysis))

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-410.1	3	3	3	3	3	3	3	3	3	-	3
MMATH21-410.2	3	3	2	3	2	3	2	2	3	-	2
MMATH21-410.3	3	3	2	3	2	3	2	2	3	--	2
MMATH21-410.4	3	3	3	3	3	3	3	3	3	-	3
Average	**3**	**3**	**2.5**	**3**	**2.5**	**3**	**2.5**	**2.5**	**3**	**-**	**2.5**

CO-PSO matrix for the course MMATH21-411 (Advanced Fluid Mechanics)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-411.1	3	3	3	3
MMATH21-411.2	3	2	3	3
MMATH21-411.3	3	3	3	3
MMATH21-411.4	3	2	3	3
Average	**3**	**2.5**	**3**	**3**

CO-PO matrix for the course MMATH21-411 (Advanced Fluid Mechanics)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-411.1	3	3	3	3	3	3	3	3	3	-	3
MMATH21-411.2	3	3	3	3	3	3	2	3	3	-	2
MMATH21-411.3	3	3	3	3	2	2	3	3	3	--	3
MMATH21-411.4	3	3	3	3	3	3	2	3	3	-	2
Average	**3**	**3**	**3**	**3**	**2.75**	**2.75**	**2.5**	**3**	**3**	**-**	**2.5**

CO-PSO matrix for the course MMATH21-412 (Boundary Value Problems)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-412.1	3	3	3	3
MMATH21-412.2	3	3	3	3
MMATH21-412.3	3	2	3	3
MMATH21-412.	3	2	3	3
Average	**3**	**2.5**	**3**	**3**

CO-PO matrix for the course MMATH21-412 (Boundary Value Problems)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-412.1	3	3	3	3	2	3	2	3	3	-	2
MMATH21-412.2	3	3	3	3	3	3	3	3	3	-	2
MMATH21-412.3	3	3	3	3	3	3	3	3	3	--	2
MMATH21-412.4	3	3	3	3	3	3	2	3	3	-	2
Average	**3**	**3**	**3**	**3**	**2.75**	**3**	**2.5**	**3**	**3**	**-**	**2**

CO-PSO matrix for the course MMATH21-413 (BIO-MATHEMATICS)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-413.1	3	3	2	2
MMATH21-413.2	3	2	3	3
MMATH21-413.3	3	3	3	3
MMATH21-413.4	3	3	3	3
Average	**3**	**2.75**	**2.75**	**2.75**

CO-PO matrix for the course MMATH21-413 (BIO-MATHEMATICS)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH 21-413.1	3	3	3	3	3	3	3	2	3	--	2
MMATH 21-413.2	3	3	3	3	3	3	3	3	3	--	3
MMATH 21-413.3	3	3	3	3	2	3	3	3	3	--	3
MMATH 21-413.4	3	3	3	3	2	3	3	3	3	--	3
Average	**3**	**3**	**3**	**3**	**2.5**	**3**	**3**	**3**	**3**	**--**	**2.75**

CO-PSO matrix for the course MMATH21-414 (Fourier and Wavelet Analysis)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-414.1	3	2	3	3
MMATH21-414.2	3	2	2	3
MMATH21-414.3	3	3	3	3
MMATH21-414.4	3	3	3	3
Average	**3**	**2.5**	**2.75**	**3**

CO-PO matrix for the course MMATH21-414 (Fourier and Wavelet Analysis)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-414.1	3	3	2	2	3	3	2	2	3	-	2
MMATH21-414.2	3	3	2	2	3	3	2	2	3	-	2
MMATH21-414.3	3	3	3	3	3	3	3	3	3	--	3
MMATH21-414.4	3	3	3	3	3	3	3	3	3	-	3
Average	**3**	**3**	**2.5**	**2.5**	**3**	**3**	**2.5**	**2.5**	**3**	**-**	**2.5**

CO-PSO matrix for the course MMATH21-415 (Linear Programming)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-415.1	3	3	3	3
MMATH21-415.2	3	3	3	3
MMATH21-415.3	3	3	3	3
MMATH21-415.4	3	3	3	3
Average	**3**	**3**	**3**	**3**

CO-PO matrix for the course MMATH21-415 (Linear Programming)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH 21-415.1	3	3	2	3	2	3	3	2	3	-	2
MMATH 21-415.2	3	3	2	3	2	3	3	2	3	-	2
MMATH 21-415.3	3	3	2	3	2	3	3	3	3	-	2
MMATH 21-415.4	3	3	2	3	2	3	3	2	2	-	2
Average	**3**	**3**	**2**	**3**	**2**	**3**	**3**	**2.25**	**2.75**	**-**	**2**

CO-PSO matrix for the course MMATH21-416 (Non Commutative Rings)

COs	PSO1	PSO2	PSO3	PSO4
MMATH21-416.1	3	2	2	2
MMATH21-416.2	3	2	2	2
MMATH21-416.3	3	2	2	2
MMATH21-416.4	3	2	2	2
Average	**3**	**2**	**2**	**2**

CO-PO matrix for the course MMATH21-416 (Non Commutative Rings)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH21-416.1	3	3	2	3	-	2	2	-	2	-	2
MMATH21-416.2	3	3	2	3	-	2	2	-	2	-	2
MMATH21-416.3	3	3	2	3	-	2	2	-	2	-	2
MMATH21-416.4	3	3	2	3	-	2	2	-	2	-	2
Average	**3**	**3**	**2**	**3**	**-**	**2**	**2**	**-**	**2**	**-**	**2**

CO-PO-PSO mapping matrix for all the courses of M.Sc. Mathematics Programme

Course Code	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3	PSO 4
MMATH 20-101	3	3	2	3		2	2		2		2	3	2	2.25	2.5
MMATH 20-102	3	2	3	3	2	2	3	2	3		2	2.5	2.75	2.75	3
MMATH 20-103	3	3	3	3	2.5	2.5	2.5	2.75	3		2.5	3	2.75	2.75	3
MMATH 20-104	3	3	2.5	3	2.5	3	2.5	2.5	3		2.5	3	2.75	2.75	3
MMATH 20-105	3	3	2	3	2	3	2.25	2.25	3		2	3	2.5	2.5	3
MMATH 20-106	3	3	2	3	3	3	3	3	3		3	2.25	3	3	2.75
MMATH 20-107	3	2.5	2.5	2.75	2.75	2.75	2	2.5	3	1	3	3	3	2.5	3
MMATH 20-201	3	3	2	3		2	2		2		2	3	2	2.25	2.25
MMATH 20-202	3	2.75	2.5	2.75	3	2.75	3	3	3		3	2.5	2.5	3	3
MMATH 20-203	3	2.75	3	3	2.75	2.75	2.75	2.75	3		2.5	3	2.75	3	3
MMATH 20-204	3	3	2.5	3	2	3	2.5	3	2.5		2	3	2.5	2.75	3
MMATH 20-205	3	3	3	3	3	2.75	2.5	2.75	3		2.75	3	2.75	3	3
MMATH 20-206	3	3	2	3	3	3	3	3	3		3	2.5	3	3	2.75
OEM20-207	3	3	2.5	3		2.5	2.75		3		3	3	2.75	2.75	3
MMATH 21-301	3	2.75	3	3	2.5	2.5	2.5	3	3		2.5	3	2.75	3	3
MMATH 21-302	3	3	2.75	3	2.5	3	3	2.5	3		2.5	3	2.75	2.75	3
MMATH 21-303	3	3	2	3	3	2.5	3	2.75	3		3	2.5	3	3	2.75
MMATH 21-304	3	3	2	3	2	3	2.25	2.25	3		2	3	2	2.5	3
MMATH 21-305	3	3	2	3		2	2		2		2	3	2	2	2
MMATH 21-306	3	3	2.75	3	2.5	2.75	2.75	3	3		2.5	3	2.5	2.75	3
MMATH 21-307	3	3	2.5	3	2.75	3	3	3	3		2.75	3	2.75	2.75	3
MMATH 21-308	3	3	2.75	3	2.5	3	3	2.5	3		3	3	3	2.75	3
MMATH 21-309	3	3	2.75	3	2	3	2.75	3	2.5		2.75	3	2.5	2.75	3
MMATH 21-310	3	3	2	3	2	3	2.75	2.25	3		2.75	3	3	3	3
MMATH 21-311	3	3	2	3		2	2		2		2	3	2	2	2.5
MMATH 21-312	3	3	2	3		2	2		2		2	3	2	3	3

Course Code	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PS O1	PS O2	PS O3	PS O4
MMATH 21-313	3	3	3	3	2.25	3	3	3	3		2.75	3	2.75	2.75	2.75
MMATH 21-314	3	3	3	3	2	2.5	2.5	2.75	3		2.5	3	2.75	2.5	3
MMATH 21-315	3	3	3	3	2.75	3	3	3	3		2.75	3	2.75	2.75	2.75
OEM21-316	3	3	2.5	3	2.5	2.25	2.75	2.5	3		3	3	2.75	2.5	3
MMATH 21-401	3	3	2.75	3	2.75	3	2.5	3	3		3	3	2.75	3	3
MMATH 21-402	3	3	3	3	2.5	3	3	3	3		3	3	3	3	3
MMATH 21-403	3	3	2	3	3	2.5	3	2.75	3		3	2.5	3	3	2.75
MMATH 21-404	3	2.5	2.5	2.75	2.75	2.75	2	2.5	3	1	3	3	3	2.5	3
MMATH 21-405	3	3	2.5	3	2.25	3	2.5	2.5	3		2.25	3	2.5	2.5	3
MMATH 21-406	3	3	2	3		2	2		2		2	3	2	2	2.25
MMATH 21-407	3	3	2.25	3	2	3	2.25	2	3		2	3	2.5	2.5	3
MMATH 21-408	3	3	3	3	2.75	2.75	3	3	3		2.75	3	3	3	3
MMATH 21-409	3	3	2	3		2	2		2		2	3	2.5	2	2.5
MMATH 21-410	3	3	2.5	3	2.5	3	2.5	2.5	3		2.5	3	2.5	2.75	3
MMATH 21-411	3	3	3	3	2.75	2.75	2.5	3	3		2.5	3	2.5	3	3
MMATH 21-412	3	3	3	3	2.75	3	2.5	3	3		2	3	2.5	3	3
MMATH 21-413	3	3	3	3	2.5	3	3	3	3		2.75	3	2.75	2.75	2.75
MMATH 21-414	3	3	2.5	2.5	3	3	2.5	2.5	3		2.5	3	2.5	2.75	3
MMATH 21-415	3	3	2	3	3	3	3	2.25	2.75		2	3	3	3	3
MMATH 21-416	3	3	2	3		2	2		2		2	3	2	2	2

6. Attainment of COs:

The attainment of COs can be measured on the basis of the results of internal assessment and semester examination. The attainment is measured on scale of 3 after setting the target for COs attainment. Table 5 shows the CO attainment levels assuming the set target of 60% marks:

Table 5: CO Attainment Levels for internal assessment

Attainment Level	
1 (low level of attainment)	50% of students score more than 60% of marks in class tests of a course.
2 (Medium level of attainment)	60% of students score more than 60% of marks in class tests of a course.
3 (High level of attainment)	70% of students score more than 60% of marks in class tests of a course.

A proper mapping of course outcomes with assessment methods should be defined before measuring the attainment level. The questions in tests for internal assessment are based on COs. Here, it is assumed that class test – I is based on first two COs (e.g. MMATH20-101.1 and MMATH20-101.2) of a course with equal weightage given to both COs. Similarly, class test – II/ Assignment Test is based on next two COs (e.g. MMATH20-101.3 and MMATH20-101.4) of a course with equal weightage given to these two COs. For each internal assessment test, the percentage of students attaining the target level of CO is estimated and average percentage will decide the attainment level of COs. Following steps may be followed for determining the attainment level in internal assessment of a course.

(i) Estimate the %age of students scoring set target (say 60%) or more in the question(s) of test -I based on first CO i.e. MMATH20-101.1
(ii) Estimate the %age of students scoring set target (60%) or more in the question(s) of test -I based on second CO i.e. MMATH20-101.2
(iii) Estimate the %age of students scoring set target (60%) or more in the question(s) of test -II /Assignment Test based on third CO i.e. MMATH20-101.3
(iv) Estimate the %age of students scoring set target (60%) or more in the question(s) of test -II /Assignment Test based on fourth CO i.e. MMATH20-101.4
(v) Take average of the percentages obtained above.
(vi) Determine the attainment level i.e. 3, 2 or 1 as per scale defined in table 5.

Note: In the above steps, it is assumed that internal assessment is based on two tests only. However if internal assessment is based on more than two tests and/or on assignments then same may by incorporated to determine the COs attainment level. There may be more than four COs for a course. The set target may also be different for different COs. These issues may resolved by the staff councils of the departments/institutes.

For determining the attainment levels for end semester examination, it is assumed that questions in the end term examination are based on all COs of the course. Attainment levels for end semester examination of a course can be determined after the declaration of the results.
The CO attainment levels for end semester examination are given in Table 6.

Table 6: CO Attainment Levels for End Semester Examination(ESE)

Attainment Level	
1 (Low level of attainment)	50% of students obtained letter grade of A or above (for CBCS programs) or score more than 60% of marks (for non-CBCS programs) in ESE of a course.
2 (Medium level of attainment)	60% of students obtained letter grade of A or above (for CBCS programs) or score more than 60% of marks (for non-CBCS programs) in ESE of a course.
3 (High level of attainment)	70% of students obtained letter grade of A or above (for CBCS programs) or score more than 60% of marks (for non-CBCS programs) in ESE of a course.

Overall CO Attainment level of a Course:

The overall CO attainment level of a course can be obtained as:

Overall CO attainment level = 50% of CO attainment level in Internal assessment + 50% of CO Attainment level in End semester examination.

The overall COs attainment level can be obtained for all the courses of the program in a similar manner.

6.1 Attainment of POs:

The overall attainment level of POs is based on the values obtained using direct and indirect methods in the ratio of 80:20. The direct attainment of POs is obtained through the attainment of COs. The overall CO attainment value as estimated above and CO-PO mapping value as shown in Table 4 are used to compute the attainment of POs. PO attainment values obtained using direct method can be written as shown in the Table 7.

Table 7: PO Attainment Values using Direct Method

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
MMATH20-101											
MMATH20-102											
MMATH20-103											
MMATH20-104											
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MMATH20-206											
OEM20-207											
MMATH21-301											
MMATH21-302											
MMATH21-303											
MMATH21-304											
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MMATH21-315											
OEM21-316											
MMATH21-401											
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MMATH21-406											
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MMATH21-410											
MMATH21-411											
MMATH21-412											
MMATH21-413											
MMATH21-414											
MMATH21-415											
MMATH21-416											
Direct PO attainment	Average of above values	Average of above values	Average of above values	Average of above values	Average of above values	Average of above values	Average of above values	Average of above values	Average of above values	Average of above values	Average of above values

The PO attainment values to be filled in above table can be obtained as follows:

For MMATH20-101-PO1 Cell:

PO1 attainment value = (Mapping factor of MMATH20-101-PO1 from Table 4 × Overall CO attainment value for the course MMATH20-101)/3

For MMATH20-104-PO1 Cell:

PO1 attainment value = (Mapping factor of MMATH20-104 -PO1 from Table 4 × Overall CO attainment value for the course MMATH20-104)/3

Similarly values for each cell of Table 7 can be obtained. The direct attainment of POs is average of individual PO attainment values.

In order to obtain the PO attainment using indirect method, a student exit survey based on the questionnaire of POs may be conducted at end of last semester of the program. The format for the same is given in Table 8. Average of the responses from the outgoing students for each PO is estimated.

The overall PO attainment values are obtained by adding attainment values estimated using direct and indirect methods in the proportion of 80:20 as follows:

Overall attainment value for PO1 =

0.8 × average attainment value for PO1 using direct method (from table 7)

+

0.2 × average response of outgoing students for PO1 (from Table 8)

Similarly overall attainment value can be obtained for each PO.

Table 8 : Questionnaire for indirect measurement of PO attainment
(For outgoing students)

At the end of my degree program I am able to do:

			Please tick any one		
PO1	Knowledge	Capable of demonstrating comprehensive disciplinary knowledge gained during course of study	3	2	1
PO2	Research Aptitude	Capability to ask relevant/appropriate questions for identifying, formulating and analyzing the research problems and to draw conclusion from the analysis	3	2	1
PO3	Communication	Ability to communicate effectively on general and scientific topics with the scientific community and with society at large	3	2	1
PO4	Problem Solving	Capability of applying knowledge to solve scientific and other problems	3	2	1
PO5	Individual and Team Work	Capable to learn and work effectively as an individual, and as a member or leader in diverse teams, in multidisciplinary settings.	3	2	1
PO6	Investigation of Problems	Ability of critical thinking, analytical reasoning and research based knowledge including design of experiments, analysis and interpretation of data to provide conclusions	3	2	1
PO7	Modern Tool usage	Ability to use and learn techniques, skills and modern tools for scientific practices	3	2	1
PO8	Science and Society	Ability to apply reasoning to assess the different issues related to society and the consequent responsibilities relevant to the professional scientific practices	3	2	1
PO9	Life-Long Learning	Aptitude to apply knowledge and skills that are necessary for participating in learning activities throughout life	3	2	1
PO10	Ethics	Capability to identify and apply ethical issues related to one's work, avoid unethical behaviour such as fabrication of data, committing plagiarism and unbiased truthful actions in all aspects of work	3	2	1
PO11	Project Management	Ability to demonstrate knowledge and understanding of the scientific principles and apply these to manage projects			
		3: Strongly Agree; 2: Agree; 1: Average			

Overall PO attainment values can be written as shown in Table 9:

Table 9: Overall PO attainment Values

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
Direct PO attainment											
Indirect PO attainment											
Overall PO attainment											
Target	2	2	2	2	1	1.5	1.5	1.5	2	-	1.5

The overall PO attainment values obtained above are compared with set target. The set target for each PO may be different and can be finalized by the staff councils of the departments/institutes. If overall PO attainment value is less than the set target value then an action plan may be prepared for improvement in the subsequent academic session.

The overall PSO attainment level based on CO-PSO mapping values and overall CO attainment values can be obtained in a similar manner.

6.2 <u>Attainment of PSOs:</u>

The overall attainment level of PSOs is based on the values obtained using direct and indirect methods in the ratio of 80:20. The direct attainment of PSOs is obtained through the attainment of COs. The overall CO attainment value as estimated above and CO-PSO mapping value as shown in Table 4 are used to compute the attainment of PSOs. PSO attainment values obtained using direct method can be written as shown in the Table 10.

Table 10: PSO Attainment Values using Direct Method

	PSO1	PSO2	PSO3	PSO4
MMATH20-101				
MMATH20-102				
MMATH20-103				
MMATH20-104				
MMATH20-105				
MMATH20-106				
MMATH20-107				
MMATH20-201				
MMATH20-202				
MMATH20-203				
MMATH20-204				
MMATH20-205				
MMATH20-206				
OEM20-207				
MMATH21-301				
MMATH21-302				
MMATH21-303				
MMATH21-304				
MMATH21-305				
MMATH21-306				
MMATH21-307				
MMATH21-308				
MMATH21-309				
MMATH21-310				
MMATH21-311				
MMATH21-312				
MMATH21-313				
MMATH21-314				
MMATH21-315				
OEM21-316				
MMATH21-401				
MMATH21-402				
MMATH21-403				
MMATH21-404				
MMATH21-405				
MMATH21-406				
MMATH21-407				
MMATH21-408				
MMATH21-409				
MMATH21-410				
MMATH21-411				
MMATH21-412				
MMATH21-413				
MMATH21-414				
MMATH21-415				
MMATH21-416				
Direct PSO attainment	Average of above values	Average of above values	Average of above values	Average of above values

The PSO attainment values to be filled in above table can be obtained as follows:

For MMATH20-101-PSO1 Cell:

PSO1 attainment value = (Mapping factor of MMATH20-101-PSO1 from Table 4 × Overall CO attainment value for the course MMATH20-101)/3

For MMATH20-104 -PO1 Cell:

PO1 attainment value = (Mapping factor of MMATH20-104 -PO1 from Table 4 × Overall CO attainment value for the course MMATH20-104)/3

Similarly values for each cell of Table 10 can be obtained. The direct attainment of PSOs is average of individual PSO attainment values.

In order to obtain the PSO attainment using indirect method, a student exit survey based on the questionnaire of PSOs may be conducted at end of last semester of the program. The format for the same is given in Table 11. Average of the responses from the outgoing students for each PSO is estimated.

The overall PSO attainment values are obtained by adding attainment values estimated using direct and indirect methods in the proportion of 80:20 as follows:

Overall attainment value for PSO1 =

0.8 × average attainment value for PSO1 using direct method (from table 10)

+

0.2 × average response of outgoing students for PSO1 (from Table 11)

Similarly overall attainment value can be obtained for each PSO.

Table 11 : Questionnaire for indirect measurement of PSO attainment
(For outgoing students)

At the end of my degree program I am able to do:

		Please tick any one		
PSO1	Have deep understanding and knowledge in the core areas of Mathematics and demonstrate understanding and application of the concepts/theories/principles/ methods/ techniques in different areas of pure and applied Mathematics.	3	2	1
PSO2	Have capability to read and understand mathematical texts, demonstrate and communicate mathematical knowledge effectively and unambiguously through oral and/or written expressions and attain skills of computing/programming/using software tools/formulating models.	3	2	1
PSO3	Attain abilities of critical thinking, logical reasoning, investigating problems, analysis, problem solving, application of mathematical methods/techniques, disciplinary knowledge so as to develop skills to solve mathematical problems having applications in other disciplines and/or in the real world.	3	2	1
PSO4	Have strong foundation in basic and applied aspects of Mathematics so as to venture into research in different areas of mathematical sciences, jobs in scientific and various industrial sectors and/or teaching career in Mathematics.	3	2	1
		3: Strongly Agree; 2: Agree; 1: Average		

Overall PSO attainment values can be written as shown in Table 12:

Table 12: Overall PSO attainment Values

	PSO1	PSO2	PSO3	PSO4
Direct PSO attainment				
Indirect PSO attainment				
Overall PSO attainment				
Target	2	2	2	2

The overall PSO attainment values obtained above are compared with set target. The set target for each PSO may be different and can be finalized by the staff councils of the departments/institutes. If overall PSO attainment value is less than the set target value then an action plan may be prepared for improvement in the subsequent academic session.

MMATH 20-101: ABSTRACT ALGEBRA

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The concept of a group is surely one of the central ideas of Mathematics. The main aim of this course is to introduce Sylow theory and some of its applications to groups of smaller orders. An attempt has been made in this course to strike a balance between the different branches of group theory, abelian groups, nilpotent groups, finite groups, infinite groups and to stress the utility of the subject. A study of modules, submodules, quotient modules, finitely generated modules etc. is also promised in this course. Similar linear transformations, Nilpotent transformations and related topics are also included in the course.

