Manipal University Jaipur

Department of Mathematics and Statistics

Summary Report

The Department of Mathematics and Statistics offers degree courses in B.Sc. (Hons.) Mathematics and M.Sc. (Mathematics). These courses have been designed in such a way that they meet the global standards of the mentioned programmes offered in other national and international universities of repute. Each of the course follow the credit base course system, wherein B.Sc. (Hons.) Mathematics course is of 148 credits and M.Sc. (Mathematics) course is of 80 credits. The course handout of each course explains the Course Outcomes (CO's), Programme Outcomes (PO's), Programme Specific Outcomes (PSO's), Assessment Plan, Syllabus, Lecture Plan, and mapping of PO's and PSO's with CO's which provides the better insight of usefulness of courses in respect to the present scenario of employability and skill enhancement.

Dr. Kalpna Sharma, Head

Department of Mathematics & Statistics

Dr. Lalita Ledwani, Dean

School of Basic Sciences

Dr. Ajay Kumar, Director

Directorate of Academics

Department of Mathematics and Statistics

M. Sc. Mathematics Programme

PROGRAM OUTCOMES

PO.1 **Critical thinking**: Critically interpret data, write reports, and apply the basics of evidence.

PO.2 **Effective Communication**: Communicate effectively by writing, connecting people, ideas, books, media, and technology.

PO.3 **Social Interaction**: Elicit views of others, mediate disagreements and help reach conclusions in group settings.

PO.4 **Effective Citizenship**: Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering.

PO.5 **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities.

PO.6 **Environment and Sustainability**: Understand the issues of environmental contexts and sustainable development.

PO.7 **Self-directed and Life-long Learning**: Acquire the ability to engage in independent and life-long learning in the broadest context socio technological changes.

PROGRAM SPECIFIC OUTCOMES

PSO.1 Describe the basic and advanced Mathematical concepts of Pure and Applied Mathematics.

PSO.2 Apply the Mathematical principles to analyze and solve a variety of real-life as well as industry problems.

PSO.3 To have necessary skills for the research and developments in theoretical and applied science through seminar, project, and publication.

S.I.N.O.	Course CODE	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	ATTAINMENT PERCENTAGE
1	MA6111	100	0	0	100	0	0	0	0	0	0	0	0	100	100	100	0	0	0	100
2	MA6112	100	0	0	100	0	0	0	0	0	0	0	0	100	100	100	0	0	0	100
3	MA6113	100	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	50
4	MA6114	100	0	100	0	100	100	100	0	0	0	0	0	100	100	100	0	0	0	100
5	MA6115	100	0	100	0	0	0	100	0	0	0	0	0	100	100	100	0	0	0	100
6	MA6116	100	0	0	100	0	0	0	0	0	0	0	0	100	100	100	0	0	0	100
7	MA6201	100	100	100	100	100	100	100	0	0	0	0	0	100	100	100	0	0	0	100
8	MA6202	100	0	0	100	0	100	100	0	0	0	0	0	100	100	100	0	0	0	100
9	MA6203	100	100	100	100	0	0	0	0	0	0	0	0	100	0	0	0	0	0	83
10	MA6204	100	0	0	100	0	0	0	0	0	0	0	0	100	100	100	0	0	0	100
11	MA6205	100	100	100	100	100	0	100	0	0	0	0	0	100	100	100	0	0	0	100
12	MA6230	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	100
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value

50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Value

MINIMUM ATTAINMENT VALUE	50
MAXIMUM ATTAINMENT VALUE	100
OVERALL PROGRAM ATTAINMENT	95
OVERALL PROGRAM ATTAINMENT LEVEL	3

Manipal University Jaipur

Department of Mathematics & Statistics

Following courses were run in the M. Sc. Mathematics programme during the session 2020-21.