Course Outcomes: This course will enable the students to:

1. Understand concepts of normal subgroup, quotient group, isomorphism, automorphism, conjugacy, G-sets, normal series, composition series, solvable group, nilpotent group and refinement theorem.

2. Learn about cyclic decomposition, alternating group A_n , simplicity of A_n for $n \geq 5$, Sylow's theorem and its applications.

3. Understand concepts of modules, submodules, direct sum, R-homomorphism, quotient module, completely reducible modules, free modules, representation of linear mappings and their ranks.

4. Learn about similar linear transformation, triangular form, nilpotent transformation, primary decomposition theorem, Jordan form, rational canonical form and elementary divisors.

Unit-I:

Normal subgroup, quotient group, normalizer and centralizer of a non-empty subset of a group G, commutator subgroups of a group. first, second and third isomorphism theorems, correspondence theorem, Aut(G), Inn(G), automorphism group of a cyclic group, G-sets, orbit of an element in group G, Cayley's theorem. conjugate elements and conjugacy classes, class equation of a finite group G and its applications, Burnside theorem. normal series, composition series, Jordan Holder theorem, Zassenhaus lemma, Scheier's refinement theorem, solvable group, nilpotent group.
(Chapter 5 and 6 of recommended book at Sr. No. 1, Chapter 5 of recommended book at Sr. No. 2)

Unit-II:
Cyclic decomposition, even and odd permutation, Alternation group A_n, simplicity of the Alternating group A_n ($n \geq 5$). Cauchy's theorem, Sylow's first, second and third theorems and its applications to group of smaller orders. groups of order p^2 and pq (q>p).
(Chapter 7, 8.4 and 8.5 of recommended book at Sr. No 1)

Unit-III:
Modules, submodules, direct sums, finitely generated modules, cyclic module. R-homomorphism, quotient module, completely reducible modules, Schur's lemma, free modules, representation of linear mapping, rank of linear mapping.
(Chapter 14 of recommended book at Sr. No 1)
Unit-IV:
Similar linear transformation, invariant subspaces of vector spaces, reduction of a linear transformation to triangular form, nilpotent transformation, index of nilpotency of a nilpotent transformation. Cyclic subspace with respect to a nilpotent transformations, uniqueness of the invariants of a nilpotent transformation. Primary decomposition theorem. Jordan blocks, Jordan canonical forms, cyclic module relative to a linear transformation, rational canonical form of a linear transformation and its elementary divisors, uniqueness of elementary divisors. (6.4. to 6.7 of recommended book of Sr. No. 3).
Recommended Books:
1 P. B. Bhattacharya, S. K. Jain, S. R. Nagpaul, Basic Abstract Algebra (Second edition), Cambridge University Press, 2012.
2. Surjit Singh and Quazi Zameeruddin : Modern Algebra ,Vikas Publishing House, 1990.
3 I. N. Herstein, Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.

MMATH20-102: COMPLEX ANALYSIS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course objectives: One objective of this course is to develop the parts of the theory that are prominent in applications of the complex numbers. Other objective is to furnish an introduction to applications of residues and conformal mapping. With regard to residues, special emphasis is given to their use in evaluating real improper integrals, finding inverse Laplace transforms, and locating zeros of functions. Conformal mapping find its use in solving boundary value problems that arise in studies of heat conduction, fluid flow and elastodynamics.

Course outcomes: This course will enable the students to:

1. Understand the concepts of limit, continuity, differentiation and integration for functions defined over a complex plane as well as for the elementary functions.
2. Solve the complex integrals of various kinds through the applications of relevant theorems, formulae and power series expansions.
3. Analyse the complex functions with singularities for zeroes and residues at poles and apply the results to solve the improper integrals.
4. Solve complex improper integrals through the indentation, transformation/mapping of integration paths so as to avoid singularities and branch points/cuts.

Unit-I:
Analytic functions; Harmonic functions; Reflection principle;
Elementary functions: Exponential, Logarithmic, Trigonometric, Hyperbolic, Inverse trigonometric , Inverse hyperbolic, Complex exponents;
Complex Integration: Definite integral; Contours; Branch cuts.
(Relevant portions from the book recommended at Sr. No. 1)

Unit-II:
Cauchy-Goursat theorem; Simply/ multiply connected domains;
Cauchy integral formula; Morera's theorem; Liouville's theorem; Fundamental theorem of algebra;
Maximum modulus principle;
Power series: Taylor series; Laurent series; Uniform/ absolute convergence.
(Relevant portions from the book recommended at Sr. No. 1)

Unit-III:
Differentiation, integration, multiplication, division of power series;
Singularities; Poles; Residues; Cauchy's residue theorem; Zeros of an analytic function;
Evaluation of improper integrals; Jordan's lemma.

(Relevant portions from the book recommended at Sr. No. 1)

Unit-IV:
Indented paths; Integration along a branch cut; Definite integrals involving sines and cosines; Winding number of closed curve; Argument principle; Rouche's theorem; Schwarz Lemma ;
Transformations: linear, bilinear (Mobius), sine, z^2, $z^{1/2}$;
Mapping: Isogonal; Conformal; Scale factors; Local inverses; harmonic conjugates.
(Relevant portions from the book recommended at Sr. No. 1)

Recommended Books:

1. Churchill, R.V. and Brown, J.W., Complex Variables and Applications, Eighth edition; McGraw Hill International Edition , 2009.
2. Ahlfors, L.V., Complex Analysis. McGraw-Hill Book Company, 1979.
3. Conway, J.B., Functions of One complex variables Narosa Publishing, 2000.
4. Priestly, H.A., Introduction to Complex Analysis Claredon Press, Orford, 1990.
5. D.Sarason, Complex Function Theory, Hindustan Book Agency, Delhi, 1994.
6. Mark J.Ablewitz and A.S.Fokas, Complex Variables : Introduction & Applications, Cambridge University Press, South Asian Edition, 1998.
7. E.C.Titchmarsn, The Theory of Functions, Oxford University Press, London.
8. S.Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, 1997.

MMATH20-103: ORDINARY DIFFERENTIAL EQUATIONS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The objectives of this course are to study the existence and uniqueness theory of solutions of initial value problems, to familiarize with system of linear and non-linear, homogeneous and non-homogeneous differential equations with constant or variable coefficients, to study theory of homogeneous and non-homogeneous linear differential equations of higher order in detail and to understand the dependence of solution on initial parameters. The aim of the course is to form a strong foundation in the theory of ordinary differential equations and to learn to apply towards problem solving.

Course Outcomes: This course will enable the students to:

1. Understand concepts of an initial value problem and its exact and approximate solutions, existence of solutions, uniqueness of solutions and continuation of solutions of an initial value problem of order one. Apply the knowledge to prove specified theorems and to solve relevant exercises
2. Learn about system of linear differential equations of first order and its preliminary concepts, homogeneous and non-homogeneous linear systems, existence and uniqueness theory, fundamental matrix, theory of adjoint systems, linear systems with constant coefficients and with periodic coefficients. Attain the skill to obtain fundamental matrix of such a given linear system to demonstrate problem solving.
3. Have deep understanding of theory of linear differential equations of higher order by getting knowledge of basic theory, Wronskian theory and fundamental sets, adjoint equations and standard theorems related to these topics. Apply methods of reduction of order and variation of parameters to solve linear and non-linear differential equations respectively and to solve higher order linear differential equations with constant coefficients.
4. Understand system of differential equations and its existence theory, dependence of solution of an IVP on initial parameters, extremal solutions, upper and lower solutions so as to be able to develop research aptitude in this area.

Unit-I:

Existence and Uniqueness of Solutions:

Existence of solutions; Initial value problem, ε-approximate solution, Equicontinuous set of functions, Ascoli lemma, Cauchy–Peano existence theorem and its corollary

Uniqueness of solutions; Lipschitz condition, Gronwall's inequality, Inequality involving approximate solutions, Method of successive approximations, Picard-Lindelöf theorem.

Continuation of solutions, Maximal interval of existence, Extension theorem.

(Relevant portions from the book of 'Theory of Ordinary Differential Equations' by Coddington and Levinson)

Unit-II:

System of linear differential equations: Preliminary definitions and notations. Linear homogeneous systems; Definition, Existence and uniqueness theorem, Fundamental matrix, Liouville formula, Adjoint systems, Reduction of the order of a homogeneous system.
Non-homogeneous linear systems; Variation of constants formula.
Linear systems with constant coefficients.
Linear systems with periodic coefficients, Floquet theory.
(Relevant portions from the book 'Theory of Ordinary Differential Equations' by Coddington and Levinson)

Unit-III:

Theory of linear differential equations: Linear Differential Equation (LDE) of order n, Basic theory of homogeneous linear equation, Wronskian theory: Definition, necessary and sufficient condition for linear dependence and linear independence of solutions of homogeneous LDE, Abel's Identity, Fundamental sets, More Wronskian theory, Reduction of order.
Non-homogeneous linear differential equation of order n: Variation of parameters.
Adjoint equations, Lagrange's Identity, Green's formula, Self adjoint equation of second order.
Linear differential equation of order n with constant coefficients; Characteristic roots, Fundamental set.
(Relevant portions from the books 'Theory of Ordinary Differential Equations' by Coddington and Levinson and the book 'Differential Equations' by S.L. Ross)

Unit-IV:

System of differential equations; Preliminary concepts, Differential equation of order n and its equivalent system of differential equations, Existence and uniqueness of solutions of system of differential equations.
Dependence of solutions on initial conditions and parameters: Preliminaries, continuity and differentiability of solution of a system of differential equations as a function of initial parameters.
(Relevant portions from the book 'Theory of Ordinary Differential Equations' by Coddington and Levinson)
Extremal solutions: Maximal and Minimal solutions.
Upper and Lower solutions, Comparison theorems, Existence via upper and lower solutions.
Bihari's inequality.
(Relevant portions from the book 'Textbook of Ordinary Differential Equations' by Deo et al.)

Recommended Text Books:

1. Earl A. Coddington and Norman Levinson, *Theory of Ordinary Differential Equations*, McGraw Hill Education , 2017.
2. Sheply L. Ross, *Differential Equations*, Wiley , 3rd Edition, 2007.
3. S.G. Deo, V. Raghavendra, Rasmita Kar, V. Lakshmikantham, *Textbook of Ordinary Differential Equations*, Tata McGraw-Hill , 2006.

Reference books:

1. P. Hartman, *Ordinary Differential Equations*, John Wiley & Sons NY, 1971.

2. G. Birkhoff and G.C. Rota, *Ordinary Differential Equations*, John Wiley & Sons, 1978.
3. G.F. Simmons, *Differential Equations*, Tata McGraw-Hill , 1993.
4. I.G. Petrovski, *Ordinary Differential Equations*, Prentice-Hall, 1966.
5. D. Somasundaram, *Ordinary Differential Equations, A first Course*, Narosa Pub., 2001.

MMATH20-104: REAL ANALYSIS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The course aims to familiarize the learner with Riemann-Stieltjes integral, uniform convergence of sequences and series of functions, functions of several variables and power series.

Course Outcomes: This course will enable the students to:

1. Understand the concept of Riemann-Stieltjes integral along its properties; integration of vector-valued functions with application to rectifiable curves.

2. Understand and handle convergence of sequences and series of functions; construct a continuous nowhere-differentiable function; demonstrate understanding of the statement and proof of Weierstrass approximation theorem.

3. Understand differentiability and continuity of functions of several variables and their relation to partial derivatives; apply the knowledge to prove inverse function theorem and implicit function theorem.

4. Learn about the concepts of power Series, exponential & logarithmic functions, trigonometric functions, Fourier series and Gamma function; apply the knowledge to prove specified theorems.

Unit-I:

Definition and existence of the Riemann-Stieltjes integral, properties of the integral, integration and differentiation, the fundamental theorem of calculus, integration of vector-valued functions, rectifiable curves. (Scope as in Chapter 6 of 'Principles of Mathematical Analysis' by Walter Rudin, Third Edition).

Unit-II:

Sequences and series of functions: Pointwise and uniform convergence of sequences of functions, Cauchy criterion for uniform convergence, Dini's theorem, uniform convergence and continuity, uniform convergence and Riemann integration, uniform convergence and differentiation. (Scope as in Sections 9.1 to 9.3 of Chapter 9 'Methods of Real Analysis' by R.R. Goldberg).

Convergence and uniform convergence of series of functions, Weierstrass M-test, integration and differentiation of series of functions, existence of a continuous nowhere-differentiable function, the Weierstrass approximation theorem (Scope as in Sections 9.4, 9.5, 9.7 of Chapter 9 & Section 10.2 of Chapter 10 of 'Methods of Real Analysis' by R.R. Goldberg).

Unit-III:

Functions of several variables: Linear transformations, the space of linear transformations on R^n to R^m as a metric space, open sets, continuity, derivative in an open subset of R^n, chain rule, partial derivatives, continuously differentiable mappings, the contraction principle, the inverse function theorem, the implicit function theorem. (Scope as in relevant portions of Chapter 9 (up to 9.29) of 'Principles of Mathematical Analysis' by Walter Rudin, Third Edition)

Unit-IV:

Power Series: Uniqueness theorem for power series, Abel's and Tauber's theorem, Taylor's theorem, Exponential & Logarithmic functions, trigonometric functions, Fourier series, Gamma function (Scope as in relevant portions of Chapter 8 of 'Principles of Mathematical Analysis' by Walter Rudin, Third Edition).

Recommended Text Books:

1. Walter Rudin, Principles of Mathematical Analysis (3rd Edition) McGraw-Hill, 2013.

2. R.R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing, 2020

Reference Books:

1. T.M. Apostol, Mathematical Analysis, Narosa Publishing House, New Delhi, 1985.

2. Gabriel Klambauer, Mathematical Analysis, Marcel Dekkar, Inc. New York, 1975.

3. A.J. White, Real Analysis; an introduction. Addison-Wesley Publishing Co., Inc., 1968.

4. E. Hewitt and K. Stromberg. Real and Abstract Analysis, Berlin, Springer, 1969.

5. Serge Lang, Analysis I & II, Addison-Wesley Publishing Company Inc., 1969.

6. S.C. Malik and Savita Arora, Mathematical Analysis, New Age International Limited, New Delhi,4th Edition 2010.

7. D. Somasundaram and B. Choudhary, A First Course in Mathematical Analysis, Narosa Publishing House, New Delhi, 1997

MMATH20-105: TOPOLOGY

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The main objective of this course is to introduce basic concepts of point set topology, basis and sub basis for a topology. Further, to study continuity, homeomorphisms, open and closed maps, product and quotient topologies and introduce notions of filters and compactness of spaces.

Course Outcomes: This course will enable the students to:

1. Know about topological spaces, understand neighbourhood system of a point and its properties, interior, closure, boundary, limit points of subsets, and base and subbase of topological spaces; apply the knowledge to solve relevant exercises.

2. Learn about first and second countable spaces, separable and Lindelof spaces, continuous functions, separation axioms and their properties.

3. Know about quotient topology; demonstrate understanding of the statements and proofs of Embedding theorem and Urysohn's Lemma.

4. Know about filters and compactness in topological spaces and apply the knowledge to prove specified theorems.

Unit-I :

Definition and examples of topological spaces, neighbourhoods, neighbourhood system of a point and its properties, interior point and interior of a set, interior as an operator and its properties, definition of a closed set as complement of an open set, limit point (accumulation point) of a set, derived set of a set, adherent point (closure point) of a set, closure of a set, closure as an operator and its properties, dense sets and separable spaces.

Base for a topology and its characterization, base for neighbourhood system, sub-base for a topology. relative (induced) topology and subspace of a topological space. Alternate methods of defining a topology using properties of neighbourhood system, interior operator, closed sets, Kuratowski closure operator. comparison of topologies on a set, about intersection and union of topologies, the collection of all topologies on a set as a complete lattice.

Unit-II:

First countable, second countable, their relationships and hereditary property. about countability of a collection of disjoint open sets in a separable and a second countable space, Lindelof theorem. Definition, examples and characterizations of continuous functions, composition of continuous functions, open and closed functions, homeomorphism.

Tychonoff product topology, projection maps, their continuity and openness, Characterization of product topology as the smallest topology such that the projections are continuous, continuity of a function from a space into a product of spaces. T_0 , T_1, T_2 spaces, productive property of T_1 and T_2 spaces.

Unit-III :

Regular and T_3 separation axioms, their characterization and basic properties i.e. hereditary and productive properties. quotient topology w.r.t. a map, continuity of function with domain a space having quotient topology, about Hausdorffness of quotient space.

Completely regular and Tychonoff ($T_{3\,1/2}$), spaces, their hereditary and productive properties. Embedding lemma, Embedding theorem, normal and T_4 spaces, Urysohn's Lemma, complete regularity of a regular normal space, Tietze's extension theorem (statement only).

Unit-IV :

Definition and examples of filters on a set, finer filter, ultra filter (u.f.) and its characterizations, Ultra Filter Principle (UFP). image of a filter under a function. convergence of filters: limit point (cluster point) and limit of a filter and relationship between them, Continuity in terms of convergence of filters. Hausdorffness and filter convergence.

Compactness: Definition and examples of compact spaces, compactness in terms of finite intersection property (f.i.p.), continuity and compact sets, compactness and separation properties. regularity and normality of a compact Hausdorff space. compactness and filter convergence, Tychonoff product theorem.

(Scope of the course is as given in chapters 1, 3, 4 & 5 of General Topology by J.L.Kelley).

Recommended Text Book :

1.J.L. Kelley : General Topology, Springer Verlag, New York, 2012.

Reference Books :

1. J. R. Munkres, Toplogy, Pearson Education Asia, 2002.

2. C.W. Patty, Foundation of Topology, Jones & Bertlett, 2009.

3. Fred H. Croom, Principles of Topology, Cengage Learning, 2009.

4. George F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 1983.

5. K. Chandrasekhara Rao, Topology, Narosa Publishing House Delhi,2009.

6. K.D. Joshi, Introduction to General Topology, Wiley Eastern Ltd, 2006.

MMATH20- 106: Practical-I

Course Credit Practical	Practical Hours per week	End Term Examination Time	Maximum Marks		
			Internal Assessment	End Term Examination	Total
2	4	4 Hours	10	40	50

Note: The examiner will set 3 questions at the time of practical examination by taking course outcomes (COs) into consideration. The examinee will be required to write two programs and execute one program successfully. The evaluation will be done on the basis of practical record, viva-voce, write up and execution of the program.

Course objectives: This is a laboratory course and objective of this course is to acquaint the students with the practical use and to train for writing codes in ANSI-C for problem solving. Also, some problem solving techniques based on papers MMATH20-101 to MMATH20-105 will be taught.

Course Outcomes: This course will enable the students to:

1. Solve practical problems related to theory courses undertaken in the Semester-I from application point of view.
2. Know syntax of expressions, statements, structures and to write source code for a program in C.
3. Edit, compile and execute the source program for desired results.
4. Debug, verify/check and to obtain output of results.

List of Programs: The following practicals will be done using the programming language C and record of those will be maintained in the practical Note Book:

1. *Use of nested if.. .else in finding the smallest of four or more numbers.*
2. *To find if a given 4-digit year is a leap year or not.*
3. *To compute AM, GM and HM of three given real values.*
4. *To invert the order of digits in a given positive integral value.*
5. *Use series sum to compute sin(x) and cos(x) for given angle x in degrees. Then, check error in verifying* $\sin^2 x+\cos^2(x) = 1$ *or other such T-identities.*
6. *Verify* $\sum n^3 = \{\sum n\}^2$, *(where n=1, 2,…, m) & check that prefix and postfix increment operator gives the same result.*
7. *Compute simple interest and compound interest for a given amount, time period, rate of interest and period of compounding.*
8. *Program to multiply two given matrices in a user defined function.*
9. *Calculate standard deviation for a set of values {x(j), j = l, 2,..., n} having the corresponding frequencies {f(j), j = l,2,...,n}.*
10. *Write the user-defined function to compute GCD of two given values and use it to compute the LCM of three given integer values.*
11. *Compute GCD of 2 positive integer values using recursion / pointer to pointer.*
12. *Check a given square matrix for its positive definite/ negative definite forms.*
13. *To find the inverse of a given non-singular square matrix.*
14. *To convert a decimal number to its binary representation and vice-versa.*
15. *Use array of pointers for alphabetic sorting of given list of English words.*

MMATH20- 107: Seminar-I

Course Credit	Seminar Hours per week	End Term Examination Time	Maximum Marks		
			Internal Assessment	End Term Examination	Total
2	2	-	50	-	50

Note: There will be no external examination. Evaluation will be done by the internal group incharge.

Course objectives: The objectives of this course are self study, understanding a topic in detail, comprehension of the subject/topic, investigating a problem, knowledge of ethics, effective communication and life-long learning.

Course Outcomes: This course will enable the students to:

1. Identify an area of interest and to select a topic therefrom realizing ethical issues related to one's work and unbiased truthful actions in all aspects of work and to develop research aptitude.
2. Have deep knowledge and level of understanding of a particular topic in core or applied areas of Mathematics, imbibe research orientation and attain capacity of investigating a problem.
3. Obtain capability to read and understand mathematical texts from books/journals/e-contents, to communicate through write up/report and oral presentation.
4. Demonstrate knowledge, capacity of comprehension and precision, capability to work independently and tendency towards life-long learning.

Note: *Each student will select a topic of one's choice, get approval from the concerned group incharge, give sittings in a library so as to read different books, prepare a seminar document, present before the group and its incharge for not less than an hour. The evaluation of the seminar will be done by the concerned group incharge by taking into account the following:*

i. Subject knowledge.
ii. Degree of difficulty, research aptitude and knowledge updation in choice of the topic.
iii. Contents.
iv. Communication.
v. Response to questions.

MMATH20-201: ADVANCED ABSTRACT ALGEBRA

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: As suggested by the name of the course itself, some of the advanced topics of abstract algebra will be taught to the students in this course including field extensions, finite fields, normal extensions, finite normal extensions as splitting fields. A study of Galois extensions, Galois groups of polynomials, Galois radical extensions shall also be made.

Course Outcomes: This course will enable the students to:

1. Understand concepts of irreducible polynomial, Eisenstein criterion, field extension, algebraic and transcendental extension, algebraically closed field.
2. Have deep understanding of Splitting fields, normal extension, multiple roots, prime field, finite field and separable extension.
3. Learn about automorphism groups, fixed field, Dedekind lemma, fundamental theorem of Galois theory, roots of unity, Cyclotomic polynomial and cyclic extension.
4. Have deep understanding of polynomials solvable by radicals, symmetric functions, ruler and compass construction.

Unit-I:
Irreducible polynomials, Eisenstein criterion, Gauss lemma. Field extension, algebraic and transcendental extension, degree of an extension, algebraic closure and algebraically closed field.

Unit-II:
Splitting field, degree of extension of splitting field. Normal extension, multiple roots, prime field, characterization of prime field, finite field, separable extension.

Unit-III:
Automorphism group, fixed field, Dedekind lemma, Galois groups of polynomials, Galois extension, fundamental theorem of Galois theory, fundamental theorem of algebra, roots of unity. Cylotomic polynomials, Klein’s four group, cyclic extension, Frobenius automorphism of a finite field.

Unit-IV:
Solvability of polynomials by radicals over Q. Symmetric functions and elementary symmetric functions. Construction with ruler and compass only.

(Chapter 15, 16, 17 & 18 of recommended book)

Recommended Text Book:
1. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Basic Abstract Algebra (2nd Edition), Cambridge University Press, Indian Edition, 2012.

Reference books:
1. Vivek Sahai and Vikas Bist, Algebra, Narosa Publishing House, 1999.
2. Surjit Singh and Quazi Zameeruddin, Modern Algebra, Vikas Publishing House, 1990.
3. Patrick Morandi, Field and Galois Theory, Springer 1996.

MMATH20-202: COMPUTER PROGRAMMING with MATLAB

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course objectives: This course is designed to train the students in the computer programming. The objective of this course is to develop a skill of writing codes in MATLAB or equivalent Open Source software for solving different types of mathematical problems which arise in the areas of Mathematical/Physical/Life/Social Sciences and Engineering.

Course outcomes: This course will enable the students to:

1. Get familiar with the importance and working of MATLAB as computation platform through the knowledge of characters, variables, operators, functions and expressions as used for elementary operations in matrix algebra along with the editing, load/save data and compilation/execution/quitting of source programs.
2. Learn the process of writing a source program in MATLAB as high-level language making use of the statements for input/output, conditional/non-sequential processing involving functions, arrays and structures.
3. Learn the plotting of the curves and surfaces, which can be edited, modified, accumulated, handled, printed, exported and used to creating movies.
4. Write source programs with objects, variables, expressions, abstract functions, math functions in symbolic form and their subsequent use for the operations/ concepts/ problems in calculus, linear algebra and differential equations.

Unit-I:

Introduction: Basics of programming; Anatomy of a program; Constants; Characters; Variables; Data types; Assignments; Operators; functions; Examples of expressions; Entering long statements; Command line editing. Good programming style.
Working with vectors: Defining a Vector, Accessing elements within a vector, Basic operations on vectors; Mathematical functions; Strings; String functions; Cell array; Creating cell array; Concatenation.
Working with Matrices: Generating matrices; Mathematical operations and functions; Deleting rows /columns; Linear algebra; Arrays; Multivariate data; Scalar expansion; Logical subscripting;
Input and output: Save/Load functions, M-files, The find function; The format function; Suppressing output;

Unit-II:

Flow Control: if and else, switch and case, for loop, while loop, continue, break, try – catch, return.
Data Structures: Multidimensional arrays; Cell arrays, Characters and text; Structures,
Scripts and Functions: Scripts; Functions; Types of functions; Global variables; Passing string arguments to functions; The eval function; Function handles; Function functions; Vectorization; Preallocation.

Unit-III:

Graphics: Plotting process; Graph components; Figure tools; Arranging graphs within a figure; Selecting plot types; Plot editing mode, Using functions to edit graphs; Modifying a graph data source; Modify a graph to enhance the presentation; Printing a graph; Exporting a graph.
Basic Plotting Functions: Creating a plot; Multiple data sets in one graph; Specifying line styles and colors; Plotting lines and markers; Imaginary and complex data; Adding plots to existing graph; Figure windows; Multiple plots in one figure; Controlling the axes; Axis labels and titles; Saving figures.
Mesh and Surface Plots: Visualizing functions of two variables; Reading/writing images.
Printing and Handle Graphics: Using the handle; Graphics object; Setting object Properties; Specifying the axes or figure, Finding the handles of existing objects.
Animations: Erase mode method, Creating movies.

Unit-IV:

Symbolic Math: Symbolic objects; Creating symbolic variables and expressions; The findsym Command; The default symbolic variable; Constructing real and complex variables; Creating abstract functions; Creating symbolic math functions; Creating an M-file.
Calculus: Limits; Differentiation; Integration; Symbolic summation; Taylor series; Examples; Simplifications and substitutions, Variable-precision arithmetic examples.
Linear Algebra: Basic algebraic operations; Linear algebraic operations; Eigenvalues; Jordan canonical form; Singular value decomposition; Eigenvalue trajectories.
Solving Equations: System of algebraic equations, System of differential equations

Recommended Books:

1. *Learning MATLAB*, COPYRIGHT 1984 - 2005 by The MathWorks, Inc.
2. Amos Gilat, *MATLAB An Introduction With Applications* 5ed, Wiley, 2008.
3. C. F. Van Loan and K.-Y. D. Fan., *Insight through Computing: A Matlab Introduction to Computational Science and Engineering*, SIAM Publication, 2009.
4. T. A. Davis and K. Sigmon, *MATLAB Primer* 7th Edition, CHAPMAN & HALL/CRC, 2005.
5. B. R. Hunt, R. L. Lipsman, J. M. Rosenberg, K. R. Coombes, J. E. Osborn, and G. J. Stuck, *A Guide to MATLAB*, Second Edition, Cambridge University Press, 2006.
6. Y.Kirani Singh, B.B. Chaudhari, *MATLAB Programming*, PHI Learning, 2007.
7. K. Ahlersten, *An Introduction to Matlab*, Bookboon.com.
8. Rudra Pratap, *Getting Started with MATLAB*, Oxford University Press, 2010.
9. C. Gomez, C. Bunks and J.-P. Chancelier, *Engineering and Scientific Computing with SCILAB*, Birkhäuser, 2012.
10. A. Quarteroni, F. Saleri and P. Gervasio, *Scientific Computing with MATLAB and Octave*, Springer Nature, 2014.

MMATH20-203: DIFFERENTIAL EQUATIONS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The objectives of this course are to learn about oscillations of second order differential equations, solving boundary value problems, critical points of linear and non-linear system of differential equations and to determine types and stability of those critical points and systems.

Course Outcomes: This course will enable the students to:

1. Understand preliminary, oscillation and Sturm' theory of second order ordinary differential equations and comparison theorems. Apply this knowledge to solve problems of checking second order ODEs for oscillatory, finding common zeros and applying Prüffer transformation.
2. Have good understanding of boundary value problems of second order, their classification and solution. Appreciate the concept of Green's function. Attain skills to solve boundary value problems which find great applications in areas of applied mathematics, science and engineering.
3. Know critical points of linear and non-linear system of differential equations, their types and stability. Understand concepts of potential energy function, limit cycles, semi orbit and limit sets. Apply the gained knowledge to determine type and stability of critical points and check for existence of limit cycles of given systems. Have a foundation to understand area of non-linear analysis of dynamical systems where mathematics and space science connect to each other.
4. Understand stability of linear, quasi-linear and non-linear systems. Learn to apply Lyapunov direct method to determine stability of such systems for investigating and solving problems.

Unit-I:

Linear second order equations: Preliminaries, Superposition principle, Riccati's equation, Prüffer transformation.
Oscillations of second order differential equations: Zero of a solution, Oscillatory and non-oscillatory equations, Abel's formula, Common zeros of solutions and their linear dependence, Sturm separation theorem, Sturm fundamental comparison theorem and its corollaries, Elementary linear oscillations, Comparison theorem of Hille-Wintner, Oscillations of $x'' + a(t)x = 0$.
(Relevant portions from the book 'Differential Equations' by S.L. Ross and the book 'Textbook of Ordinary Differential Equations' by Deo et al.)

Unit-II:

Second order boundary value problems (BVP): Linear problems; periodic boundary conditions, regular linear BVP, singular linear BVP; non-linear BVP,

Sturm-Liouville BVP; Definition, Characteristic values and Characteristic functions. Orthogonality of characteristic functions.

Green's functions: Definition and Properties. Applications of boundary value problems, Picard's theorem.

(Relevant portions from the book 'Differential Equations' by S.L. Ross and the book 'Textbook of Ordinary Differential Equations' by Deo et al.)

Unit-III:

Non-linear Differential Equations: Autonomous systems; Phase plane, Paths and Critical points, Types of critical points; Node, Center, Saddle point, Spiral point, Stability of critical points, Critical points and paths of linear systems; Basic theorems and their applications.

Critical points and paths of non-linear systems; Basic theorems and their applications. Non-linear conservative systems, Potential energy function, Dependence on a parameter.

Limit Cycles and periodic solutions, Benedixson's non-existence criterion, Half-path, Limit set, Statement of Poincaré-Benedixson theorem and its uses.

(Relevant portions from the book 'Differential Equations' by S.L. Ross)

Unit-IV:

Stability of linear and non-linear systems: System of equations with constant coefficients, linear equation with constant coefficients.

Lyapunov Stability: Stability of solution of a differential system, Positive definite and semidefinite functions, Negative definite and semidefinite functions, Decrescent function,

Lyapunov function, Lyapunov's theorems on stability.

Stability of quasi-linear systems. Boundedness of solutions of a second order differential equations.

(Relevant portions from the book 'Textbook of Ordinary Differential Equations' by Deo et al.)

Recommended Text Books:

1. Sheply L. Ross, *Differential Equations*, Wiley , 3rd Edition, 2007.
2. S.G. Deo, V. Raghavendra, Rasmita Kar, V. Lakshmikantham, *Textbook of Ordinary Differential Equations*, Tata McGraw-Hill , 2006.

Reference books:

1. Earl A. Coddington and Norman Levinson, *Theory of Ordinary Differential Equations*, McGraw Hill Education , 2017.
2. P. Hartman, *Ordinary Differential Equations*, John Wiley & Sons NY, 1971.
3. G. Birkhoff and G.C. Rota, *Ordinary Differential Equations*, John Wiley & Sons, 1978.
4. G.F. Simmons, *Differential Equations*, Tata McGraw-Hill , 1993.
5. Mohan C Joshi, *Ordinary Differential Equations, Modern Perspective*, Narosa Publishing House, 2006.

MMATH20-204: MEASURE AND INTEGRATION

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The main objective is to familiarize with Lebesgue outer measure, measurable sets, measurable functions, Lebesgue integration, fundamental integral convergence theorems, functions of bounded variation, differentiation of an integral, absolutely continuous functions and Lp-spaces.

Course Outcomes: This course will enable the students to:
1. Understand the concepts of measurable sets and Lebesgue measure; construct a non-measurable set; apply the knowledge to solve relevant exercises.
2. Know about Lebesgue measurable functions and their properties; and apply the knowledge to prove Egoroff's theorem, Lusin's theorem and F.Riesz theorem.
3. Understand the requirement and the concept of the Lebesgue integral (as a generalization of the Riemann integration) along its properties and demonstrate understanding of the statement and proofs of the fundamental integral convergence theorems.
4. Know about the concepts of differentiation of monotonic function, functions of bounded variations, differentiation of an integral and absolutely continuous functions; apply the knowledge to prove specified theorems.

Unit-I:
Lebesgue outer measure, elementary properties of outer measure, measurable sets and their properties, Lebesgue measure of sets of real numbers, algebra of measurable sets, Borel sets and their measurability, characterization of measurable sets in terms of open, closed, F_σ and G_δ sets, existence of a non-measurable set.

Unit-II:
Lebesgue measurable functions and their properties, the almost everywhere concept, characteristic functions, simple functions, approximation of measurable functions by sequences of simple functions, Borel measurability of a function.

Littlewood's three principles, measurable functions as nearly continuous functions. Lusin's theorem, almost uniform convergence, Egoroff's theorem, convergence in measure, F.Riesz theorem that every sequence which is convergent in measure has an almost everywhere convergent subsequence.

Unit-III:
The Lebesgue Integral: Shortcomings of Riemann integral, Lebesgue integral of a bounded

function over a set of finite measure and its properties, Lebsegue integral as a generalization of the Riemann integral, Bounded convergence theorem, Lebesgue theorem regarding points of discontinuities of Riemann integrable functions.
Integral of a non-negative function, Fatou's lemma, Monotone convergence theorem, integration of series, the general Lebesgue integral, Lebesgue convergence theorem.

Unit-IV:

Differentiation and Integration: Differentiation of monotone functions, Vitali's covering lemma, the four Dini derivatives, Lebesgue differentiation theorem, functions of bounded variation and their representation as difference of monotone functions.
Differentiation of an integral, absolutely continuous functions and their properties, convex functions, Jensen's inequality. The Lp-spaces and their completeness.

Recommended Text Book:

H.L. Royden, Real Analysis (3rd Edition) Prentice-Hall of India, 2008.

Reference Books:

1. G.de Barra, Measure theory and integration, New Age International, 2014.
2. P.R. Halmos, Measure Theory, Van Nostrans, Princeton, 1950.
3. I.P. Natanson, Theory of functions of a real variable, Vol. I, Frederick Ungar Publishing Co., 1961.
4. R.G. Bartle, The elements of integration, John Wiley & Sons, Inc.New York, 1966.
5. K.R. Parthsarthy, Introduction to Probability and measure, Macmillan Company of India Ltd.,Delhi, 1977.
6. P.K. Jain and V.P. Gupta, Lebesgue measure and integration, New Age International (P) Ltd., Publishers, New Delhi, 1986.

MMATH20-205: MECHANICS OF SOLIDS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: In this course, basic theory of mechanics of solids is introduced. First, the laws of transformations and tensors will be introduced. Mathematical theory of deformations, analysis of strain and analysis of stress in elastic solids will be learnt next. A student will also learn basic equations of elasticity and variational methods. In this course, the students will be exposed to the mathematical theory of elasticity and other techniques which find applications in areas of civil and mechanical engineering and Earth and material sciences. This course will expose a student to Applied Mathematics and will form a sound basis for doing research in the number of areas involving solid mechanics.

Course Outcomes: This course will enable the students to:

1. Understand the concept of tensors as a generalized form of directional entities and to explore their properties through the operations of algebra and calculus. Be familiar with affine transformation and infinitesimal deformation.
2. Understand analysis of strain and stress tensors. Prepare a strong foundation to learn theory of elasticity to solve scientific problems.
3. Relate strain tensor and stress tensor through anisotropic elastic moduli, subjected to reflection/rotational symmetries to define elastic isotropy, and using theorems/ principles to explore the role of these relations in strain energy, compatibility and uniqueness of solution.
4. Learn variational methods to solve boundary value problems in elasticity. Learn to prove standard theorems related to theory of variational problems and to apply these techniques/methods by minimizing the potential / strain / complementary energies to solve scientific problems in mechanics of solids and get exposed to research problems in the field of elasticity.

Unit-I:
Tensor Algebra: Coordinate-transformation, Cartesian Tensors of different order.

Properties of tensors. Isotropic tensors of different orders and relation between them. Symmetric and skew symmetric tensors. Tensor invariants. Deviatoric tensors. Eigen-values and eigen-vectors of a tensor.

Tensor Analysis: Scalar, vector, tensor functions, Comma notation.

Gradient, divergence and curl of a vector / tensor field.

(Relevant portions of Chapters 2 and 3 of book by D.S. Chandrasekharaiah and L.Debnath)

Affine transformation, Infinitesimal affine deformation.

(Relevant portions of Chapter 1 of the book by I.S. Sokolnikoff).

Unit-II:

Analysis of Strain: Strain tensor, Geometrical Interpretation of strain components. Strain quadric of Cauchy. Principal strains, Invariants, General infinitesimal deformation. Examples of strain, Equations of compatibility.

(Relevant portions of Chapter 1 of the book by I.S. Sokolnikoff).
Analysis of Stress : Stress Vector, Stress tensor, Equations of equilibrium, Transformation of coordinates. Stress quadric of Cauchy, Principal stresses. Maximum normal and shear stresses. Mohr's circles. Examples of stress.

(Relevant portions of Chapter 2 of the book by I.S. Sokolnikoff).

Unit-III:

Equations of Elasticity: Generalised Hooke's Law, Anisotropic symmetries, Homogeneous Isotropic media. Elasticity moduli for Isotropic media. Equilibrium and dynamic equations for an isotropic elastic solid. Strain energy function and its connection with Hooke's Law.

Beltrami-Michell compatibility equations. Uniqueness of solution. Clapeyron's theorem. Saint-Venant's principle.

(Relevant portions of Chapter 3 of book by I.S. Sokolnikoff).

Unit-IV:

Variational Methods: Variational problems and Euler's Equations, Theorem of minimum potential energy. Theorem of minimum complementary energy. Reciprocal theorem of Betti and Rayleigh. Ritz method: one and two dimensional cases. Galerkin method. Method of Kantorovich.

(Relevant portions of Chapter 7 of the book by I.S. Sokolnikoff).

<u>Recommended Text Books:</u>

1. I.S. Sokolnikoff, Mathematical Theory of Elasticity, Tata-McGraw Hill Publishing Company Ltd., New Delhi, 1977.
2. D.S. Chandrasekharaiah and Lokenath Debnath, Continuum Mechanics, Academic Press, 2014.

Reference Books:

1. A.E.H. Love, A Treatise on the Mathematical Theory of Elasticity Dover Publications, New York.
2. Y.C. Fung. Foundations of Solid Mechanics, Prentice Hall, New Delhi, 1965.
3. Shanti Narayan, Text Book of Cartesian Tensor, S. Chand & Co., 1950.
4. S. Timeshenko and N. Goodier. Theory of Elasticity, McGraw Hill, New York, 1970.
5. I.H. Shames, Introduction to Solid Mechanics, Prentice Hall, New Delhi, 1975.

MMATH20-206: Practical-II

Course Credit Practical	Practical Hours per week	End Term Examination Time	Maximum Marks		
			Internal Assessment	End Term Examination	Total
2	4	4 Hours	10	40	50

Note: The examiner will set 3 questions at the time of practical examination by taking course outcomes (COs) into consideration. The examinee will be required to write two programs and execute one program successfully. The evaluation will be done on the basis of practical record, viva-voce, write up and execution of the program.

Course objectives: This course aims to train the students for practical implementations of the features of MATLAB/SCILAB/Octave programming, which they study as a theory course MMATH20-202. Also, implementation of some problem solving techniques, based on papers MMATH20-201 to MMATH20-205, should be learnt.

Course Outcomes: This course will enable the students to:

1. Solve practical problems related to theory courses undertaken in the Semester-II from application point of view.
2. Know syntax of expressions, statements, data types, structures, commands and to write source code for a program in MATLAB/SCILAB/Octave.
3. Edit, compile/interpret and execute the source program for desired results.
4. Debug, verify/check and to obtain output of results.

List of Programs: The following practicals will be done on the MATLAB/SCILAB/Octave platform and record of those will be maintained in the practical Note Book:

1. Plot a circle for given centre and a point on the boundary. Find its perimeter and area.
2. To compute the arithmetic mean, geometric mean and harmonic mean for the values {x(j), j=1,2,...,n} and the corresponding frequencies {f(j), j=1,2,...,n}.
3. Find the inverse of a given matrix and verify the result by using built-in function.
4. Use switch…case to calculate the income tax on a given income at the existing rates.
5. Write function for the greatest common divisor (gcd) of two given positive integers and use it to find the least common multiple (lcm) of three given positive integer values. Get the result using built-in functions as well.
6. Solve a cubic equation with given coefficients and verify the solution through built-in function.
7. Identify the location of a given point (x,y) i) at origin, ii) on x-axis or y-axis iii) in quadrant I, II, III or IV. Verify through x-y plot.
8. Write functions to calculate sin(x) and cos(x) as series sum of n terms. Use these functions to plot sin(x), cos(x), sin(x) +cos(x), x in $[0,2\pi]$, for n=2,5,10. Display the deviation of curves from those obtained via built-in functions.
9. For given coefficients (a, b, c, d, e), solve the equation $ax^2+ by^2+2cx+2dy+e=0$ to plot the corresponding conic, viz. parabola/ hyperbola/ ellipse/ circle or else.
10. For given perimeter and number of sides, plot the polygon and calculate its area.

11. Use polar coordinates to plot 4 circles in a plot with common centre but of different radii.
12. For 4 spheres with given centre and radii, plot their surfaces as different subplots in a figure.
13. Least square fitting of a straight line to given set of points on a plane. Compare the plot this line with the plots of least-square fit polynomials of degree 2 to 5.
14. For a given square matrix A, find its eigenvalues (p) after solving the determinant |A-pI| into an algebraic equation.
15. For a given square matrix of order 3, find the eigen-values and eigen-vectors and check the result with the use of built-in function.

Reference Books:

1. B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, *A Guide to MATLAB*, Second Edition, Cambridge University Press, 2006.
2. T. A. Driscoll, *Learning MATLAB*; Society for Industrial and Applied Mathematics ,2009.
3. K. Sigmon and T.A. Davis, *MATLAB Primer 7th Edition*, CRC Press, 2005.

OEM20-207: BASIC MATHEMATICS-I

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
2	0	3 Hours	10	40	50

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 4 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course objectives: The main objective of this course is to familiarize the students with some of the topics from Analysis and Algebra, namely, convergence of sequences and series, Fourier series, algebra of matrices, rank of a matrix, systems of linear equations, characteristic roots and characteristic vectors of a square matrix.

Course Outcomes: This course will enable the students to:

1. Understand convergence of sequences and series; attain the skill to handle the convergence of various infinite series.
2. Know about the Fourier series, conditions for Fourier expansion; attain the skill to compute Fourier series of various functions.
3. Know about the algebra of matrices, rank of a matrix; attain the skill to find the rank of matrices.
4. Solve systems of linear equations and find characteristic roots and characteristic vectors of a square matrix.

Unit-I:
Sequences and series: sequences, bounded, convergent and monotonic sequences, infinite series, convergence and divergence of an infinite series, positive term series, geometric series, comparison test for positive term series, Cauchy's root test, D'Alembert's ratio test. Raabe's test, logarithmic test, integral test, Gauss's test. (Scope as in relevant portions of chapters 3 and 4 of the book recommended at Sr. No. 1)

Unit-II:
Fourier Series : Periodic function, Euler's formulae, conditions for Fourier expansion, functions having points of discontinuity, even and odd functions, Fourier series for even and odd functions, half range Fourier series. (Scope as in relevant portions of chapter 1 of the recommended at Sr. No. 2)

Unit-III:
Algebra of matrices: Basic operations on matrices, special type of square matrices: idempotent matrix, nilpotent matrix, involutary matrix, orthogonal matrix, unitary matrix; rank of a matrix (Scope as in relevant portions of chapters 2 and 4 of the book recommended at Sr. No. 3)

Unit-IV:
Systems of linear equations:, system of linear homogeneous equations, systems of linear non-homogeneous equations, matrices of reflection and rotation.