S. No.	Course Code	Course Name	Semester
1	MA6111	Advanced Linear Algebra	I
2	MA6112	Mathematical Analysis	I
3	MA6113	Differential Equations	I
4	MA6114	Advanced Complex Analysis	I
5	MA6115	Mathematical Statistics	I
6	MA6116	Topology-I	I
7	MA6201	Partial Differential Equations	II
8	MA6202	Optimization Theory and Techniques	II
9	MA6203	Functional Analysis	II
10	MA6204	Measure theory & Integration	II
11	MA6205	Research Methodology & Technical Writing	II
12	MA6230	Lab on Optimization Theory and Techniques	II

Dr. Kalpna Sharma

Head, Department of Mathematics & Statistics

MANIPAL UNIVERSITY JAIPUR

School of Basic Sciences

Department of Mathematics & Statistics
Course Hand-out

Advanced Linear Algebra| MA 6111 | 4 Credits | 4 0 0 4

Session: Nov, 2020- Feb, 2021| Class: M.Sc. Mathematics | Course Coordinator: Dr. Ashok Kumar Pal

A. Introduction: Dept. of Mathematics & Statistics offer the course Advanced Linear Algebra for M.Sc. Mathematics Students. The aim of this course to motivate students to develop research ability in students by theoretical approach and create interest in pure mathematics. The course will develop a depth understanding of Linear Algebra by some concept of different linear operator, Linear Transformations, and Inner product. The course will develop mental ability in the Linear Algebraic problem and their solutions.

B. Course Outcomes: At the end of the course, students will be able to

[MA6111.1] Describe the concept of linear transformations, dual space and annihilator of the vector space.
[MA6111.2]. Describe the concept orthonormality, inner-product and isometry on inner-product and relative theorem.
[MA6111.3] Describe the concept the different linear operator and algebra of homomorphism in the vector spaces.
[MA6111.4] Describe the concept in diagonalization of matrix, canonical form, bilinear forms and classification of real quadric form.
[MA6111.5] Evaluate the solution of mathematical problem, which make them employable.

C. Program Outcomes and Program Specific Outcomes

[PO.1]. **Critical thinking:** Critically interpret data, write reports and apply the basics of evidence.
[PO.2]. **Effective Communication:** Communicate effectively by writing, connecting people, ideas, books, media and technology.
[PO.3]. **Social Interaction:** Elicit views of others, mediate disagreements and help reach conclusions in group settings.
[PO.4]. **Effective Citizenship:** Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering**.**
[PO.5]. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities.
[PO.6]. **Environment and Sustainability:** Understand the issues of environmental contexts and sustainable development.
[PO.7]. **Self-directed and Life-long Learning:** Acquire the ability to engage in independent and life-long learning in the broadest context socio technological changes.

PROGRAM SPECIFIC OUTCOMES:

[PSO.1]. Describe the basic and advanced Mathematical concepts of Pure and Applied Mathematics.
[PSO.2]. Apply the Mathematical principles to analyze and solve a variety of real-life as well as industry problems.
[PSO.3]. To have necessary skills for the research and developments in theoretical and applied science through seminar, project, and publication.

D. Assessment Rubrics:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Close Book)	20
	Sessional Exam II (Close Book)	20
	Quizzes and Assignment	20
End Term Exam (Summative)	End Term Exam (Close Book)	40
	Total	100

Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.
Quizzes	3 Quizzes (Close Book)

E. Syllabus

Linear Transformations: Recall of vector space, basis, dimension and related properties, algebra of linear transformations, vector space of linear transformations L(U,V), dimension of space of linear transformations, change of basis and transition matrices, linear functional, dual basis, computing of a dual basis, dual vector spaces, annihilator, second dual space, dual transformations;

Inner-Product Spaces: Normed space, Cauchy-Schwartz inequality, pythagorean theorem, projections, orthogonal projections, orthogonal complements, orthonormality, matrix representation of inner-products, Gram-Schmidt orthonormalization process, Bessel's inequality, Riesz representation theorem and orthogonal transformation, Inner product space isomorphism, operators on inner-product spaces, isometry on inner-product spaces and related theorems,

Adjoint operator, self-adjoint operator, normal operator and their properties, matrix of adjoint operator , algebra of Hom (V,V), minimal polynomial, invertible linear transformation, characteristic roots, characteristic polynomial and related results; Diagonalization: Diagonalization of matrices, invariant subspaces, Cayley-Hamilton theorem, canonical form, Jordan Form. Forms on vector spaces, bilinear functionals, symmetric bilinear forms, skew symmetric bilinear forms, rank of bilinear forms, quadratic forms, and classification of real quadratic forms.