Characteristic roots and characteristic vectors of a square matrix. Characteristic matrix and characteristic equation of a matrix, Cayley-Hamilton theorem (without proof). (Scope as in relevant portions of chapters 6 and 11 of the book recommended at Sr. No. 3)

Recommended Text Books:
1. S.C. Malik and Savita Arora: Mathematical Analysis, New Age International Publishers, 2017.
2. S. Sreenadh, S. Ranganatham, M.V.S.S.N. Prasad and V.R. Basu : Fourier series and integral transforms, S. Chand & Company (Pvt) Ltd., 2014.
3. Shanti Narayan and P.K. Mittal: A text book of matrices, S. Chand & Company (Pvt) Ltd., 2018.

Reference Books:
1. R.G. Bartle and D.R. Sherbert : Introduction to Real Analysis, John Wiley & Sons, 2000.
2. R.R. Goldberg : Methods of Real Analysis, Oxford and IHB Publishing Company, New Delhi, 1970.
3. Seymour Lipschutz and Marc Lipson : Linear Algebra, Third Edition, McGraw Hill Education, 2005.

MMATH21-301: FLUID MECHANICS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: Fluid mechanics is a branch of continuum mechanics which deals with mechanics of fluids (liquids and gases) of ideal and viscous types. Fluid mechanics has a wide range of applications in the areas of mechanical engineering, civil engineering, chemical engineering, geophysics, astrophysics, and biology. This course aims to provide basic concepts, laws and theories of fluid dynamics and to prepare a foundation to understand the motion of fluid and develop concept, models and techniques which enables to solve the two and three dimensional problems of fluid flow and help in advanced studies and research in the broad area of fluid motion.

Course Outcomes: This course will enable the students to:

1. Be familiar with continuum model of fluid flow, classify fluid/flows, Stream, path and streak lines, rotational and irrotational motion. Understand Eulerian and Lagrangian descriptions of fluid motion, law of conservation of mass and boundary surfaces. Attain ability to derive equation of continuity and problem solving.
2. Learn to derive equations of motion, Bernouli equation, vorticity equation corresponding to different problems of fluid dynamics and to solve those equations. Prove theorems on circulation and energy in fluid flow. Make strong foundation for doing research in the area of fluid mechanics and bio-mechanics.
3. Understand motion of sphere in a fluid and fluid flow past a sphere at rest; sources, sinks, doublets and their images. Learn to solve three dimensional flow problems of fluid dynamics.
4. Understand two dimensional flow problems, stream function, axi-symmetric flow, complex potential, source, sink and doublets in two dimensions, Milne-Thomson circle theorem, Blasius theorem. Attain skills to solve fluid flow problems in two dimensions. Get exposure to research problems in fluid dynamics.

Unit-I:

Kinematics of fluid in motion: Real fluids and ideal fluids, Velocity at a point of a fluid. Lagrangian and Eulerian methods. Stream lines, Path lines and Streak lines. Vorticity and Circulation, Vortex lines, Velocity potential, Irrotational and rotational motions. Acceleration at a point of fluid, Local and particle rates of change.

Equation of continuity. Conditions at a rigid boundary, boundary surfaces.

(Relevant portions from the recommended text books at Sr. No. 1 & 2)

Unit-II:

Pressure at a point in a fluid, Conditions at a boundary of two immiscible fluids. Equation of Motion : Lagrange's and Euler's equations of Motion. Bernoulli's equation, Applications of the Bernoulli Equation in one–dimensional flow problems, Steady motion under conservative body forces.

Kelvins circulation theorem, Vorticity equation. Energy equation for incompressible flow. Kinetic energy of irrotational flow. Kelvins minimum energy theorem. Mean value of the velocity potential. Kinetic energy of infinite liquid. Uniqueness theorems.
(Relevant portions from the recommended text books at Sr. No. 1 & 2)

Unit-III:

Axially symmetric flows. Sphere at rest in a uniform stream, Sphere in motion in fluid at rest at infinity. Equation of motion of a sphere. Kinetic energy generated by impulsive motion. Motion of two concentric spheres.

Three-dimensional sources, sinks and doublets. Images of sources, sinks and doublets in rigid impermeable infinite plane and in impermeable spherical surfaces.
(Relevant portions from the recommended text books at Sr. No. 1 & 2)

Unit-IV:

Two-dimensional flows: Use of cylindrical polar coordinates, Stream function, Some fundamental stream functions, Axisymmetric flow, Equations satisfied by Stokes's stream function in irrotational flow, Basic Stokes's stream functions, Boundary conditions satisfied by the stream function.

Irrotational plane flows: Complex potential, Image systems in plane flows. Milne-Thomson circle theorem. Circular cylinder in uniform stream with circulation. Blasius theorem.
(Relevant portions from the recommended text books at Sr. No. 1 & 2)

Recommended Text Books:

1. F. Chorlton, *Text-book of Fluid Dynamics*, CBS Publishers and Distributors Pvt. Ltd., 2018.
2. Michael E. O'Neill and F. Chorlton, *Ideal and Incompressible Fluid Dynamics*, Ellis Horwood, 1986.

Reference Books:

1. G.K. Batchelor, *An Introduciton to Fluid Dynamics*, Cambridge University Press, 2000.
2. A.J. Chorin and A. Marsden, *A Mathematical Introduction to Fluid Dynamics*, Springer-Verlag, New York, 1993.
3. L.D. Landau and E.M. Lifshitz, *Fluid Mechanics*, Pergamon Press, 1987.
4. H. Schlichting, *Boundary Layer Theory*, Springer, 2016.
5. S. W. Yuan, *Foundations of Fluid Mechanics*, Prentice Hall of India Ltd., 1988.
6. A.D. Young, *Boundary Layers*, AIAA Education Series, Washington DC, 1989.
7. W.H. Besant and A.S. Ramsey, *A Treatise on Hydromechanics*, Part-II, CBS Publishers, Delhi, 2006.

MMATH21-302: FUNCTIONAL ANALYSIS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The main objective is to familiarize with normed linear spaces, Banach spaces, inner product spaces and Hilbert spaces. The four fundamental theorems: Hahn-Banach Theorem, Uniform Boundedness Theorem, Open Mapping Theorem and Closed Graph Theorem are the highlights of the course. We also make an excursion into Hilbert spaces, introducing basic concepts and proving the classical theorems associated with the names of Riesz, Bessel and Parseval, along with classifying operators into self-adjoint, unitary and normal operators.

Course Outcomes: This course will enable the students to:
1. Know about the requirements of a norm; completeness with respect to a norm; understand relation between compactness and dimension of a space; check boundedness of a linear operator and relate to continuity; convergence of operators by using a suitable norm; apply the knowledge to compute the dual spaces.
2. Extend a linear functional under suitable conditions; apply the knowledge to prove Hahn Banach Theorem for further application to bounded linear functionals on C[a,b]; know about adjoint of operators; understand reflexivity of a space and demonstrate understanding of the statement and proof of uniform boundedness theorem.
3. Know about strong and weak convergence; understand open mapping theorem, bounded inverse theorem and closed graph theorem; distinguish between Banach spaces and Hilbert spaces; decompose a Hilbert space in terms of orthogonal complements.
4. Understand totality of orthonormal sets and sequences; represent a bounded linear functional in terms of inner product; classify operators into self-adjoint, unitary and normal operators.

Unit-I:

Normed linear spaces, Banach spaces, finite dimensional normed spaces and subspaces, equivalent norms, compactness and finite dimension, F.Riesz's lemma.

Bounded and continuous linear operators, differentiation operator, integral operator, bounded linear extension, bounded linear functionals, normed spaces of operators, dual spaces with examples. (Scope as in relevant parts of Chapter 2 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Unit-II:
Hahn-Banach theorem for normed linear spaces, application to bounded linear functionals on C[a,b], Riesz-representation theorem for bounded linear functionals on C[a,b], adjoint operator, norm of the adjoint operator.
Reflexive spaces, uniform boundedness theorem and some of its applications to the space of polynomials and Fourier series. (Scope as in relevant parts of sections 4.1 to 4.7 of Chapter 4 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Unit-III:
Strong and weak convergence, open mapping theorem, bounded inverse theorem, closed linear operators, closed graph theorem. (Scope as in relevant parts of sections 4.8, 4.12 and 4.13 of Chapter 4 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)
Inner product spaces, Hilbert spaces and their examples, Schwarz inequality, continuity of inner product, orthogonal complements and direct sums, minimizing vector, orthogonality, projection theorem, characterization of sets in Hilbert spaces whose space is dense. (Scope as in relevant parts of sections 3.1 to 3.3 of Chapter 3 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Unit-IV:
Orthonormal sets and sequences, Bessel's inequality, series related to orthonormal sequences and sets, total (complete) orthonormal sets and sequences, Parseval's identity, separable Hilbert spaces. (Scope as in relevant parts of sections 3.4 to 3.6 of Chapter 3 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Riesz representation theorem for bounded linear functionals on a Hilbert space, sesquilinear form, Riesz representation theorem for bounded sesquilinear forms on Hilbert spaces. Hilbert-adjoint operator, its existence and uniqueness, properties of Hilbert-adjoint operators, self-adjoint, unitary and normal operators. (Scope is as in relevant parts of sections 3.8 to 3.10 of Chapter 3 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Recommended Text Book:
E.Kreyszig: Introductory Functional Analysis with Applications, Wiley India, 2007.

Reference Books:
1. G.F.Simmons: Introduction to Topology and Modern Analysis, McGraw Hill Book Co.,New York, 1983.
2. C.Goffman and G.Pedrick: First Course in Functional Analysis, Prentice Hall of India, New Delhi, 1987.
3. G.Bachman and L.Narici, Functional Analysis, Dover Publications, 2000.
4. L.A.Lustenik and V.J.Sobolev, Elements of Functional Analysis, Hindustan Publishing Corporation, New Delhi, 1971.
5. J.B.Conway: A Course in Functional Analysis, Springer-Verlag, 1990.
6. P.K.Jain, O.P.Ahuja and Khalil Ahmad: Functional Analysis, Second Edition,New Age International(P) Ltd. & Wiley Eastern Ltd., New Delhi, 2010.

MMATH21-303: Practical-III

Course Credit Practical	Practical Hours per week	End Term Examination Time	Maximum Marks		
			Internal Assessment	End Term Examination	Total
2	4	4 Hours	10	40	50

Note: The examiner will set 3 questions at the time of practical examination by taking course outcomes (COs) into consideration. The examinee will be required to write two programs and execute one program successfully. The evaluation will be done on the basis of practical record, viva-voce, write up and execution of the program.

Course objectives: The objective of this laboratory course is to write codes for numerical methods and to execute those source programs using either of MATLAB/SCILAB/Octave platforms. In addition, hand on experience of using built-in functions, provided in the libraries of these platforms/software, for verification/ supplementing the source program should be realized. Also, some problem solving techniques based on papers MMATH21-301 to MMATH21-302 will be taught.

Course Outcomes: This course will enable the students to:

1. Understand the algorithms for solving listed mathematical problems and to solve practical problems related to core courses undertaken in the Semester-III from application point of view.
2. Write source codes using either of MATLAB/SCILAB/Octave programming.
3. Edit, compile/interpret and execute the source program for desired results.
4. Verify/check results using built-in MATLAB/SCILAB/Octave functions.

List of Programs: The following practicals will be done on the MATLAB/SCILAB/Octave platform and record of those will be maintained in the practical Note Book:

1. Solutions of simultaneous linear equations: Gauss-elimination method and Gauss-Jordan method.
2. Solutions of simultaneous linear equations using Jacobi method and Gauss-Seidel method.
3. Solution of algebraic / transcendental equations using Bisection method and Regula-falsi method.
4. Solution of algebraic / transcendental equations using Secant method and Newton-Raphson method.
5. Inversion of matrices using adjoints; Jordan method.
6. Numerical differentiation: using various differentiation formulas for error reduction.
7. Numerical integration using composite methods based on trapezoidal rule.
8. Numerical integration using composite Simpson1/3 rule and 3/8 rule.
9. Solution of ordinary differential equations Euler method and Modified Euler method.
10. Solution of ordinary differential equations using Runge-Kutta methods.
11. Statistical problems on central tendency (mean, mode, median) and dispersion (standard variation, standard error).

12. Least square method to fit polynomial (curve) of given degree to given data set.
13. Plotting of special functions.

Reference Books:

1. S.R. Otto, J.P. Denier, An Introduction to Programming and Numerical Methods in MATLAB, Springer-Verlag, London, 2005.
2. William J. Palm III and William Palm, Introduction to MATLAB 7 for Engineers 2nd Edition, The McGraw-Hill Higher Education London, 2003.

MMATH21-304: ADVANCED TOPOLOGY

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The main objective of this course is to familiarize with some advanced topics in topology. Starting from the convergence of sequences in topological spaces and in first axiom topological spaces, we move on to the introduction and convergence of nets in topological spaces followed by canonical way of converting nets to filters and vice versa. The concepts of metrisable spaces and paracompactness also form a part of the course along with some topics from algebraic topology including the fundamental group, Euclidean simplexes, singular simplexes etc.

Course Outcomes: This course will enable the students to:
1. Know about nets in topological spaces; learn canonical way of converting nets to filters and vice versa; understand the concepts of connectedness and local connectedness.
2. Have understanding of metrisable spaces and Urysohn's metrisation theorem; know about locally finite family and its equivalent forms, paracompactness of a metrisable space; apply knowledge to prove Nagata-Smirnov metrisation theorem and Smirnov metrisation theorem.
3. Understand homotopy classes, fundamental group, Euclidean simplexes and related concepts.
4. Learn about singular simplexes homology and relative homology groups; demonstrate understanding of the statement and proof of the excision theorem.

Unit-I:
Convergence of sequences in topological spaces and in first axiom topological spaces, Nets in topological spaces, convergence of nets, Hausdorffness and convergence of nets, Subnets and cluster points, canonical way of converting nets to filters and vice versa, their convergence relations (Scope as in theorems 2-3,5-8 of Chapter 2 of Kelley's book recommended at Sr. No.1)

Connected spaces, connected subspaces of the real line, components and local connectedness (Scope as in relevant portions of sections 23-26 of Chapter 3 of the book by 'Munkres' recommended at Sr. No. 2)

Unit-II:
Definition and examples of metrisable spaces, Urysohn's metrisation theorem. Locally finite family, its equivalent forms, countably locally finite family, refinement, open refinement, closed refinement of a family, existence of countably locally finite open covering of a metrisable space, Nagata-Smirnov metrisation theorem, Paracompactness, normality of a paracompact Hausdorff

space, paracompactness of a metrisable space and of regular Lindelof space, Smirnov metrisation theorem.
(Scope as in theorems 34.1, 39.1-39.2. 40.3, 41.1-41.5 and 42.1 of Chapter 6 of the book by 'Munkres' recommended at Sr. No. 2)

Unit-III:
Relation of homotopy of paths based at a point and homotopy classes, product of homotopy classes, Fundamental group, change of base point topological invariance of fundamental group.
(scope as in relevant parts of Chapter IV of the book by 'Wallace' recommended at Sr. No.3)

Euclidean simplex, its convexity and its relation with its faces, standard Euclidean simplex, linear mapping between Euclidean simplexes of same dimension (scope as in relevant parts of Chapter V of the book by 'Wallace' recommended at Sr. No.3)

Unit-IV:
Singular simplexes and group of p-chains on a space, special singular simplex on and its boundary, induced homomorphism between groups of chains, boundary of a singular simplex and a chain, cycles and boundaries on a space, homologous cycles, homology and relative homology groups, induced homomorphism on relative homology groups, induced homomorphism on relative homology groups, topological invariance of relative homology groups, Prisms, homotopic maps and homology groups.
(scope as in relevant parts of Chapter VI of the book by 'Wallace' recommended at Sr. No.3)

Join of a point and a chain, Barycentric subdivision operator B, diameter of a Euclidean simplex and a singular simplex, operator H and its relation with B, representation of an element of a relative cycle made up of singular simplexes into members of a given open cover of the space, the excision theorem
(scope as in relevant parts of Chapter VII of the book by 'Wallace' recommended at Sr. No.3)

Recommended Text Books:
1.J.L.Kelley, General Topology, Springer Verlag, New York, 2012.
2. J.R.Munkres, Topology, Pearson Education Asia, 2002.
3. A.H.Wallace, Introduction to Algebraic Topology, Dover Publications, 2007

Reference Books:
1. K. Chandrasekhara Rao, Topology, Narosa Publishing House Delhi,2009.
2. Fred H. Croom, Principles of Topology, Cengage Learning, 2009.
3. K.D. Joshi, Introduction to General Topology, Wiley Eastern Ltd, 2006.
4. C.W.Patty, Foundation of Topology, Jones & Bertlett, 2009.
5. George F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 1983.

MMATH21-305: COMMUTATIVE ALGEBRA

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The course is designed to give an exposure of the concepts in commutative rings and modules defined on commutative rings. The course contains exact sequences of modules, tensor product modules, localisation, primary decomposition of an ideal. This course also contains Integrally closed domains, Noether's normalization theorem, chain conditions on rings and modules, primary decomposition of an ideal in Notherian rings. Structure theorem of Artinian rings.

Course Outcomes: This course will enable the students to:

1. Learn about free modules, projective modules, tensor products and flat modules.
2. Learn about ideals, local rings, localisation and applications.
3. Understand Noetherian modules, primary decomposition, Artinian modules and length of a module.
4. Understand integral elements, integral extensions, integrally closed domains, finiteness of integral closure.

Unit-I:

Free module, submodules, cyclic modules, homomorphism of R-modules, rank of Module. exact sequence, projective modules, Shanuel's lemma, tensor products, finitely generated R-algebra, flat modules.

Unit-II:

Ideals, maximal ideals, prime ideals, nilpotent elements, nil radical, Jacobson radical of R, comaximal, Chinese remainder theorem, extension and contraction of ideal, local rings, Nakayama lemma, localisation and quotients, localisation of localisation, applications, patching up of localisations.

Unit-III:

Noetherian modules, Hilbert's basis theorem, primary ideal, primary decomposition. first and second uniqueness theorem, Artinian modules, structure of Artinian rings, composition series of R-module, Jordan Holder theorem, length of a module.

Unit-IV:
Integral elements, integral closure, integral extensions, lying above, going up theorem, integrally closed domains, going-down theorem, finiteness of integral closure, Noether's normalisation theorem, weak nullstellensatz, Hilbert's nullstellensatz.
(Chapter 1, 2, 3 & 4 of the recommended book)

Recommended Book:
1. N.S.Gopal Krishnan : Commutative Algebra , Orient Blackswan Private Limited, 2017.

Reference books:
1. M.F.Atiyah and I.G.Macdonald : Introduction to Commutative Algebra, Addison-Wesley Publishing Company, 1969.
2. O. Zariski and P. Samuel : Commutative Algebra I, Springer, 1958.

MMATH21-306: DIFFERENTIAL GEOMETRY

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: Differential geometry is a discipline that uses the techniques of differential calculus, vector calculus and linear algebra to study problems in geometry and the mathematical analysis of curves and surfaces in space is studied in this course. The objective is to learn about curves in space and other related concepts; surfaces, envelopes, developable surfaces; curves on surfaces; and Geodesics.

Course Outcomes: This course will enable the students to:

1. Understand concepts of curves in space and other related concepts like tangent, principal normal, curvature, binormal, torsion, centre of curvature, spherical curvature, involutes, evolutes, Bertrand curves and to solve related problems
2. Understand and distinguish surfaces and their characteristics, developable surfaces, family of surfaces and curvilinear coordinates. Demonstrate knowledge to solve related problems of geometry.
3. Learn about curves on surfaces, conjugate systems, asymptotic lines, isometric lines, null lines etc. and minimal curves.
4. Derive equations of Gauss and Codazzi, Mainardi-Codazzi relations and Bonnet's theorem. Understand concepts of geodesics and curves in relation to geodesics and apply knowledge in problem solving.

Unit-I:

Curves: Tangent, principal normal, curvature, binormal, torsion, Serret-Frenet formulae, locus of center of curvature, spherical curvature, locus of centre of spherical curvature, curve determined by its intrinsic equations, helices, spherical indicatrix of tangent, etc., involutes, evolutes, Bertrand curves.

Unit-II:

Envelopes and Developable Surface : Surfaces, tangent plane, normal. One parameter family of surfaces; Envelope, characteristics, edge of regression, developable surfaces. Developables associated with a curve; Osculating developable, polar developable, rectifying developable. Two parameter family of surfaces; Envelope, characteristic points and examples.

Curvilinear Coordinates, First order magnitudes, directions on a surface, the normal, second order magnitudes, derivatives of **n**, curvature of normal section, Meunier's theorem.

(Relevant portions from the books '*Differential Geometry of Three Dimensions*' by C.E. Weatherburn)

Unit-III:
Curves on a surface : Principal directions and curvatures, first and second curvatures, Euler's theorem, Dupin's indicatrix, the surface z = f(x, y), surface of revolution. Conjugate systems; conjugate directions, conjugate systems. Asymptotic lines, curvature and torsion. Isometric lines; isometric parameters. Null lines, minimal curves.

Unit-IV:
The equations of Gauss and of Codazzi: Gauss's formulae for $\boldsymbol{r}_{11}, \boldsymbol{r}_{12}, \boldsymbol{r}_{22}$, Gauss characteristic equation, Mainardi-Codazzi relations, alternative expression, Bonnet's theorem, derivatives of the angle ω.

Geodesics: Geodesic property, equations of geodesics, surface of revolution, torsion of a geodesic. Curves in relation to Geodesics; Bonnet's theorem, Joachimsthal's theorems, vector curvature, geodesic curvature, Bonnet's formula.
(Relevant portions from the books '*Differential Geometry of Three Dimensions*' by C.E. Weatherburn)

Recommended Text Book:

1. C.E. Weatherburn, *Differential Geometry of Three Dimensions*, Radha Publishing House, Calcutta, 1988.

<u>Reference Books:</u>

1. John A. Thorpe, *Elementary Topics in Differential Geometry*, Springer Science & Business Media, 1994.
2. B.O. Neill, *Elementary Differential Geometry*, Academic Press, 1997.
3. Erwin Kreyszig, *Differential Geometry*, Dover Publications, 2013.
4. S. Sternberg, *Lectures on Differential Geometry*, Reprinted by AMS, 2016.
5. Nirmala Prakash, *Differential Geometry*, Tata McGraw-Hill Publishing Company Limited, 1992.
6. R.S. Millman and G.D. Parker, Elements of Differential Geometry, Prentice-Hall, 1977.

MMATH21-307: ELASTICITY

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course objectives: This course is in continuation to the course MMATH20-205 (Mechanics of Solids) being taught as a core paper in second semester. This paper deals with elastostatics problems on extension, torsion, bending and flexure of beams through the application of forces and couples. The techniques used to solve these problems involve the applications of complex analysis (analytic functions, conformal mappings) as well. The boundary value problems arising in plane elasticity are solved for analytical solutions. Some techniques of solving the three-dimensional elastodynamics problems are also discussed.

Course outcomes: This course will enable the students to:

1. Understand concepts of extension and torsion and learn to solve different elastostatics problems of extension and torsion of beams.
2. Learn techniques to make use of complex analysis (analytic functions, conformal mappings) for solving elastostatics problems. Be familiar with flexure of beams of different cross-sections.
3. Understand plane deformation, plain stress and Airy Stress function and attain capability to solve two dimensional problems in elasticity for analytical solutions.
4. Learn techniques for solving some scientifically important elastodynamics problems in three-dimensions and understand vibrations of elastic solids and wave propagation in such solids.

Unit-I:

Extension : Extension of beams by longitudinal forces, Beam stretched by its own weight, Bending of beams by terminal couples.

Torsion : Torsion of a circular shaft, Torsion of cylindrical bars, Torsional rigidity. Torsion and stress functions. Lines of shearing stress. Torsion of elliptic cylinder. Simple torsion problems, effect of grooves.

(Relevant sections 30–37 of Chapter 4 of the book recommended at Sr. No. 1)

Unit-II:

Torsion of rectangular beam, Torsion of triangular prism. Solution of torsion problems by means of conformal mapping. Torsion-membrane analogy, Torsion of hollow beams, Torsion of anisotropic beams. Flexure of beams by terminal loads, Flexure of circular and elliptic beams, Bending of rectangular beams, Bending of circular pipes.

(Relevant sections 38, 44-47, 51-57, 59; Chapter 4 of the book recommended at Sr. No. 1)

Unit-III:

Two dimensional problems : Plane deformation, Generalized plane stress, Plane elastostatic problems, . Airy stress function. General solution of biharmonic equation, Stresses and displacements in terms of complex potentials. The structure of functions $\varphi(z)$ and $\psi(z)$. First and second boundary value problems in plane elasticity. Existence and uniqueness of the solutions. (Relevant sections 65-74 of Chapter 5 of the book recommended at Sr. No. 1)

Unit-IV:
Three dimensional problems: General solutions; Concentrated forces; Deformation of elastic half-space by normal loads; The problem of Boussinesq. Elastic sphere: pressures, harmonics, equilibrium. Betti's Integration method. Vibrations of elastic solids, Wave propagation in infinite regions, Surface waves.
(Relevant sections 90-97, 102-104 of Chapter 6 of the book recommended at Sr. No. 1)

Recommended Books:

1. I.S. Sokolnikoff, Mathematical Theory of Elasticity, Tata McGraw Hill Publishing Company Ltd., New Delhi, 1977.
2. A.E.H. Love, A Treatise on the Mathematical Theory of Elasticity Dover Publications, New York.
3. Y.C. Fung. Foundations of Solid Mechanics, Prentice Hall, New Delhi, 1965.
4. D.S. Chandrasekharaiah and L. Debnath, Continuum Mechanics, Academic Press, 1994.
5. S. Timoshenko and N. Goodier. Theory of Elasticity, McGraw Hill, New York, 1970.
6. I.H. Shames, Introduction to Solid Mechanics, Prentice Hall, New Delhi, 1975.

MMATH21-308: ADVANCED NUMERICAL ANALYSIS

<table>
<tr><td colspan="2">Course Credit</td><td rowspan="2">End Term Examination Time</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>Internal Assessment</td><td>End Term Examination</td><td>Total</td></tr>
<tr><td>4</td><td>1</td><td>3 Hours</td><td>20</td><td>80</td><td>100</td></tr>
</table>

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course objectives: This course considers the high-end numerical methods, which are often required to get the numerical results from research studies in applied sciences and engineering. The objective of the course is to equip learners with specialized tools for solving transcendental and polynomial equations, system of linear equations, eigen-value problems, numerical differentiation, numerical integration, ordinary/partial differential equations so as to enable them to draw the algorithm of these numerical methods that form the basis to write source programs in any programming language.

Course outcomes: This course will enable the students to:

1. Learn about errors which arise during computation due to roundoff or truncation or number representation and the high-end numerical methods for solving transcendental and polynomial equations.
2. Attain the skills of solving system of linear equations using direct and iterative schemes and analysis of such schemes. Know to apply finite difference schemes/operators for numerical differentiation.
3. Learn advanced numerical methods to evaluate integrals for solving linear/non-linear first/second order IVP/BVP involving ODEs .
4. Understand the finite difference methods for solving parabolic, elliptic and hyperbolic PDEs and attain capability to use such methods in scientific problem solving.

Unit-I

Error Analysis: Errors, Absolute, relative and percentage errors; Significant digits and numerical instability, Propagation of errors in arithmetic operations, Significant errors, Representation of numbers in computer, Normalized floating point representation and its effects.

Solution of Polynomial and Transcendental Equations: Iteration methods; First order, second order and higher order methods, Accelaration of the convergence, Efficiency of a method, Newton-Raphson method for multiple roots, Modified Newton-Raphson method, Muller method and Chebyshev method, Birge-Vieta method, Bairstow method, Graeffe's root squaring method, Solutions of systems of non-linear equations.

Unit-II:

Systems of Linear Equations: Matrix inverse methods, Triangularization method, Cholesky Method, Matrix partition method, Operation count, Ill-conditioned linear systems, Moore-Penrose inverse method, Least square solutions for inconsistent systems. Iteration methods Successive over relaxation (SOR) method, Convergence analysis. Eigen values and eigen vectors, bounds on eigen values, Given's method, Rutishauser method, Householder's method for symmetric matrices, Power method.

Numerical Differentiation based on difference formulae, Richardson's extrapolation method, Cubic spline method, Method of undetermined coefficients.

Unit-III:

Numerical Integration: Weddle's rule, Newton-Cotes method, Gauss-Legendre, Gauss-Chebyshev, Gauss-Laguerre, and Gauss-Hermite integration methods. Composite integration method, Euler-Maclaurin's formula, Romberg Integration, Double integration.

Numerical Solution of Ordinary Differential Equations: Estimation of local truncation error of Euler and single step methods. Bounds of local truncation error and convergence analysis of multistep methods, Predictor-Corrector methods; Adams-Bashforth methods, Adams-Moulton formula, Milne-Simpson method, System of Differential Equations. Finite difference method for solving second order IVPs and BVPs, Shooting method for boundary value problems.

Unit-IV:

Solving Partial Differential Equations: Finite difference approximations to partial derivatives, solving parabolic equations using implicit and explicit formulae, C-N scheme and ADI methods; solving elliptic equations using Gauss-elimination, Gauss-Seidel method, SOR method, and ADI method , solving hyperbolic equations using method of characteristics, explicit and implicit methods, Lax-Wendroff's method.

Recommended Books:

1. Gupta, R. S., *Elements of Numerical Analysis*, Cambridge Univ. Press, 2015.
2. Jain, M. K., Iyengar, S.R.K. and Jain, R.K., *Numerical Methods for Scientific and Engineering Computation*, 6th Edition, New Age International Publishers, 2012.
3. Pal, M., *Numerical Analysis for Scientists and Engineers*, Narosa Publishing House Pvt. Ltd., 2008.
4. Mathews, John H. and Fink Kurtis D., *Numerical Methods Using Matlab*, Fourth edition; PHI Learning Private Ltd., 2009.
5. Gourdin, A. and Boumahrat, M., *Applied Numerical Methods*, PHI Learning Private Ltd., 2004.

MMATH21-309: FUZZY SETS AND APPLICATIONS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling; and are facilitators for common-sense reasoning in decision making in the absence of complete and precise information. The main objective of this course is to familiarize the students with fuzzy sets, operations on fuzzy sets, fuzzy numbers, fuzzy relations, possibility theory and fuzzy logic.

Course Outcomes: This course will enable the students to:

1. Learn about fuzzy sets; understand fuzzy-set-related notions such as α level sets, convexity, normality, support, etc., their properties and various operations on fuzzy sets.
2. Understand the concepts of t-norms, t-conforms, fuzzy numbers; extend standard arithmetic operations on real numbers to fuzzy numbers.
3. Understand various type of fuzzy relations.
4. Apply fuzzy set theory to possibility theory and Fuzzy logic.

Unit-I:

Fuzzy Sets: Basic definitions, α -cuts, strong α -cuts, level set of a fuzzy set, support of a fuzzy set, the core and height of a fuzzy set, normal and subnormal fuzzy sets, convex fuzzy sets, cutworthy property, strong cutworthy property, standard fuzzy set operations, standard complement, equilibrium points, standard intersection, standard union, fuzzy set inclusion, scalar cardinality of a fuzzy set, the degree of subsethood (Scope as in relevant parts of sections 1.3-1.4 of Chapter 1 of the book by Klir & Yuan).

Additional properties of α cuts involving the standard fuzzy set operators and the standard fuzzy set inclusion, Representation of fuzzy sets, three basic decomposition theorems of fuzzy sets Extension principle for fuzzy sets: the Zedah's extension principle, Images and inverse images of fuzzy sets, proof of the fact that the extension principle is strong cutworthy but not cutworthy (Scope as in relevant parts of Chapter 2 of the book by Klir & Yuan)

Operations on fuzzy sets: types of operations, fuzzy complements, equilibrium of a fuzzy complement, equilibrium of a continuous fuzzy complement, first and second characterization theorems of fuzzy complements (Scope as in relevant parts of sections 3.1 and 3.2 of Chapter 3 of the book by Klir & Yuan).

Unit-II:
Fuzzy intersections (t-norms), standard fuzzy intersection as the only idempotent t-norm, standard intersection, algebraic product, bounded difference and drastic intersection as examples of t-norms, decreasing generator, the Pseudo-inverse of a decreasing generator, increasing generators and their Pseudo-inverses, convertion of decreasing generators and increasing generators to each other, characterization theorem of t-norms(statement only). Fuzzy unions (t-conorms), standard union, algebraic sum, bounded sum and drastic union as examples of t-conorms, characterization theorem of t-conorms (Statement only), combination of operations, aggregation operations (Scope as in relevant parts of sections 3.3 to 3.6 of Chapter 3 of the book by Klir & Yuan).

Fuzzy numbers, relation between fuzzy number and a convex fuzzy set, characterization of fuzzy numbers in terms of its membership functions as piecewise defined functions, fuzzy cardinality of a fuzzy set using fuzzy numbers, arithmetic operations on fuzzy numbers, extension of standard arithmetic operations on real numbers to fuzzy numbers, lattice of fuzzy numbers, (R, MIN, MAX) as a distributive lattice, fuzzy equations, equation A+X = B, equation A.X = B (Scope as in relevant parts of Chapter 4 of the book by Klir & Yuan)

Unit-III:
Fuzzy Relations: Crisp and fuzzy relations, projections and cylindrical extensions, binary fuzzy relations, domain, range and height of a fuzzy relation, membership matrices, sagittal diagram, inverse of a fuzzy relation, composition of fuzzy relations, standard composition, max-min composition, relational join, binary relations on a single set, directed graphs, reflexive irreflexive, antireflexive, symmetric, asymmetric, antisymmetric, transitive (max-min transitive), non transitive, antitransitive fuzzy relations. Fuzzy equivalence relations, fuzzy compatibility relations, α -compatibility class, maximal α -compatibles, complete α -cover, reflexive undirected graphs, fuzzy ordering relations, fuzzy upper bound, fuzzy pre ordering, fuzzy weak ordering, fuzzy strict ordering, fuzzy morphisms. Sup-i compositions of Fuzzy relations, Inf-i compositions of Fuzzy relations.
(Scope as in the relevant parts of Chapter 5 of the book by Klir & Yuan)

Unit-IV:
Possibility Theory : Fuzzy measures, continuity from below and above, semicontinuous fuzzy measures, examples and simple properties; Evidence Theory, belief measure, superadditivity, monotonicity, plausibility measure, subadditivity, basic assignment, its relation with belief measure and plausibility measure, focal element of basic assignment, body of evidence, total ignorance, Dempster`s rule of combination, examples; Possibility Theory, necessity measure, possibility measure, implications, possibility distribution function, lattice of possibility distributions, joint possibility distribution. Fuzzy sets and possibility theory, Possibility theory versus probability theory (Scope as in the relevant parts of Chapter 7 of the book by Klir & Yuan)

Fuzzy Logic: An overview of classical logic, about logic functions of two variables, Multivalued logics, Fuzzy propositions,Fuzzy Quantifiers,Linguistic Hedges, Inference from conditional fuzzy propositions, inference from conditional and qualified propositions, inference from unqualified propositions. (Scope as in the relevant parts of Chapter 8 of the book by Klir & Yuan)

Recommended Text Book :

1. G. J. Klir and B. Yuan : Fuzzy Sets and Fuzzy : Logic Theory and Applications, Prentice Hall of India, 2008

Reference Books:

1. Kwang H. Lee, First Course on Fuzzy Theory and Applications, Springer International Edition, 2005.
2. H.J. Zimmerman, Fuzzy Set Theory and its Applications, Allied Publishers Ltd., New Delhi, 1991.
3. John Yen, Reza Langari, Fuzzy Logic - Intelligence, Control and Information, Pearson Education, 1999.
4. A.K. Bhargava, Fuzzy Set Theory, Fuzzy Logic & their Applications, S. Chand & Company Pvt. Ltd., 2013.

MMATH21-310: MATHEMATICAL STATISTICS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: Mathematical statistics is very useful in all branches of science as well as all branches of social sciences. The concept of mathematical statistics is surely one of the popular branch of applied mathematics. The main aim of this course is to introduce descriptive measures, probability, random distribution, probability models, mathematical expectation, correlation coefficient, discrete probability distributions, continuous probability distributions, sampling probability distributions, stochastic convergence, stochastic independence, statistical inference. An attempt has been made in this course to strike a balance between the different concepts of mathematical statistics.

Course Outcomes: This course will enable the students to:

1. Understand descriptive measures, probability, random variables and distribution functions
2. Understand mathematical expectation, generating functions, law of large numbers, correlation and regression
3. To learn about discrete probability distributions, continuous probability distributions and sampling distributions
4. To learn about large sample theory and statistical inference

Unit-I:

Measures of central tendency, measures of dispersion, measures of skewness, measures of Kurtosis. Probability-Basic terminology, addition theorem of probability, Boole's inequality, conditional probability, Multiplication theorem of probability, independent events. Bayes' theorem. Distribution function, discrete random variable, continuous random variable, two dimensional random variable, transformation of one dimensional random variable, transformation of two dimensional random variable.

(2.1 to 2.17, 3.1 to 3.3, 3.9 to 3.15, 4.2, 5.1 to 5.7 of recommended book)

Unit-II:

Mathematical expectation, expectation of random variable, expectation of function of random variable, properties of expectation and variance , Covariance, Cauchy-schwarz inequality, Jenson inequality, moment generating function, cumulants, characteristic function, Chebychev's Inequality, convergence in probability, weak law of large numbers, scatter diagram, karl pearson's coefficients of Correlation, Linear regression.

(6.1 to 6.7, 7.1 to 7.3 , 7.5 to 7.7, 10.1 to 10.4, 11.1 to 11.2 of recommended book)

Unit-III:

Discrete probability distributions-uniform distributions, Bernoulli distributions, Binomial distributions, Poisson distributions. Continuous probability distribution- Normal distributions, rectangular distributions, triangular distributions, Gamma distributions. Central limit theorem. Sampling distributions- chi square distribution, Student's 't' distribution, F distribution, relation between t and F , relation between F and chi-square.
(8.1 to 8.5, 9.1 to 9.5, 9.13, 15.1 to 15.3, 16.2, 16.5, 16.7, 16.8 of recommended book)

Unit-IV:

Large sample theory- types of sampling, parameter and statistic, test of significance, procedure for testing of hypothesis. Statistical inference- characteristic of estimators, Cramer-Rao inequality, MVU, Rao-Blackwell theorem.
(14.1 to 14.5, 17.1 to 17.3, 17.5 of recommended book)

Recommended Book:

1. S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons, 2014.

Reference book:

1. R.V. Hogg and A.T. Craig, Introduction to Mathematical Statistics, Amerind Pub. Co. Pvt. Ltd. New Delhi, 1972.

MMATH21-311: NUMBER THEORY

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The concept of number theory is surely one of the oldest ideas of Mathematics. The main aim of this course is to introduce arithmetic functions, Diophantine equations, Farey sequences, geometry of numbers, continued fractions. An attempt has been made in this course to strike a balance between different concepts of number theory.

Course Outcomes: This course will enable the students to:

1. Understand concept of greatest integer function, arithmetic function, mobius inversion formula, recurrence function, combinatorial number theory .
2. Find solution of Diophantine equations and rational points on curve.
3. Understand concept of Farey fractions, irrational numbers and geometry of numbers.
4. Have deep understanding of simple continued fractions, approximation to irrational number, Pell’s equation.

Unit-I:

Greatest integer function, Arithmetic function, multiplicative function, completely multiplicative function, mobius- inversion formula, recurrence function, combinational number theory.

Unit-II:

Solution of the equation ax+by =c, simultaneous linear equations, Unimodular matrices, Pythagorean triangles, some assorted examples, ternary quadratic forms, rational points on curves.

Unit-III:

Farey sequences, rational approximations, Hurwitz theorem, irrational numbers, Blichfeldt’s principle, Minkowski’s Convex body theorem, Lagrange’s four square theorem.

Unit-IV:

Euclidean algorithm, finite and infinite continued fractions, approximations to irrational numbers, Best possible approximations, Hurwitz theorem, Periodic continued fractions, Pell's equation.

(Chapter 4, 5.1 to 5.6, chapter 6 and 7 of recommended book at Sr. No. 1)

Recommended Book:

1. Ivan Niven, Herbert S. Zuckerman , Hugh L. Montgomery, An Introduction to the Theory of Numbers, John Wiley & Sons (Fifth Edition), 1991.
2. G.H. Hardy and E.M. Wright, An introduction to the theory of numbers, Oxford University Press, 6^{th} Ed, 2008.

MMATH21-312: ALGEBRAIC CODING THEORY

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The course contains systematic study of coding and communication of messages. This course is concerned with devising efficient encoding and decoding procedures using modern algebraic techniques. The course begins with basic results of error detection and error correction of codes, thereafter codes defined by generator and parity check matrices are given. The course also contains polynomial codes, Hamming codes, construction of finite fields and thereafter the construction of BCH codes. Linear codes, MDS codes, Reed-Solomon codes, Perfect codes, Hadamard matrices and Hadamard codes are also the part of the course.

Course Outcomes: This course will enable the students to:

1. Understand group codes, matrix encoding techniques, polynomial codes and Hamming codes.
2. Have deep understanding of finite fields, BCH codes.
3. Learn about linear codes, cyclic codes, self dual binary cyclic codes.
4. Learn about MDS codes, Hadamard matrices and Hadamard codes.

Unit-I:

Group codes, elementary properties, matrix encoding techniques. Generator and parity check matrices, polynomial codes. Vector space and polynomial ring, binary representation of numbers, Hamming codes.
(Chapter 1, 2 & 3 of recommended book at Sr. No. 1)

Unit-II:

Basic properties of finite fields, irreducible polynomial over finite field, roots of unity. (7.1 to 7.3 of recommended book at Sr. No. 2)
Some examples of primitive polynomials, BCH codes. (Chapter 4 of recommended book at Sr. No. 1)

Unit-III:

Linear codes, generator and parity check matrices, dual code of a linear code, Weight distribution of the dual code of a binary linear code, new codes obtained from given codes, cyclic codes, check polynomials, BCH and Hamming codes as cyclic codes, Non-binary Hamming codes, Idempotent , solved examples and invariance property, cyclic codes and group algebras, self dual binary cyclic codes.
(Chapter 5, 6 of recommended book at Sr. No. 1)

Unit-IV:

Necessary and sufficient condition for MDS codes, the weight distribution of MDS codes, an existence problem, Read Solomon codes. Hadamard matrices and Hadamard codes.(Chapter 9 and 11 of recommended book at Sr. No. 1)

Recommended Text Books:

1. L.R. Vermani, Elements of Algebraic Coding Theory, CRC Press, 1996.
2. Steven Roman, Coding and Information Theory, Springer-Verlag, 1992.

MMATH21-313: FINANCIAL MATHEMATICS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course objectives: No one can deny the fact that financial markets play a fundamental role in economic growth of nations by helping efficient allocation of investment of individuals to the most productive sectors of the economy. Financial sector has seen enormous growth over the past thirty years in the developed world. This growth has been led by the innovations in products referred to as financial derivatives that require great deal of mathematical sophistication and ingenuity in pricing and in creating an insurance or hedge against associated risks. Hence, this course is for anyone who is interested in the applications of finance, particularly advanced /latest business techniques. Students are required to know elementary calculus (derivatives and partial derivatives, finding maxima or minima of differentiable functions of one or more variables, Lagrange multipliers, the Taylor formula and integrals), probability (random variables and probability (binomial & normal) distributions, expectation, variance and covariance, conditional probability and independence) and linear algebra (systems of linear equations, add, multiply, transpose and invert matrices, and compute determinants).

Course outcomes: This course will enable the students to:

1. Understand the fundamentals of financial mathematics through derivatives, payoff functions, options, trader types, asset price models, random walks/ motion, no-arbitrage and relevant formula/simulation /hypothesis.
2. Use the Black-Scholes analysis for European options, risk neutrality, delta hedging, trading strategy involving options, along with the variations on Black-Scholes models for options on dividend-paying assets, warrants and futures.
3. Solve Black-Scholes equation using Monte-Carlo method, binomial methods, finite difference methods including fast algorithms for solving linear systems and design free boundary value problem, linear complementary problem, fixed domain problem for American option to be solved with projective/implicit methods.
4. Work on exotic options, path-dependent options, derivatives through bond models and interest rate models, convertible bonds and to learn stochastic calculus for its use in Brownian motion, stochastic integrals, stochastic differential equations and diffusion process.

Unit-I:

Fundamentals of Financial Mathematics: Financial Markets, derivatives; Payoff functions, Options, Types of traders Asset Price Models: Discrete/continuous models and their solutions; Random walks; The Brownian motion; Ito’s formula; Simulation of asset price model; Hypothesis of no-arbitrage-opportunities; Basic properties of option prices

Unit-II:

Black-Scholes Analysis: The Black-Scholes Equation; Exact solution for European options; Risk Neutrality; The delta hedging; Trading strategy involving options.