F. Reference Book:

K. B. Datta, Matrix and Linear Algebra, Prentice Hall of India Pvt. Ltd, New Delhi, 2007.
P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, First course in Linear Algebra, New Age International Ltd, 2012
K. Hoffman and R. Kunze, Linear Algebra, 2nd edition, Prentice Hall, Englewood Cliffs, New Jersey, 2014.
S. Kumaresan, Linear Algebra-A geometric approach, Prentice Hall of India, 2000.
R. B. Dash and D. K. Dalai, Fundamentals of Linear Algebra, Himalaya Publishing house, 2008.
S. Lang, Linear Algebra, 3rd edition, Springer-Verlag, New York 2005.

G. Lecture Plan:

Lec No	Topics	Session Objective	Mode of Delivery (Online/Classroom)	Corresponding CO	Mode of Assessing the Outcome
1	Introduction, aims and objectives of the course and elementary fundamentals of Linear Algebra	Know the basics of the course and understand its applications	Lecture	MA6111.1	Assignments Class Quiz Mid-Term I End-Term
2	Recall of vector space, basis,	Recall of vector space, basis,	Lecture	MA6111.1	
3	dimension and related properties	Understand the dimension and related properties.	Lecture	MA6111.1	
4	algebra of linear transformations	Understand the algebra of linear transformations.	Lecture	MA6111.1	
5	Exercise and doubts	Know the doubts	Lecture	MA6111.2	
6	vector space of linear transformations L(U,V),	Know the basics of the linear transformation	Lecture	MA6111.2	
7	dimension of space of linear transformations	Understand the concept of dimension of space of linear transformations.	Lecture	MA6111.2	
8	Exercise and doubts	Understand the concept of dimension of the space.	Lecture	MA6111.2	
9	change of basis and transition matrices	Know the concept of change of basis and transition matrices	Lecture	MA6111.2	
10	linear functional, dual basis	basics of the linear functional, dual basis.	Lecture	MA6111.2	
11	computing of a dual basis	To understand the concept of dual basis.	Lecture	MA6111.2	
12	dual vector spaces	To understand the problem.	Lecture	MA6111.2	
13	annihilator	Know the concept of annihilator.	Lecture	MA6111.3	
14	second dual space	Know the basics of the second dual space	Lecture	MA6111.3	
15	dual transformations	Know the basics of the dual transformations	Lecture	MA6111.3	
16	Inner-Product Spaces	To understand the Inner-Product Spaces.	Lecture	MA6111.3	
17	Normed space	Know the concept of limit of the sequences	Lecture	MA6111.3	
18	Cauchy-Schwartz inequality	Know the basics of limit of a sequences.	Lecture	MA6111.3	
19	Pythagorean theorem	Know the concept of convergence sequences.	Lecture	MA6111.3	
20	projections, orthogonal projections	Know the concept of convergence sequences	Lecture	MA6111.3	
21	orthogonal complements	To understand the problem.	Lecture	MA6111.3	
22	orthonormality	Know the concept of convergence sequences	Lecture	MA6111.3	