Variations on Black-Scholes models: Options on dividend-paying assets; Warrants; Futures and futures options

Unit-III:

Numerical Methods (Solving B.S equation): Monte Carlo method; Binomial Methods; Finite difference methods; Fast algorithms for solving linear systems;

American Option: free boundary value problem; linear complementary problem; fixed domain problem; Projective/implicit method for American put/call

Unit-IV:

Exotic Options: Binaries; Compounds; Chooser options; Barrier option; Asian/lookback options;

Path-Dependent Options: Average strike options; Lookback Option

Bonds and Interest Rate Derivatives: Bond Models; Interest models; Convertible Bonds

Stochastic calculus: Brownian motion; Stochastic integral; Stochastic differential equation; Diffusion process

Recommended Books:

1. Financial Mathematics: I-Liang Chern Department of Mathematics, National Taiwan University
2. Sheldon M. Ross, An Introduction to Mathematical Finance, Cambridge Univ. Press.
3. Robert J. Elliott and P. Ekkehard Kopp. Mathematics of Financial Markets, Springer-Verlag, New York Inc.
4. Robert C. Marton, Continuous-Time Finance, Basil Blackwell Inc.
5. Daykin C.D., Pentikainen T. and Pesonen M., Practical Risk Theory for Actuaries, Chapman & Hall.

MMATH21-314: INTEGRAL EQUATIONS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: This course is designed to get acquainted with the concept of integral equations and the methods to find their solutions. A student will learn about integral equations, their classifications, eigen values and eigen functions, method of successive approximations, iterative methods, resolvent kernel. Fredholm three theorems are main part of the first section. In the second section, symmetric kernels, Riesz-Fisher theorem, Hilbert-Schmidt, solution of a symmetric integral equation, Abel's integral equation and Cauchy type singular integral equation are learnt.

Course outcomes: This course will enable the students to:

1. Understand the concept of integral equations to identify different constituents to classify them and to apply the eigen-system method for solving the Fredholm type with separable kernel.
2. Derive procedures to for iterative methods to solve integral equations of both Fredholm and Volterra types without restricting the kernel to be separable and proving specific theorems of Fredholm's theory.
3. Design methods for solving the integral equations with symmetric kernel as linear/bilinear expansions over an orthonormal system of functions and to prove various theorems to analyse these methods. Apply the knowledge to solve problems.
4. Learn the use of numerical method for finding an eigenvalue and the analytical methods to solve the singular integral equations from Cauchy-type to Hilbert-type, which involve Cauchy's principal value, closed/open contours and the Riemann-Hilbert problem.

Unit-I:

Definition of Integral Equations and their classifications. Eigen values and Eigen functions. Special kinds of Kernel, Convolution Integral. The inner or scalar product of two functions. Reduction to a system of algebraic equations. Fredholm alternative, Fredholm theorem, Fredholm alternative theorem, an approximate method.
(Relevant portions from the chapters 1 and 2 of the book recommended at Sr. No. 1).

Unit-II:

Method of successive approximations, Iterative scheme for Fredholm and Volterrra Integral equations of the second kind. Conditions of uniform convergence and uniqueness of series solution. Some results about the resolvent Kernel. Application of iterative scheme to Volterra integral equations of the second kind. Classical Fredholm's theory, the method of solution of Fredholm equation, Fredholm's First theorem, Fredholm's second theorem, Fredhom's third theorem.
(Relevant portions from the chapters 3 and 4 of the book recommended at Sr. No. 1).

Unit-III:
Symmetric Kernels, Complex Hilbert space. An orthonormal system of functions, Riesz-Fisher theorem, A complete two-Dimensional orthonormal set over the rectangle $a \le s \le b, c \le t \le d$. Fundamental properties of Eigenvalues and Eigenfunctions for symmetric Kernels. Expansion in eigen functions and Bilinear form. Hilbert-Schmidt theorem and some immediate consequences.
Definite Kernels and Mercer's theorem. Solution of a symmetric Integral Equation. Approximation of a general ℓ_2-Kernel (not necessarily symmetric) by a separable Kernel. The operator method in the theory of integral equations.
(Relevant portions from the chapter 7 of the book recommended at Sr. No. 1).
Unit-IV:
Rayleigh-Ritz method for finding the first eigenvalue. The Abel Intergral Equation. Inversion formula for singular integral equation with Kernel of the type h(s)-h(t), $0<\alpha<1$, Cauchy's principal value for integrals solution of the Cauchy-type singular integral equation, closed contour, unclosed contours and the Riemann-Hilbert problem. The Hilbert-Kernel, solution of the Hilbert-Type singular Intergal equation.
(Relevant portions from the chapter 8 of the book recommended at Sr. No. 1).
Recommended Books:

1. Ram P. Kanwal, *Linear Integral Equations: Theory & Techniques*, Springer Science & Business Media, 2012.
2. S.G. Mikhlin, *Linear Integral Equations* (translated from Russian) ,Hindustan Book Agency, 1960.
3. F.G Tricomi, *Integral Equations,* Courier Corporation, 1985.
4. Abdul J. Jerri, *Introduction to Integral Equations with Applications*, Wiley-Interscience, 1999.
5. Ian N. Sneddon, *Mixed Boundary Value Problems in potential theory*, North Holland Publishing Co., 1966.
6. Ivar. Stakgold, *Boundary Value Problems of Mathematical Physics* Vol.I, II, Society for Industrial and Applied Mathematics, 2000.

MMATH21- 315: MATHEMATICAL MODELING

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course objectives: A mathematical model is a description of a system (device or a phenomenon) using mathematical concepts and language. The process of developing a mathematical model is defined as mathematical modeling. A mathematical model may help to explain a system and to study the effects of different components, and to make predictions about the system. During this course, the students will learn basic concepts of mathematical modeling and to construct mathematical models for population dynamics, epidemic spreading, economics, medicine, arm-race, battle, genetics and other areas of physical/life/social sciences. The course also aims to let the students learn mathematical modeling through ordinary/partial differential equations and probability generating function.

Course outcomes: This course will enable the students to:

1. Understand the need/techniques/classification of mathematical modeling through the use of first order ODEs and their qualitative solutions through sketching.
2. Learn to develop mathematical models using systems of ODEs to analyse/predict population growth, epidemic spreading for their significance in economics, medicine, arm-race or battle/war.
3. Attain the skill to develop mathematical models involving linear ODEs of order two or more and difference equations, for their relevance in probability theory, economics, finance, population dynamics and genetics.
4. Develop mathematical models through PDEs for mass-balance, variational principles, probability generating function, traffic flow problems alongwith relevant initial & boundary conditions.

Unit-I:

Mathematical modeling: need, techniques, classification and illustrative examples; Mathematical modeling through ordinary differential equations of first order; qualitative solutions through sketching.

Unit-II:

Mathematical modeling in population dynamics, epidemic spreading and compartment models; mathematical modeling through systems of ordinary differential equations; mathematical modeling in economics, medicine, arm-race, battle.

Unit-III:

Mathematical modeling through ordinary differential equations of second order. Higher order (linear) models. Mathematical modeling through difference equations: Need, basic theory;

mathematical modeling in probability theory, economics, finance, population dynamics and genetics.

Unit-IV:

Mathematical modeling through partial differential equations: simple models, mass-balance equations, variational principles, probability generating function, traffic flow problems, initial & boundary conditions.
(Scope of the syllabus is from relevant portions of Chapters 1 to 6 of the book recommended at Sr. No. 1)

Recommended Book

1. J.N. Kapur: *Mathematical Modelling*, New Age International Ltd., 1988.
2. M. Adler, *An Introduction to Mathematical Modelling*, HeavenForBooks.Com, 2001.
3. S.M. Moghadas, M.J.-Douraki, *Mathematical Modelling: A Graduate Text Book*, Wiley, 2018.
4. E.A. Bender, *An Introduction to Mathematical Modeling*, Dover Publication, 2000.

OEM21-316: BASIC MATHEMATICS-II

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
2	0	3 Hours	10	40	50

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 4 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks. Use of non-programmable scientific calculator will be allowed in the examination.

Course objectives: This course has been designed to introduce numerical methods to the students of the faculty of sciences. The students will come to learn different popular numerical methods for solving transcendental and polynomial equations, system of linear equations, curve fitting, numerical differentiation, numerical integration, solution of ordinary differential equations. After successful completion of the course, a student will be able to draw the algorithm for the use of numerical methods in source programs of any programming language.

Course outcomes: This course will enable the students to:

1. Learn the use of numerical methods for solving transcendental and polynomial equations and direct methods for solving system of linear equations.
2. Solve system of linear equations through iterative methods and knowledge of using various interpolation methods for fitting polynomials to a data-set / function.
3. Understand finite difference schemes/operators for numerical differentiation and attain ability to apply numerical methods for solving definite integrals.
4. Learn numerical techniques for solving linear first order IVP involving ODEs .

Unit-I:

Solution of Polynomial and Transcendental Equations: Bisection method, secant method, Regula-Falsi method, Newton-Raphson method.

Solution of Systems of Linear Equations: Gauss elimination method, Gauss-Jordan method, Triangularization method.

Unit-II:

Iterative methods for Solving Systems of Linear Equations: Jacobi method, Gauss-Seidel iteration method.

Curve fitting: Least-square approximation for fitting a straight line and polynomials of given degree.

Unit-III:

Numerical Differentiation: Methods based on Newton's forward difference formula, Newton's forward difference formula and Sterling's formula.

Numerical Integration: Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule, Romberg integration, Newton-Cotes integration formula.

Unit-IV:

Solution of Differential Equations: Initial value problem; Taylor series method, Picard method of successive approximation, Euler's method, Runge-Kutta methods of second order and fourth order.

Recommended Books

1. Sastry, S.S., *Introductory Methods of Numerical Analysis***,** Fifth edition, PHI learning , 2012.
2. Jain, M. K., Iyengar, S.R.K.| and Jain, R.K., *Numerical Methods for Scientific and Engineering Computation, 6th Edition***,** New Age International Publishers, 2012.
3. Rajaraman, V., *Computer Oriented Numerical Methods***,** Fourth edition, PHI learning, 2018.
4. Gourdin, A. and Boumahrat, M., *Applied Numerical Methods*, PHI Learning Private Ltd., 1996.

MMATH21-401: MECHANICS AND CALCULUS OF VARIATIONS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

NOTE : The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt five questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: Analytical mechanics deals with motion of a system as a whole not as individual particles and takes in to account the constraints of the system to solve problems. This course let the students to understand basic concepts of analytical mechanics, calculus of variations, degrees of freedom, generalized coordinates, Lagrangian mechanics, Hamiltonian mechanics, principles of least action and Hamilton-Jacobi theory.

Course Outcomes: This course will enable the students to:

1. Understand moments and products of inertia, kinetic energy of a rigid rotating body, Laws of conservation of momentum, angular momentum and energy. Demonstrate knowledge to solve related problems of mechanics.
2. Learn about three dimensional rigid body dynamics and generalized coordinates.
3. Understand Lagrange's equation for potential forces, Variational principles, Hamiltonian, Canonical transformations and Hamilton Jacobi equation.
4. Understand concepts calculus of variations and to solve variational problems of different forms of functionals.

Unit-I:

Moments and products of inertia, The theorems of parallel and perpendicular axes, Angular momentum of a rigid body about a fixed point and about fixed axes, Principal axes.

Kinetic energy of a rigid body rotating about a fixed point, Momental ellipsoid – equimomental system, Coplanar distributions, General motion of a rigid body.

Problems illustrating the laws of motion, Problems illustrating the law of conservation of angular momentum, Problems illustrating the law of conservation of energy, Problems illustrating impulsive motion.

(Relevant portions from the book 'Textbook of Dynamics' by F. Chorlton).

Unit-II:
Euler's dynamical equations for the motion of a rigid body about a fixed point, Further properties of rigid motion under no forces, Some problems on general three-dimensional rigid body motion, The rotating earth.
Note on dynamical systems, Preliminary notions, Generalized coordinates and velocities, Virtual work and generalized forces, Derivation of Lagrange's equations for a holonomic system, Case of conservative forces, Generalized components of momentum and impulse. Lagranges equations for impulsive forces, Kinetic energy as a quadratic function of velocities. Equilibrium configurations for conservative holonomic dynamical systems, Theory of small oscillations of conservative holonomic dynamical systems.
(Relevant portions from the book 'Textbook of Dynamics' by F. Chorlton).

Unit-III:
Lagrange's equations for potential forces, Variational principles in Mechanics: Hamilton's principle, The principle of least action. Hamiltonian and canonical equations of Hamilton. Basic integral invariant of Mechanics. Canonical transformations, Hamilton Jacobi equation.
(Relevant portions from the text book recommended at Sr. No. 2).

Unit-IV:
Functional and its variation, Euler's (Euler-Lagrange) equations, Variational problems for functionals depending on one independent and one dependent variable(s) and its (i) first derivative (ii) higher derivatives with fixed end conditions, Variational problems for functionals depending on n functions of a single independent variable and functional depending on a function and its n derivatives, Functionals dependent on functions of several independent variables. Variational problems in parametric form. Natural boundary conditions and transition conditions, Invariance of Euler's equation. Conditional extremum. Variational problem with moving boundaries. Some basic problems in calculus of variations: shortest distance, minimum surface of revolution, Brachistochrone problem, isoperimetric problem and geodesic problems.
(Relevant portions from the text books recommended at Sr. No. 3 & 4).

Recommended Text Books:

1. F. Chorlton, *Text Book of Dynamics* 2nd Ed, CBS, 2002.
2. F. Gantmacher, *Lectures in Analytical Mechanics*, Mir Publishers, 1975.
3. Francis B. Hilderbrand, *Methods of Applied Mathematics* , Dover Publications, 1992.
4. A.S. Gupta, *Calculus of Variations with Applications*, PHI Learning Pvt. Ltd., 1996.

Reference Books:

1. H. Goldstein, C.P. Poole and J.L. Safko, *Classical Mechanics* (3rd edition), Pearson, 2011.
2. I.M. Gelfand and S.V. Fomin, *Calculus of Variations*, Dover Publications, 2012.
3. S.K. Sinha, *Classical Mechanics*, Alpha Science International Limited, 2009.
4. Louis N. Hand and Janet D. Finch, Analytical Mechanics, Cambridge University Press, 2008.

MMATH21-402: PARTIAL DIFFERENTIAL EQUATIONS

<table>
<tr><td colspan="2">Course Credit</td><td rowspan="2">End Term Examination Time</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>Internal Assessment</td><td>End Term Examination</td><td>Total</td></tr>
<tr><td>4</td><td>1</td><td>3 Hours</td><td>20</td><td>80</td><td>100</td></tr>
</table>

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course objectives: The learning objective of this paper is to study partial differential equations (PDE) which are used to describe a wide variety of phenomena such as sound, heat, electrostatics, electrodynamics, fluid dynamics, elasticity and mechanics. During this course, a student will learn about partial differential equations including definition, classifications, analytical theory and methods of solutions of IVP, transport equations, Laplace's equation, Poisson's equation and heat equations, Green's function and method of solving PDEs by Green's function approach. Other component of the learning objective is to study Wave equation, solutions of wave equation in different forms, Kirchhoff's and Poisson's formula, solution of non-homogeneous wave equation, solution of Laplace, heat and wave equations by method of separation of variables, similarity solutions and by using Fourier and Laplace transforms.

Course outcomes: This course will enable the students to:

1. Classify the PDE of different orders into elliptic/ parabolic/ hyperbolic types and work on the methods to solve homogeneous and non-homogeneous elliptic equations.
2. Understand the role of Green's function in solving PDE and work on the methods/principle used to derive formulas for solutions of homogeneous and non-homogeneous parabolic/heat equations.
3. Use various methods to solve the homogeneous and non–homogeneous wave equations, one to three dimensional, in different coordinate systems. Capacity to apply those techniques/methods to numerous problems that arise in science, engineering and other disciplines.
4. Learn to solve non-linear first order PDEs through complete integrals, envelopes, characteristics and solve Laplace, heat and wave equations using method of separation of variables and using integral transforms.

Unit-I:

Partial Differential Equations (PDE) of k^{th} order: Definition, examples and classifications. Initial value problems. Transport equations homogeneous and non-homogeneous, Radial solution of Laplace's Equation: Fundamental solutions, harmonic functions and their properties, Mean value Formula.

Poisson's equation and its solution, strong maximum principle, uniqueness, local estimates for harmonic functions, Liouville's theorem, Harnack's inequality.
(Relevant portions from the recommended text books given at Sr. No. 1 & 2)

Unit-II:
Green's function and its derivation, representation formula using Green's function, symmetry of Green's function, Green's function for a half space and for a unit ball. Energy methods: uniqueness, Drichlet's principle.

Heat Equations: Physical interpretation, fundamental solution. Integral of fundamental solution, solution of initial value problem, Duhamel's principle, non-homogeneous heat equation, Mean value formula for heat equation, strong maximum principle and uniqueness. Energy methods.
(Relevant portions from the recommended text books given at Sr. No. 1 & 2)

Unit-III:
Wave equation- Physical interpretation, solution for one dimentional wave equation, D'Alemberts formula and its applications, Reflection method, Solution by spherical means Euler-Poisson_Darboux equation. Kirchhoff's and Poisson's formula (for n=2, 3 only).

Solution of non –homogeneous wave equation for n=1,3. Energy method. Uniqueness of solution, finite propagation speed of wave equation.
(Relevant portions from the recommended text books given at Sr. No. 1 & 2)
Unit-IV:
Non-linear first order PDE- complete integrals, envelopes, Characteristics of (i) linear, (ii) quasilinear, (iii) fully non-linear first order partial differential equations. Hamilton Jacobi equations.
Other ways to represent solutions: Method of Separation of variables for the Hamilton Jacobi equations, Laplace, heat and wave equations. Similarity solutions (plane waves, traveling waves, solitons, similarity under scaling).

Fourier Transform, Laplace Transform, Convertible non-linear into linear PDE, Cole-Hop Transform, Potential functions, Hodograph and Legendre transforms. Lagrange and Charpit methods.
(Relevant portions from the recommended text books given at Sr. No. 1 & 2)
Recommended Text Books:
1. L.C. Evans, *Partial Differential Equations*, Graduate Studies in Mathematics, American Mathematical Society, 2014.
2. Ian N. Sneddon, *Elements of Partial Differential Equations*, Dover Publications, 2006.
Reference Books:
1. T. Amarnath, *An Elementary Course in Partial Differential Equations*, Jones & Bartlett Publishers, 2009.
2. P. Parsad and R. Ravindran, *Partial Differential Equations*, New Age / International Publishers, 2005.
3. John F. *Partial Differential Equations*, Springer-Verlag, New York, 1971.

MMATH21-403: Practical-IV

Course Credit Practical	Practical Hours per week	End Term Examination Time	Maximum Marks		
			Internal Assessment	End Term Examination	Total
2	4	4 Hours	10	40	50

Note: The examiner will set 3 questions at the time of practical examination by taking course outcomes (COs) into consideration. The examinee will be required to write two programs and execute one program successfully. The evaluation will be done on the basis of practical record, viva-voce, write up and execution of the program.

Course objectives: The objective of this course is to make the students familiar with the R programming. This course also focuses on the statistical analysis of data structures using the programming and visualization features of R language**.** Also, some problem solving techniques based on papers MMATH21-401 to MMATH21-402 will be taught.

Course Outcomes: This course will enable the students to:

1. Solve practical problems related to core courses undertaken in the Semester-IV from application point of view.
2. Understand the basics of R programming language including data types, variables, operators, expressions, input/output statements, control structures and functions.
3. Understand built in functions and tools of general use in R and know how to use those.
4. Learn entering, plotting, manipulation and interpretation of data using statistical functions of R.

List of Programs: The following practicals will be done on the R platform/software package and record of those will be maintained in the practical Note Book:

1. Starting R, entering data, storing data as a vector.
2. Entering data into R;
   i. Using c
   ii. Using scan
   iii. Using scan with file
   iv. Editing your data
   v. Reading in tables of data
   vi. Spreadsheet data
3. Practical examples illustrating templates of functions, for loops and conditional expressions in R.
4. Find mean, variance and standard deviation using R functions.

5. Practical examples with univariate data:
    i. Categorical data; Using tables, factors, bar chart, pie chart
    ii. Numerical data; measures of center and spread
    iii. Stems and leaf charts, histograms, boxplots, frequency polygons using R functions
6. Comparison of bivariate data with plots.
7. Program to fit linear regression line.
8. Program to find Spearman's rank correlation coefficient.
9. Practical examples of plotting graphs using points, abline, lines, plot and curve R functions.
10. Practical examples of storing, accessing and manipulating multivariate data in data frames.

11. Generate random numbers using uniform, normal, binomial, exponential distributions.

12. To estimate confidence interval using p-test.
13. To estimate confidence interval using t-test.
14. To estimate confidence interval using z-test.
15. Hypothesis testing by mean and median.

Reference Books:

1. John Verzani, *Using R for Introductory Statistics*, Chapman and Hall/CRC, 2014.
2. John Verzani, simple R-*Using R for Introductory Statistics*, lecture notes in pdf format, open source.

MMATH21- 404: Seminar-II

Course Credit	Seminar Hours per week	End Term Examination Time	Maximum Marks		
			Internal Assessment	End Term Examination	Total
2	2	-	50	-	50

Note: There will be no external examination. Evaluation will be done by the internal group incharge.

Course objectives: The objectives of this course are self study, understanding a topic in detail, comprehension of the subject/topic, investigating a problem, knowledge of ethics, effective communication and life-long learning.

Course Outcomes: This course will enable the students to:

1. Identify an area of interest and to select a topic therefrom realizing ethical issues related to one's work and unbiased truthful actions in all aspects of work and to develop research aptitude.
2. Have deep knowledge and level of understanding of a particular topic in core or applied areas of Mathematics, imbibe research orientation and attain capacity of investigating a problem.
3. Obtain capability to read and understand mathematical texts from books/journals/e-contents, to communicate through write up/report and oral presentation.
4. Demonstrate knowledge, capacity of comprehension and precision, capability to work independently and tendency towards life-long learning.

Note: *Each student will select a topic of one's choice from emerging areas of Mathematics, get approval from the concerned group incharge, give consulting library so as to read different books/e-resources, prepare a seminar document , present before the group and its incharge for not less than an hour. The evaluation of the seminar will be done by the concerned group incharge by taking into account the following:*

i. Subject knowledge.
ii. Degree of difficulty, research aptitude and knowledge updation in choice of the topic.
iii. Contents.
iv. Communication.
v. Response to questions.

MMATH21- 405: ADVANCED COMPLEX ANALYSIS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The main objective of this course is to understand the notion of logarithmically convex function and its fusion with maximum modulus theorem, the spaces of continuous, analytic and meromorphic functions, Runge's theorem and topics related with it, introduce harmonic function theory leading to Dirichlet's problem, theory of range of an entire function leading to Picard and related theorems.

Course Outcomes: This course will enable the students to

1. Understand the basics of logarithmically convex functions that helps in extending maximum modulus theorem; learn about spaces of continuous, analytic and meromorphic functions.
2. Be familiar with Riemann mapping theorem, Weierstrass' factorization theorem, Gamma functions and its properties.
3. Understand Runge's theorem; know harmonic function theory on a disk; apply the knowledge in solving Dirichlet's problem; know about Green's function.
4. Know how big the range of an entire function is ; prove Picard and related theorems.

Unit-I:

Convex functions and Hadamard's three circles theorem, Phragmen-Lindelöf theorem.
Spaces of continuous functions, Arzela-Ascoli theorem, Spaces of analytic functions, Hurwitz's theorem, Montel's theorem, Spaces of meromorphic functions.

Unit-II:

Riemann mapping theorem, Weierstrass' factorization theorem, Factorization of sine function, Gamma function and its properties, functional equation for gamma function, Bohr-Mollerup theorem, Reimann-zeta function, Riemann's functional equation, Euler's theorem.

Unit-III:

Runge's theorem, Simply connected regions, Mittag-Leffler's theorem. Analytic continuation, Power series method of analytic continuation , Schwarz reflection principle. Monodromy theorem and its consequences.

Harmonic functions, Maximum and minimum principles, Harmonic function on a disk, Harnack's theorem, Sub-harmonic and super-harmonic functions, Dirichlet's problems, Green's function.

Unit-IV:

Entire functions :Jensen's formula, Poisson–Jensen formula. The genus and order of an entire function, Hadamard's factorization theorem.

The range of an analytic function : Bloch's theorem, Little-Picard theorem, Schottky's theorem, Montel-Carathedory theorem, Great Picard theorem.

Recommended Text Book:

J. B.Conway, Functions of one complex variable, Narosa Publishing House, 2002.

Reference Books :

1. Ahlfors, L.V., Complex Analysis, Mc. Graw Hill Co., Indian Edition, 2017.
2. Churchill, R.V. and Brown, J.W., Complex Variables and Applications McGraw Hill Publishing Company, 1990.
3. Priestly, H.A., Introduction to Complex Analysis Claredon Press, Orford, 1990.
4. Liang-shin Hann & Bernard Epstein, Classical Complex Analysis, Jones and Bartlett Publishers International, London, 1996.
5. D.Sarason, Complex Function Theory, Hindustan Book Agency, Delhi, 1994.
6. Mark J.Ablewitz and A.S.Fokas, Complex Variables : Introduction & Applications, Cambridge University Press, South Asian Edition, 1998.
7. E.C.Titchmarsh, Theory of Functions, Oxford University Press, London, 1939.
8. S.Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, 1997.
9. D.C. Ullrich, Complex Made Simple, American Mathematical Society, 2008.
10. L. Hahn, B. Epstein, Classical Complex Analysis, Jones and Bartlett, 1996.
11. W. Rudin, Real and Complex Analysis, Third Edition, Tata McGraw-Hill, 2006.

MMATH21-406: ALGEBRAIC NUMBER THEORY

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The concept of ALGEBRAIC NUMBER THEORY is surely one of the recent ideas of mathematics. The main aim of this course is to introduce Norm and trace, Ideals in the ring of algebraic number field, Dedekind domains, Fractional ideals, Chinese Remainder theorem, Different of an algebraic number field, Hurwitz constant, Ideal class group, Minkowski's bound and Quadratic reciprocity.

Course Outcomes: This course will enable the students to:

1. Understand concept of integral bases and discriminant of algebraic number field, ring of algebraic integers and ideal in the ring of algebraic integers
2. Learn about integrally closed domains, Dedekind domain, fractional ideals and unique factorization , different of an algebraic number field, Dedekind theorem
3. Learn about Hurwitz's lemma, Hurwitz constant, finiteness of the ideal class group, class number of an algebraic number field, Diophantine equations, minkowski's bound
4. Understand Legendre symbol, gauss sums, law of quadratic reciprocity, quadratic field, primes in special progression, class number of quadratic fields

Unit-I:

Norm and trace of algebraic numbers and algebraic integers, Bilinear map on algebraic number field K. Integral basis and discriminant of an algebraic number field, Index of an element of K, Ring O_k of algebraic integers of an algebraic number field K. Ideals in the ring of algebraic number field K.

Unit-II:

Integrally closed domains. Dedekind domains. Fractional ideals of K. Factorization of ideals as a product of prime ideals in the ring of algebraic integers of an algebraic number field K. G.C.D. and L.C.M. of ideals in O_k. Chinese Remainder theorem, order of ideal in prime ideal, ramification degree of prime ideals, different of an algebraic number field K, Dedekind theorem.

Unit-III:
Euclidean rings. Hurwitz Lemma and Hurwitz constant. Equivalent fractional ideals. Ideal class group. Finiteness of the ideal class group. Class number of the algebraic number field K. Diophantine equations, Minkowski's bound.
Unit-IV:
Legendre Symbol, Jacobi symbol, Gauss sums, Law of quadratic reciprocity, Quadratic fields, Primes in special progression, class number of quadratic fields.
(Chapter 4, 5, 6 & 7 of recommended book)

Recommended Book:
1. Jody Esmonde and M.Ram Murty, Problems in Algebraic Number Theory, Springer Verlag, 1998.

Reference books:
1. Paulo Ribenboim: Algebraic Numbers, Wiley-Interscience, 1972.
2. R. Narasimhan and S. Raghavan: Algebraic Number Theory, Mathematical Pamphlets-4, Tata Institute of Fundamental Research,1966.

MMATH21-407: GENERAL MEASURE AND INTEGRATION THEORY

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The main objective of this course is to familiarize with general theory of measure and integration, in particular, with measurable functions, sequences of measurable functions, integrable functions, product measures, finite signed measures and integration over locally compact spaces.

Course Outcomes: This course will enable the students to:

1. Understand the concept of measure defined on a ring of sets, its properties; extension, uniqueness and completeness of measures; measurable spaces, measurable and simple functions.
2. Have deep understanding of the concepts of convergence in measure, almost uniform convergence; apply the knowledge to prove Egoroff's theorem, Riesz-Weyl theorem; learn about integrable functions, indefinite integrals; demonstrate understanding of the statement and proof of the monotone convergence theorem.
3. Understand the concepts of product measures; apply the knowledge to prove Fubini's theorem; understand signed measures; demonstrate understanding of the statement and proof of the Jordan-Hahn decomposition, Radon-Nikodym theorem.
4. Know about the concepts of Baire sets, Baire measures, regularity of measures on locally compact spaces; apply the knowledge to prove Riesz-Markoff representation theorem related to the representation of a bounded linear functional on the space of continuous functions.

Unit-I:

Measures, some properties of measures, outer measures, extension of measures, uniqueness of extension, completion of a measure, the LUB of an increasingly directed family of measures.(Scope as in the Sections 3-6, 9-10 of Chapter 1 of the book 'Measure and Integration' by S.K. Berberian).

Measurable spaces, measurable functions, combinations of measurable functions, limits of measurable functions, localization of measurability, simple functions (Scope as in Chapter 2 of the book 'Measure and Integration' by S.K. Berberian).

Unit-II:

Measure spaces, almost everywhere convergence, convergence in measure, almost uniform convergence, Egoroff's theorem, Riesz-Weyl theorem (Scope as in Chapter 3 of the book 'Measure and Integration' by S.K. Berberian).

Integrable simple functions, non-negative integrable functions, integrable functions, indefinite integrals, the monotone convergence theorem, mean convergence (Scope as in Chapter 4 of the book 'Measure and Integration' by S.K. Berberian)

Unit-III:

Product Measures: Rectangles, Cartesian product of two measurable spaces, sections, the product of two finite measure spaces, the product of any two measure spaces, product of two σ-finite measure spaces, Fubini's theorem. (Scope as in Chapter 6 (except section 42) of the book 'Measure and Integration' by S.K. Berberian)

Finite Signed Measures: Absolute continuity, finite singed measure, contractions of a finite signed measure, purely positive and purely negative sets, comparison of finite measures, Lebesgue decomposition theorem, a preliminary Radon-Nikodym theorem, Jordan-Hahn decomposition of a finite signed measure, domination of finite signed measures, the Radyon-Nikodym theorem for a finite measure space, the Radon-Nikodym theorem for a σ - finite measure space (Scope as in Chapter 7 (except Section 53) of the book 'Measure and Integration' by S.K.Berberian).

Unit-IV:

Integration over locally compact spaces: continuous functions with compact support, G_δ's and F_σ's, Baire sets, Baire-sandwich theorem, Baire measures, Borel sets, Regularity of Baire measures, Regular Borel measures, Integration of continuous functions with compact support, Riesz-Markoff representation theorem (Scope as in relevant parts of the sections 54-57, 60, 62, 66 and 69 of Chapter 8 of the book 'Measure and Integration' by S.K.Berberian)

Recommended Text Book:

S.K. Berberian: Measure and Integration, American Mathematical Society, Reprint edition, 2011.

Reference Books:

1. H.L.Royden, Real Analysis (3rd Edition) Prentice-Hall of India, 2008.
2. G.de Barra, Measure theory and integration, New Age International,2014.
3. P.R.Halmos: Measure Theory, Springer New York, 2013.
4. I.K.Rana: An Introduction to Measure and Integration, Narosa Publishing House, Delhi, 1997.
5. R.G.Bartle: The Elements of Integration, John Wiley and Sons, Inc. New York, 1966.

MMATH21-408: MATHEMATICAL ASPECTS OF SEISMOLOGY

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: Seismology is the study of earthquakes and deals with the generation and propagation of seismic waves. This course has been designed to study applications of mathematics in the field of seismology and will first introduce about the interior of the Earth and basic concepts related to earthquakes viz. causes, observation and location of earthquakes, magnitude and energy etc. The students will learn the mathematical representation of waves, solutions of wave equation in different forms and wave phenomena in detail; elastic waves, their reflection and refraction; mathematical models for the propagation of surface waves and source problems.

Course Outcomes: This course will enable the students to:

1. Understand introductory concepts of earthquakes, seismology and wave propagation so as to form a strong foundation to learn the subject. Know mathematical representation of progressive waves and wave characteristics. Have knowledge to solve wave equation in different coordinate systems.
2. Learn damping, modulation, inhomogeneity and dispersion of waves, representation of spherical waves and their expansion in terms of plane waves. Learn techniques to solve wave equation in order to obtain D'Alembert, Kirchoff, Poisson and Helmholtz formulae which find great importance in energy transport phenomenon in science and engineering.
3. Learn about seismic waves and understand reflection and refraction of seismic waves. Apply knowledge of mathematics and knowledge attained in first two COs to formulate mathematical models having application in seismology and to solve such problems.
4. Understand surface waves and seismic sources (area, line and point). Attain skills to formulate and solve Lamb's problems. Attain knowledge and mathematical tools to pursue research in the area of seismology and to contribute to the science and society.

Unit-I:

Introduction to Seismology: Earthquakes, Causes of earthquakes; Elastic rebound theory, Location of earthquakes, Strength of earthquakes; Earthquake magnitude and intensity, Observation of earthquakes; Seismograms, Seismometers, Earthquake Focal Mechanisms, Energy released by earthquakes, Seismic waves as probes of Earth's interior, Interior of the earth.

General form of progressive waves, Harmonic waves, Plane waves, Wave equation. Principle of superposition, Stationary waves. Special types of solutions: Progressive and Stationary type solutions of wave equation in Cartesian, cylindrical and spherical coordinate systems.

(Relevant articles from the book "*Waves*" by Coulson & Jeffrey)

Unit-II:

Equation of telegraphy. Exponential form of harmonic waves. D'Alembert's formula. Inhomogeneous wave equation, Boundary conditions and mixed problems, Extension of solutions by reflection.

Doppler Effect, Beats, Amplitude modulation, Dispersion, Group velocity, Relation between phase velocity and group velocity, Motion of wave packets.

(Relevant articles from the book "*Waves*" by Coulson & Jeffrey)

Spherical waves. Expansion of a spherical wave into plane waves: Sommerfield's integral. Kirchoff's solution of the wave equation, Poissons's formula, Helmholtz's formula.

(Relevant articles from the book "*Mathematical Aspects of Seismology*" by Markus Bäth).

Unit-III:

Seismic waves: Reduction of equation of motion to wave equations. P and S waves and their characteristics. Polarization of plane P and S waves; Wave potentials. Energy in a plane wave. Snell's law of reflection and refraction. Ray parameter and slowness.

Reflection of plane P and SV waves at a free surface. Partition of reflected energy. Reflection at critical angles.

Reflection and reflection of plane P, SV and SH waves at an interface. Special cases of Liquid-Liquid interface, Liquid-Solid interface and Solid-Solid interface.

(Relevant articles from the book, "*Elastic waves in Layered Media*" by Ewing et al).

Unit-IV:

Surface waves: Rayleigh waves, Love waves and Stoneley waves.

(Relevant articles from the book, "*Elastic waves in Layered Media*" by Ewing et al).

Two dimensional Lamb's problems in an isotropic elastic solid: Area sources and Line Sources in an unlimited elastic solid. A normal force acts on the surface of a semi-infinite elastic solid, tangential forces acting on the surface of a semi-infinite elastic solid.

Three dimensional Lamb's problems in an isotropic elastic solid: Area sources and Point sources in an unlimited elastic solid, Area source and Point source on the surface of semi-infinite elastic solid.

Haskell matrix method for Love waves in multilayered medium.

(Relevant articles from the book "*Mathematical Aspects of Seismology*" by Markus Bäth).

Recommended Books:

1. C.A. Coulson and A. Jeffrey, Waves: A mathematical approach to the common types of wave motion, Longman Higher Education, 1977, Published online by Cambridge University Press, 2016.
2. M. Bath, *Mathematical Aspects of Seismology*, Elsevier Publishing Company, 1968.
3. W.M. Ewing, W.S. Jardetsky and F. Press, *Elastic Waves in Layered Media*, McGraw Hill Book Company, 1957.

Reference Books:

1. P.M. Shearer, Introduction to Seismology, Cambridge University Press,(UK) 1999.
2. Jose Pujol, Elastic Wave Propagation and Generation in Seismology, Cambridge Universty Press, 2003.
3. Seth Stein and Michael Wysession, An Introduction to Seismology, Earthquakes and Earth Structure, Blackwell Publishing Ltd., 2003.
4. Aki, K. and P.G. Richards, Quantitative Seismology: theory and methods, W.H. Freeman, 1980.
5. Bullen, K.E. and B.A. Bolt, *An Introduction to the Theory of Seismology*, Cambridge Universty Press, 1985.
6. C.M.R. Fowler, *The Solid Earth*, Cambridge University Press, 1990.

MMATH21-409: ADVANCED DISCRETE MATHEMATICS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The course consists of two sections. In the first section lattices are defined as algebraic structures. This section contains various types of lattices i.e. modular, distributive and complimented lattices.The notion of independent elements in modular lattices is introduced. Boolean algebra has been introduced as an algebraic system. Basic properties of finite Boolean algebra and application of Boolean algebra to switching circuit theory is also given.
Section two contains graph theory. In this section students will be taught connected graphs, Euler's theorem on connected graphs, trees and their basic properties. This section also contains fundamental circuits and fundamental cut-sets, planner graphs, vector space associated with a graph, and the matrices associated with graphs, paths, circuits and cut-sets. The contents of this paper find many applications in computer science and engineering science.

Course Outcomes: This course will enable the students to:

1. Understand concept of lattices, Boolean algebra.
2. Apply lattices to switching circuits.
3. Understand concept of graph, path, circuits, tree, fundamental circuits, cut-set and cut-vertices.
4. Understand concept of planer and dual graph, circuit and cut-set subspace, fundamental circuit matrix, cut- set matrix, path matrix and adjacency matrix.

Unit-I:
Properties of lattice, modular and distributive lattices. Boolean algebra, basic properties, Boolean polynomial, ideals, minimal forms of Boolean polynomials. (Chapter 1 of recommended book at Sr. No. 1)

Unit-II:
Switching circuits, application of lattice to switching circuits.
(2.1 of chapter 2 of recommended book at Sr. No. 1)

Unit-III:
Finite and infinite graphs, Incidence and degree, Isolated vertex, pendant vertex, Null graph, isomosphism, subgraphs, a puzzle with multicolored cubes, walks, paths and circuits. Connected and disconnected graphs, Components of a graph, Euler graphs, Hamiltonian paths and circuits,

The traveling salesman problem. Trees and their properties, pendant vertices in a tree, distance and centers in a tree, rooted and binary tree. Spanning tree, fundamental circuits. Spanning tree in a weighted graph. Cut-sets and their properties. Fundamental circuits and cut-sets. Connectivity and separability. Network flows. (1.1 to 1.5, 2.1 to 2.10, 3.1 to 3.10, 4.1 to 4.6 of recommended book at Sr. No. 2)

Unit-IV:
Planner graphs. Kuratowski's two graphs. Representation of planner graphs. Euler formula for planner graphs. Geometric dual, vector and vector spaces, Vector space associated with a graph. Basis vectors of a graph. Circuit and cut-set subspaces. Intersection and joins of W_C and W_S. Incidence matrix, submatrices of A(G), Circuit matrix, Fundamental circuit matrix, and its rank, Cut-set matrix, path matrix and adjacency matrix .
(5.1 to 5.6, 6.4 to 6.7, 6.9, 7.1 to 7.4, 7.6, 7.8 & 7.9 of recommended book at Sr. No. 2)

Recommended Books:
1. Rudolf Lidl & Gunter Pilz, Applied Abstract Algebra, Springer-Verlag, Second Edition, 1998.
2. Narsingh Deo, Graph Theory with application to Engineering and Computer Science, Prentice Hall of India, 1979.

Reference books:
1. Nathan Jacobson: Lectures in Abstract Algebra Vol. I, D Van Nostrand Company Inc., 1961.
2. L.R.Vermani and Shalini, A course in discrete Mathematical structures, Imperial College Press, London, 2011.

MMATH21-410: ADVANCED FUNCTIONAL ANALYSIS

<table>
<tr><td colspan="2">Course Credit</td><td rowspan="2">End Term Examination Time</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>Internal Assessment</td><td>End Term Examination</td><td>Total</td></tr>
<tr><td>4</td><td>1</td><td>3 Hours</td><td>20</td><td>80</td><td>100</td></tr>
</table>

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: Spectral theory is one of the main branches of modern functional analysis and its applications. The main objective of this course is to familiarize with some advanced topics in functional analysis which include spectral theory of linear operators in normed spaces, compact linear operators on normed spaces and their spectrum, and spectral theory of bounded self-adjoint linear operators and unbounded linear operators in Hilbert spaces.

Course Outcomes: This course will enable the students to:
1. Undersatnd the spectrum of a bounded operator, spectral properties of bounded linear operators; apply the knowledge to prove spectral mapping theorem for polynomials; be familiar with Banach algebras and its properties.
2. Learn about compact linear operators on normed spaces, their spectral properties and application to operator equations involving compact linear operators.
3. Understand the spectral properties of bounded self-adjoint linear operators; apply the knowledge to prove spectral theorem for bounded self adjoint linear operators and extend the spectral theorem to continuous functions.
4. Understand the basics of unbounded linear operators on Hilbert spaces; adjoints of unbounded linear operators; spectral properties of self-adjoint operators; multiplication and differentiation operators.

Unit-I:
Spectrum of a bounded operator: point spectrum, continuous spectrum and residual spectrum, spectral properties of bounded linear operators, the closedness and compactness of the spectrum of a bounded linear operator on a complex Banach space; further properties of resolvent and spectrum, spectral mapping theorem for polynomials. (Scope as in relevant parts of Sections 7.1 to 7.4 of Chapter 7 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Non-emptiness of the spectrum of a bounded linear operator on a complex Banach space, spectral radius, spectral radius formula, Banach algebras, resolvent set and spectrum of a Banach algebra element, further properties of Banach algebras, spectral radius of a Banach algebra element, non-emptiness of the spectrum of a Banach algebra element. (Scope as in relevant parts of Sections 7.5 to 7.7 of Chapter 7 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Unit –II:
Compact linear operators on normed spaces, compactness criterion, conditions under which the limit of a sequence of compact linear operators is compact, weak convergence and compact operators, separability of range, adjoint of compact operators, Spectral properties of compact linear operators on normed spaces, eigen values of compact linear operators, closedness of the range of T_λ, further spectral properties of compact linear operators. (Scope as in relevant parts of Sections 8.1 to 8.4 of Chapter 8 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Operator equations involving compact linear operators, necessary and sufficient conditions for the solvability of various operator equations, further theorems of Fredholm type. Fredholm alternative. (Scope as in relevant parts of Sections 8.5 to 8.7 of Chapter 8 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Unit –III:
Spectral theory of bounded self-adjoint linear operators : spectral properties of bounded self adjoint operators, positive operators, projection operators and their properties. (Scope as in relevant parts of Sections 9.1 to 9.6 of Chapter 9 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Spectral family of a bounded self adjoint linear operator, spectral representation of bounded self-adjoint linear operators, spectral theorem for bounded self-adjoint linear operators, extension of the spectral theorem to continuous functions, properties of the spectral family of a bounded self adjoint operator. (Scope as in relevant parts of Sections 9.7 to 9.11 of Chapter 9 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Unit-IV:
Unbounded linear operators and their Hilbert adjoints, Hellinger-Toeplitz theorem, Hilbert-adjoint, symmetric and self-adjoint linear operators. Closed linear operators and closures, spectral properties of self adjoint linear operators. (Scope as in relevant parts of Sections 10.1 to 10.4 of Chapter 10 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Spectral representation of unitary operators : Wecken's lemma, spectral theorem for unitary operators, spectral representation for self-adjoint linear operators, multiplication and differentiation operators. (Scope as in relevant parts of Sections 10.5 to 10.7 of Chapter 10 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)

Recommended Text Book:
E.Kreyszig: Introductory Functional Analysis with Applications, Wiley India, 2007.

Reference Books:
1. G.F. Simmons: Introduction to Topology and Modern Analysis, McGraw Hill Book Co.,New York, 1983.
2. R. Bhatia, Notes on Functional Analysis, TRIM series, Hindustan Book Agency, India, 2009.
3. J.E. Conway, A course in Operator Theory, Graduate Studies in Mathematics, Volume 21, AMS, 1999.
4. Martin Schechter, Principles of Functional Analysis, American Mathematical Society, 2004.
5. W. Rudin, Functional Analysis, TMH Edition, 1974.

MMATH21-411: ADVANCED FLUID MECHANICS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: This course deals with mechanics of real (viscous) fluids and objective of this course is to let the students have deep understanding of gas dynamics, dynamics of viscous fluids and boundary layer theory. This is a strong foundation course to pursue research in the areas of Fluid Mechanics, Computational Fluid Dynamics, Bio-Mechanics, Mathematical Modeling and Mathematical Biology.