23	matrix representation of inner-products	Know the concept of convergence sequences	Lecture	MA6111.3	
24	Gram-Schmidt orthonormalization process	Know the concept of convergence sequences	Lecture	MA6111.3	
25	Bessel's inequality	Know the concept of convergence sequences	Lecture	MA6111.3 MA6111.5	
26	Riesz representation theorem and orthogonal transformation	To understand the problem.	Lecture	MA6111.3	
27	Inner product space isomorphism	Understand the impulse and reaction turbine	Lecture	MA6111.3	
28	operators on inner-product spaces	Understand the concept of monotonic sequences.	Lecture	MA6111.3 MA6111.5	
29	isometry on inner-product spaces and related theorems	Understand the concept of monotonic sequences.	Lecture	MA6111.3	Assignments Class Quiz Mid-Term II End-Term
30	Exercise and doubts	To understand the problem.	Lecture	MA6111.3	
31	Exercise and doubts	Understand the concept of monotonic sequences.	Lecture	MA6111.3 MA6111.5	
32	Adjoint operator	Understand the concept of subsequences.	Lecture	MA6111.3	
32	self-adjoint operator	To understand the problem.	Lecture	MA6111.3 MA6111.5	
33	normal operator and their properties	Understand the concept of subsequences.	Lecture	MA6111.3	
34	matrix of adjoint operator	Understand the concept of infinite series	Lecture	MA6111.4	
35	algebra of Hom (V,V)	To understand the problem.	Lecture	MA6111.4 MA6111.5	
36	minimal polynomial	Know the basics of the infinite series	Lecture	MA6111.4	
37	invertible linear transformation	Know the concept of convergence and divergence series.	Lecture	MA6111.4	
38	characteristic roots	Know the concept of convergence and divergence series.	Lecture	MA6111.4	
39	characteristic polynomial and related results	Know the concept of convergence and divergence series	Lecture	MA6111.4	
40	Diagonalization of matrices	Know the concept of convergence and divergence series	Lecture	MA6111.4	Assignments Class Quiz End-Term
41	invariant subspaces	Know the concept of convergence and divergence series	Lecture	MA6111.4	
42	Cayley-Hamilton theorem	Know the concept of convergence and divergence series	Lecture	MA6111.4	
43	canonical form, Jordan Form.	Know the concept of convergence and divergence series	Lecture	MA6111.4	

44	bilinear functionals	Know the concept of convergence and divergence series	Lecture	MA6111.4	
45	symmetric bilinear forms	Know the concept of convergence and divergence series	Lecture	MA6111.4 MA6111.5	
46	skew symmetric bilinear forms	Know the concept of convergence and divergence series	Lecture	MA6111.4	
47	rank of bilinear forms	Understand the concept of Alternating series	Lecture	MA6111.4	
48	quadratic forms, and classification of real quadratic forms	Understand the concept of Alternating series	Lecture	MA6111.4 MA6111.5	
49	Exercise and doubts	Know the concept of convergence and divergence of Alternating series	Lecture	MA6111.4 MA6111.5	

H. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES							CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PSO 1	PSO 2	PSO 3
MA6111.1	Describe the concept of linear transformations, dual space and annihilator of the vector space	1							2	3	3
MA6111.2	Describe the concept orthonormality, inner-product and isometry on inner-product and relative theorem.	1							3	2	
MA6111.3	Describe the concept the different linear operator and algebra of homomorphism in the vector spaces.	1			2				2	2	2
MA6111.4	Describe the concept in diagonalization of matrix, canonical form, bilinear forms and classification of real quadric form	1			2				3	1	
MA6111.5	Evaluate the solution of mathematical problem, which make them employable	1							1	1	2

MANIPAL UNIVERSITY JAIPUR

School of Basic Sciences

Department of Mathematics & Statistics
Course Hand-out

Mathematical Analysis| MA 6112 | 4 Credits | 4 0 0 4

Session: Jul, 2020- Dec, 2020| Class: M.Sc. Mathematics I Sem | Course Coordinator: Dr. Ram Naresh Saraswat

A. Introduction: Dept. of Mathematics & Statistics offer the course Mathematical Analysis for M.Sc. Mathematics Students. The aim of this course to motivate students to develop research ability in students by theoretical approach and create interest in pure mathematics. The course will develop a depth understanding of Real Analysis by some concept of RS-integral, Sequences and Series of functions and their uniform convergency. The course will develop mental ability in the Real Analysis problem and their solutions.

B. Course Outcomes: At the end of the course, students will be able to

[MA6112.1] Describe the concept of Riemann Stieltje's Integral, vector-valued functions and rectifiable curves
[MA6112.2]. Describe the concept of Sequence and series of functions.
[MA6112.3] Describe the concept the functions of several variables.
[MA6112.4] Describe the concept in transformations on Lagrange multipliers method, Jacobian
[MA6112.5] Evaluate the solution of mathematical problem, which make them employable.