Course Outcomes: This course will enable the students to:

1. Understand wave motion, including sound, in a gas; Sonic, subsonic, supersonic, isentropic types of flows; shock waves and flow of gas through a nozzle. Capacity to solve simple gas flow problems.
2. Have thorough knowledge of viscous fluids; stress, strain rate and relations between them and equations of motion for viscous fluids.
3. Identify those viscous fluid flow problems whose exact solutions can be found and to learn the methods to solve such problems. Apply the knowledge to solve real world problems.
4. Recognize concepts of dynamical similarity, dimensional analysis, Reynolds number, Wever Number, Mach Number, Froude Number, Eckert Number, Buckingham π-theorem and its applications. Understand the concept of boundary layer and the associated theory. Get exposure to real fluid flow problems of science and engineering.

Unit-I:

Wave motion in a Gas. Speed of sound in a gas. Equation of motion of a Gas. Subsonic, sonic and supersonic flows. Isentropic gas flow, Flow through a nozzle. Shock waves.
(Relevant portions from the recommended text book at Sr. No. 1)

Unit-II:

Stress components in a real fluid. Relation between Cartesian components of stress. Translational motion of fluid element. Rate of strain quadric and principal stresses.

Transformation of rates of strains. Stress analysis in fluid motion. Relations between stress and strain rate.

The co-efficient of viscosity and laminar flow. Newtonian and non-Newtonian fluids. Navier-Stokes equations of motion. Equations of motion in cylindrical and spherical polar coordinates.

(Relevant portions from the recommended text book at Sr. No. 1)

Unit-III:

Some solvable problems in viscous flow: Steady motion between parallel planes, Steady flow through tube of uniform cross-section (Poiseuille Flow), Steady flow between concentric rotating cylinders. Steady viscous flow in tubes of uniform cross-section: Uniqueness theorem; Flow through tubes of uniform elliptic, equilateral triangular and rectangular cross-sections. Diffusion of vorticity. Energy dissipation due to viscosity. Steady flow past a fixed sphere. Unsteady flow over a flat plate. Flow in convergent and divergent chennals.

(Relevant portions from the recommended text book at Sr. No. 1)

Unit-IV:

Dynamical similarity. Dimensional analysis. Buckingham π-theorem and its applications to viscous and compressible fluid flow. Reynolds number, Weber Number, Mach Number, Froude Number, Eckert Number

.

Prandtl boundary layer theory, Boundary layer thickness, Boundary layer equation in two-dimensions. The boundary layer flow over a flat plate (Blasius solution). Characteristic boundary layer parameters. Karman integral equations. Karman-Pohlhausen method.

(Relevant portions from the recommended text book at Sr. No. 2)

Recommended Text Books:

1. F. Chorlton, *Text-book of Fluid Dynamics*, CBS Publishers and Distributors Pvt. Ltd., 2018.
2. S. W. Yuan, *Foundations of Fluid Mechanics*, Prentice Hall of India Ltd., 1988.

Reference Books:

1. G.K. Batchelor, *An Introduciton to Fluid Dynamics*, Cambridge University Press, 2000.
2. A.J. Chorin and A. Marsden, *A Mathematical Introduction to Fluid Dynamics*, Springer-Verlag, New York, 1993.
3. L.D. Landau and E.M. Lifshitz, *Fluid Mechanics*, Pergamon Press, 1987.
4. H. Schlichting, *Boundary Layer Theory*, Springer, 2016.
5. A.D. Young, *Boundary Layers*, AIAA Education Series, Washington DC, 1989.
6. W.H. Besant and A.S. Ramsey, *A Treatise on Hydromechanics*, Part-II, CBS Publishers, Delhi, 2006.

MMATH21-412: BOUNDARY VALUE PROBLEMS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each section and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each section and the compulsory question. All questions carry equal marks.

Course Objectives: The objective of this course is to learn to solve the boundary value problems. Boundary value problems find applications in all area of science and engineering. The different techniques to solve boundary value problems and mixed boundary value problems are studied in this course. Such problems can be solved with Green's function approach, Integral transform methods and by using Perturbation techniques. One of the objective to study this course is to expose a student to real world problems that are formulated as boundary value problems.

Course Outcomes: This course will enable the students to:

1. Reduce boundary value problems involving ODEs to the equivalent integral and to solve such problems with Green's function and Modified Green's function approaches. Apply these techniques in problem solving.
2. Learn to find solutions of boundary value problems involving Laplace's equation, Poisson's equation and Helmoltz's equation by using theory of integral equations and Green's function. Attain skill to solve such BVP which arise frequently in different branches of engineering and sciences.
3. Learn to solve the integral equations by integral transform methods. Apply the gained knowledge in solving mixed boundary problems.
4. Understand Perturbation methods and attain capability to apply perturbation techniques in solving different listed boundary value problems of Electrostatics, Hydrodynamics and Elasticity.

Unit-I:

Applications to Ordinary Differential Equations; Initial value problems, Boundary Value Problems. Dirac Delta functions. Green's function approach to reduce boundary value problems of a self-adjoint-differential equation with homogeneous boundary conditions to integral equation forms. Green's function for N^{th}-order ordinary differential equation. Modified Green's function.

(Relevant portions from the Chapter 5 of the book “Linear Integral Equations, Theory and Techniques by R.P.Kanwal”).

Unit-II:
Applications to partial differential equations: Integral representation formulas for the solution of the Laplace and Poisson Equations. The Newtonian, single-layer and double-layer potentials, Interior and Exterior Dirichlet problems, Interior and Exterior Neumann problems. Green’s function for Laplace’s equation in a free space as well as in a space bounded by a ground vessel. Integral equation formulation of boundary value prolems for Laplace’s equation. Poisson’s Integral formula. Green’s function for the space bounded by grounded two parallel plates or an infinite circular cylinder. The Helmholtz equation.
(Relevant portions from the Chapter 6 of the book “Linear Integral Equations, Theory and Techniques by R.P.Kanwal”).

Unit-III:
Integral Transform methods: Introduction, Fourier transform. Laplace transform. Convolution Integral. Application to Volterra Integral Equations with convolution-type Kernels. Hilbert transform.
Applications to mixed Boundary Value Problems: Two-part Boundary Value problems, Three-part-Boundary Value Problems, Generalized Three-part Boundary Value problems.
(Relevant portions from the Chapter 9 & 10 of the book “Linear Integral Equations, Theory and Techniques by R.P. Kanwal”).

Unit-IV:
Integral equation perturbation methods: Basic procedure, Applications to Electrostatics, Low-Reynolds-Number Hydrodynamics: Steady stokes Flow, Boundary effects on Stokes flow, Longitudinal oscillations of solids in stokes Flow, Steady Rotary Stokes Flow, Rotary Oscillations in Stokes Flow, Rotary Oscillation in Stokes Flow, Oseen Flow-Translation Motion, Oseen Flow-Rotary motion Elasticity, Boundary effects, Rotation, Torsion and Rotary Oscillation problems in elasticity, crack problems in elasticity, Theory of Diffraction.
(Relevant portions from the Chapter 11 of the book “Linear Integral Equations, Theory and Techniques by R.P.Kanwal”).

Recommended Books:

1. Ram P. Kanwal, *Linear Integral Equations: Theory & Techniques*, Springer Science & Business Media, 2012.
2. S.G. Mikhlin, *Linear Integral Equations* (translated from Russian) ,Hindustan Book Agency, 1960.
3. F.G Tricomi, *Integral Equations*, Courier Corporation, 1985.
4. Abdul J. Jerri, *Introduction to Integral Equations with Applications*, Wiley-Interscience, 1999.
5. Ian N. Sneddon, *Mixed Boundary Value Problems in potential theory*, North Holland Publishing Co., 1966.
6. Ivar Stakgold, *Boundary Value Problems of Mathematical Physics* Vol.I, II, Society for Industrial and Applied Mathematics, 2000.

MMATH21-413: BIO-MATHEMATICS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course objectives: This paper deals with a widely acceptable fact that many phenomena in life sciences and environment sciences can be modelled mathematically. Biology offers a rich variety of topics that are amenable to mathematical modeling, but some of the genuinely interesting are touched in this paper. It is assumed that students have no knowledge of biology, but they are expected to learn a substantial amount during the course. The ability to model problems using mathematics may not require much of the memorization, but it does require a deep understanding of basic principles and a wide range of mathematical techniques. Students are required to know differential equations and linear algebra. Topics in stochastic modeling are also touched, which requires some knowledge of probability.

Course outcomes: This course will enable the students to:

1. Derive population growth laws/models regulated through logistic equation, involving species competition, Lotka-Volterra predator-prey equations to develop the theory of age-structured populations using both discrete- and continuous-time models for their applications in life cycle of a hermaphroditic worm.
2. Model smaller populations those exhibit stochastic effects so as to analyze births rates in finite populations for their role in mathematical models of infectious disease epidemics and endemics so as to predict the future spread of a disease and to develop strategies for containment and eradication.
3. Learn the mathematical modeling of the evolution/maintenance of polymorphism to understand population genetics, influence of natural selection, genetic drift, mutation, and migration (i.e., evolutionary forces) in changing the Allele frequencies.
4. Derive mathematical models for biochemical reactions, including catalyzed by enzymes, based on the law of mass action, enzyme kinetics, fundamental enzymatic properties (i.e., competitive inhibition, allosteric inhibition, cooperativity) so as to know about DNA chemistry and the genetic code for alignment of DNA/RNA sequences by brute force, dynamic programming or gaps.

Unit-I:

Population Dynamics: The Malthusian growth ; The Logistic equation; A model of species competition; The Lotka-Volterra predator-prey model;

Age-structured Populations : Fibonacci’s rabbits; The golden ratio Φ; The Fibonacci numbers in a sunflower; Rabbits are an age-structured population; Discrete age-structured populations; Continuous age-structured populations; The brood size of a hermaphroditic worm.

Unit-II:

Stochastic Population Growth : A stochastic model of population growth; Asymptotics of large initial populations; Derivation of the deterministic model; Derivation of the normal probability distribution; Simulation of population growth.
Infectious Disease Modeling: The SI model; The SIS model; The SIR epidemic disease model; Vaccination ; The SIR endemic disease model ; Evolution of virulence.

Unit-III:

Population Genetics: Haploid genetics; Spread of a favored allele; Mutation-selection balance ; Diploid genetics; Sexual reproduction; Spread of a favored allele; Mutation-selection balance; Heterosis; Frequency-dependent selection; Linkage equilibrium; Random genetic drift.

Unit-IV:

Biochemical Reactions: The law of mass action; Enzyme kinetics; Competitive inhibition; Allosteric inhibition; Cooperativity. Sequence Alignment: DNA ; Brute force alignment; Dynamic programming; Gaps; Local alignments; Software.

Recommended Books:

1. Mathematical Biology, Lecture notes for MATH 4333, (Jeffrey R. Chasnov)
2. Mathematical Biology I. An Introduction, Third Edition, (J.D. Murray)

MMATH21-414: FOURIER AND WAVELET ANALYSIS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: Wavelet analysis is a modern supplement to classical Fourier analysis. In some cases Wavelet analysis is much better than Fourier analysis in the sense that fewer terms suffice to approximate certain functions. The main objective of this course is to familiarize with the standard features of Fourier transforms along with more recent developments such as the discrete and fast Fourier transforms and wavelets. We consider the idea of a multiresolution analysis and the course we follow is to go from MRA to wavelet bases.

Course Outcomes: This course will enable the students to:
1. Have an idea of the finite Fourier transform, convolution on the circle group T, the Fourier transform and residues and know about continuous analogue of Dini's theorem and Lipschitz's test.
2. Know about (C,1) summability for integrals, understand the Fejer-Lebesgue inversion theorem, Parseval's identities, the L_2 theory, Plancherel theorem and Mellin transform.
3. Have understanding of the Discrete and Fast Fourier transforms, and Buneman's Algorithm.
4. Understand Multiresolution Analysis, Mother wavelets; construction of scaling function with compact support, Shannon wavelets, Franklin wavelets, frames, splines and the continuous wavelet transform.

Unit-I:
Fourier Transform: The finite Fourier transform, the circle group T, convolution to T, (L (T),+,*) as a Banach algebra, convolutions to products, convolution on T, the exponential form of Lebesgue's theorem, Fourier transform : trigonometric approach, exponential form, Basics/examples.
Fourier transform and residues, residue theorem for the upper and lower half planes, the Abel kernel, the Fourier map, convolution on R, inversion, exponential form, inversion, trigonometric form, criterion for convergence, continuous analogue of Dini's theorem, continuous analogue of Lipschitz's test, analogue of Jordan's theorem.
(Scope as in relevant parts of Chapter 5 of the book "Fourier and Wavelet Analysis" by Bachman, Narici and Beckenstein)

Unit-II:
(C,1) summability for integrals, the Fejer-Lebesgue inversion theorem,the continuous Fejer Kernel, the Fourier map is not onto, a dominated inversion theorem, criterion for integrability of $\hat{f}$

Approximate identity for $L_1(R)$, Fourier Sine and Cosine transforms, Parseval's identities, the L_2 theory, Parseval's identities for L_2, inversion theorem for L_2 functions, the Plancherel theorem, A sampling theorem, the Mellin transform, variations.

(Scope as in relevant parts of Chapter 5 of the book "Fourier and Wavelet Analysis" by Bachman, Narici and Beckenstein)

Unit-III:
Discrete Fourier transform, the DFT in matrix form, inversion theorem for the DFT, DFT map as a linear bijection, Parseval's identities, cyclic convolution, Fast Fourier transform for N=2 , Buneman's Algorithm, FFT for N=RC, FFT factor form. (Scope as in relevant parts of Chapter 6 of the book "Fourier and Wavelet Analysis" by Bachman, Narici and Beckenstein)

Unit-IV:
Wavelets : orthonormal basis from one function , Multiresolution Analysis, Mother wavelets yield Wavelet bases, Haar wavelets, from MRA to Mother wavelet, Mother wavelet theorem, construction of scaling function with compact support, Shannon wavelets, Riesz basis and MRAs, Franklin wavelets, frames, splines, the continuous wavelet transform. (Scope as in relevant parts of Chapter 7 of the book "Fourier and Wavelet Analysis" by Bachman, Narici and Beckenstein)

Recommended Text Book :
1. G. Bachman, L. Narici and E. Beckenstein : Fourier and Wavelet Analysis, Springer, 2000

Reference Books :
1. Hernandez and G. Weiss : A first course on wavelets, CRC Press, New York, 1996
2. C. K. Chui: An introduction to Wavelets, Academic Press,1992
3. I. Daubechies : Ten lectures on wavelets, CBMS_NFS Regional Conferences in Applied Mathematics, 61, SIAM, 1992
4. V. Meyer, Wavelets, algorithms and applications SIAM, 1993
5. M.V. Wickerhauser: Adapted wavelet analysis from theory to software, Wellesley,MA, A.K. Peters, 1994
6. D. F. Walnut: An Introduction to Wavelet Analysis, Birkhauser, 2002
7. K. Ahmad and F.A. Shah: Introduction to Wavelets with Applications, World Education Publishers, 2013

MMATH21-415: LINEAR PROGRAMMING

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: Real life systems can have dozens or hundreds of variables, or more, which may not be handled through standard algebraic techniques. Such systems are used every day in the organization and allocation of resources and are generally handled through linear programming based on "optimization techniques". Linear programming deals with the problems of maximizing or minimizing a linear function subject to linear constraints in the form of equalities or inequalities. The general process for solving linear-programming exercises is to graph the constraints to form a walled-off area called "feasibility region". Then, corners of this feasibility region are tested to find the highest (or lowest) value of the outcome (or resources).

Course Outcomes: This course will enable the students to:

1. Learn background for linear programming, theory of simplex method, detailed development and computational aspects of the simplex method.
2. Discuss simplex method in detail, resolution of the degeneracy problem .
3. Discuss revised simplex method.
4. Understand duality theory and its ramifications, transportation problem.

Unit-I:

Simultaneous linear equations, Basic solutions, Linear transformations, Point sets, Lines and hyperplanes, Convex sets, Convex sets and hyperplanes, Convex cones, Restatement of the LP problem, Slack and surplus variables, Preliminary remarks on the theory of the simplex method, Reduction of any feasible solution to a basic feasible solution, Definitions and notations regarding LP problems. Improving a basic feasible solution, Unbounded solutions, Optimality conditions, Alternative optima, Extreme points and basic feasible solutions.

The simplex method, Selection of the vector to enter the basis, Degeneracy and breaking ties, Further development of the transformation formulas, The initial basic feasible solution, artificial variables, Inconsistency and redundancy, Tableau format for simplex computations, Use of the tableau format, Conversion of a minimization problem to a maximization problem, Review of the simplex method.

(Chapter 2, 3 & 4 of recommended book)

Unit-II:
The two-phase method for artificial variables, Phase I, Phase II, Numerical examples of the two-phase method, Requirements space, Solutions space, Determination of all optimal solutions, Unrestricted variables, Charnes' perturbation method regarding the resolution of the degeneracy problem.
Selection of the vector to be removed, Definition of b(€). Order of vectors in b(€), Use of perturbation technique with simplex tableau format, Geometrical interpretation of the perturbation method. The generalized linear programming problem, The generalized simplex method, Examples pertaining to degeneracy, An example of cycling.
(Chapter 5, 6 of recommended book)

Unit-III:
Revised simplex method: Standard Form I, Computational procedure for Standard Form I, Revised simplex method: Standard Form II, Computational procedure for Standard Form II, Initial identity matrix for Phase I, Comparison of the simplex and revised simplex methods,
The product form of the inverse of a non-singular matrix.
(Chapter 7 of recommended book)

Unit-IV:
Alternative formulations of linear programming problems, Dual linear programming problems, Fundamental properties of dual problems, Other formulations of dual problems, Complementary slackness, Unbounded solution in the primal, Dual simplex algorithm, Alternative derivation of the dual simplex algorithm, Initial solution for dual simplex algorithm, The dual simplex algorithm; an example, geometric interpretations of the dual linear programming problem and the dual simplex algorithm. A primal dual algorithm, Examples of the primal-dual algorithm.
Transportation problem, properties of matrix A, the simplex method and transportation problem, simplification resulting from all $y_{ij}^{\alpha\beta} = \pm 1$ or 0, the transportation problem tableau, bases in the transportation tableau, the stepping stone algorithm, an example. (Chapter 8 & 9.1 to 9.8 of recommended book)

Recommended Text Book:
1. G. Hadley, Linear Programming, Narosa Publishing House, 2002.

Reference book:
1. S.I. Gauss, Linear Programming: Methods and Applications, 4th Ed., McGraw-Hill, New York, 1975.

MMATH21-416: NON-COMMUTATIVE RINGS

Course Credit		End Term Examination Time	Maximum Marks		
L	T		Internal Assessment	End Term Examination	Total
4	1	3 Hours	20	80	100

Note: The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 8 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks.

Course Objectives: The course has been designed to give an exposure of the advanced ring theory. Course contains some special example of rings i.e. differential polynomial rings, group rings, skew group rings, triangular rings, Hurwitz's rings of integral quaternion's, DCC and ACC in triangular rings, Dedekind finite rings, simple and semi-simple modules, projective and injective modules. Nil radical and Jacobson radical of matrix rings are also part of the course. The course also contains sub-direct product of rings and commutativity theorems of Jacobson-Herstein and Herstein-Kaplansky. Finally theory of finite division rings is given.

Course Outcomes: This course will enable the students to:

1. Understand basic terminology and examples of non-commutative rings, simple and semi-simple modules and rings, Wedderburn-Artin Theorem, Schur's Lemma, Minimal ideals, Amitsur Theorem on non-inner derivations.
2. Understand Jacobson radical of a ring R, Jacobson semi-simple rings, Hopkins-Levitzki Theorem. Jacobson radical of the matrix ring, Amitsur Theorem on radicals, Nakayama's Lemma, Von Neumann regular rings, E. Snapper's Theorem.
3. Understand Prime and semi-prime ideals and rings. Lower and upper nil radical of a ring R . Amitsur theorem on nil radical of polynomial rings, Brauer's Lemma, Levitzki theorem , Density Theorem, Structure theorem for left primitive rings.
4. To learn about Subdirectly reducible and irreducible rings, Birchoff's Theorem, G.Shin's Theorem, Commutativity Theorems , Division rings, Wedderburn's Little Theorem, Herstein's Lemma and theorem, Jacobson and Frobenius Theorem, Cartan-Brauer-Hua Theorem.

Unit-I:

Basic terminology and examples of non-commutative rings i.e. Hurwitz's ring of integral quaternions, Free k-rings. Rings with generators and relations. Hilbert's Twist, Differential polynomial rings, Group rings, Skew group rings, Triangular rings, D.C.C. and A.C.C. in triangular rings. Dedekind finite rings. Simple and semi-simple modules and rings. Spliting homomorphisms. Projective and Injective modules.

Ideals of matrix ring M_n (R). Structure of semi simple rings. Wedderburn-Artin Theorem Schur's Lemma. Minimal ideals. Indecomposable ideals. Inner derivation δ. δ-simple rings. Amitsur Theorem on non-inner derivations.

Unit-II:

Jacobson radical of a ring R.Annihilator ideal of an R-module M. Jacobson semi-simple rings. Nil and Nilpotent ideals. Hopkins-Levitzki Theorem. Jacobson radical of the matrix ring M_n (R). Amitsur Theorem on radicals. Nakayama's Lemma. Von Neumann regular rings. E. Snapper's Theorem. Amitsur Theorem on radicals of polynomial rings.

Unit-III:

Prime and semi-prime ideals. m-systems. Prime and semi-prime rings. Lower and upper nil radical of a ring R Amitsur theorem on nil radical of polynomial rings. Brauer's Lemma. Levitzki theorem on nil radicals. Primitive and semi-primitive rings. Left and right primitive ideals of a ring R. Density Theorem. Structure theorem for left primitive rings.

Unit-IV:

Sub-direct products of rings. Subdirectly reducible and irreducible rings. Birchoff's Theorem. Reduced rings. G.Shin's Theorem. Commutativity Theorems of Jacobson, Jacobson-Herstein and Herstein Kaplansky. Division rings. Wedderburn's Little Theorem. Herstein's Lemma. Jacobson and Frobenius Theorem. Cartan-Brauer-Hua Theorem. Herstein's Theorem.

(1.1 to 1.26, 2.1 to 2.9, 3.1 to 3.19, 4.1 to 4.27, 5.1 to 5.10, 10.1 to 10.30, 11.1 to 11.20, 12.1 to 12.11 and 13.1 to 13.26 of recommended book).

Recommended Book:

1. T.Y. Lam : A First Course in Noncommutive Rings, Springer-Verlag, 1990.

Reference book:

1. I.N. Herstein : Non-Commutative Rings carus monographs in Mathematics ,Vol.15., Math. Asso. of America, 1968.