C. Program Outcomes and Program Specific Outcomes

[PO.1]. **Critical thinking:** Critically interpret data, write reports and apply the basics of evidence.
[PO.2]. **Effective Communication:** Communicate effectively by writing, connecting people, ideas, books, media and technology.
[PO.3]. **Social Interaction:** Elicit views of others, mediate disagreements and help reach conclusions in group settings.
[PO.4]. **Effective Citizenship:** Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering**.**
[PO.5]. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities.
[PO.6]. **Environment and Sustainability:** Understand the issues of environmental contexts and sustainable development.
[PO.7]. **Self-directed and Life-long Learning:** Acquire the ability to engage in independent and life-long learning in the broadest context socio technological changes.

PROGRAM SPECIFIC OUTCOMES:

[PSO.1]. Describe the basic and advanced Mathematical concepts of Pure and Applied Mathematics.
[PSO.2]. Apply the Mathematical principles to analyze and solve a variety of real-life as well as industry problems.
[PSO.3]. To have necessary skills for the research and developments in theoretical and applied science through seminar, project, and publication.

D. Assessment Rubrics:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Close Book)	20
	Sessional Exam II (Close Book)	20
	Quizzes and Assignment	20
End Term Exam (Summative)	End Term Exam (Close Book)	40
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Quizzes	3 Quizzes (Close Book)	

E. Syllabus

Riemann-Stieltjes Integral: Introduction, existence and properties, integration and differentiation, fundamental theorem of calculus, integration of vector-valued functions, rectifiable curves;

Sequence and Series of Functions: Pointwise and uniform convergence, Cauchy criterion for uniform convergence, Weirstrass M test, Abel and Dirichlet tests for uniform convergence, uniform convergence and continuity, uniform convergence and differentiation, Weierstrass approximation theorem, power series, uniform convergence and uniqueness theorem, Abel theorem, Taylor's theorem.

Functions of Several Variables: Linear transformations, Euclidean space Rn, derivatives in an open subset of Rn, chain rule, partial derivatives, continuously differentiable mapping, Young and Schwarz theorems, Taylor theorem, higher order differentials, explicit and implicit functions, implicit function theorem, inverse function theorem, change of variables, extreme values of explicit functions, stationary values of implicit functions, Lagrange multipliers method, Jacobian and its properties.

Reference Book:

1. W. Rudin, Principles of Mathematical Analysis, 3rd edition, McGraw-Hill, Kogakusha, 2017.
2. H.L. Royden, Real Analysis, Macmillan Pub. Co., Inc. 4th edition, New York, 2009.
3. S.C. Malik and Savita Arora, Mathematical Analysis, New Age International Limited, New Delhi, 2012.
4. T. M. Apostol, Mathematical Analysis, Addison-Wesley Publishing Company, 2008.
5. G. De Barra, Measure Theory and Integration, Wiley Eastern Limited, 2003.
6. R. G. Bartle, The Elements of Real Analysis, Wiley International Edition, 2011.

G. Lecture Plan:

Lec No	Topics	Session Objective	Mode of Delivery (Online/Classroom)	Corresponding CO	Mode of Assessing the Outcome
1	Introduction, aims and objectives of the course and elementary fundamentals of Mathematical Analysis	Know the basics of the course and understand its applications	Lecture	MA6112.1	Assignments Class Quiz Mid-Term I End-Term
2	Riemann-Stieltjes Integral: Introduction	Recall of Riemann integral	Lecture	MA6112.1	
3	existence and properties of integrals	Understand the integrals and related properties.	Lecture	MA6112.1	
4	integration and differentiation	Understand the integration and differentiation in RS.	Lecture	MA6112.1	
5	Exercise and doubts	Know the doubts	Lecture	MA6112.2	
6	fundamental theorem of calculus	Know the basics of the RS integrals	Lecture	MA6112.2	
7	integration of vector-valued functions	Know the basics of the RS integrals	Lecture	MA6112.2	
8	Exercise and doubts	Know the basics of the RS integrals	Lecture	MA6112.2	
9	rectifiable curves;	Know the basics of the RS integrals	Lecture	MA6111.2	
10	Sequence and Series of Functions:	basics of Sequence and Series of Functions	Lecture	MA6112.2	
11	Pointwise and uniform convergence	To understand the concept of Pointwise and uniform convergence.	Lecture	MA6112.2	
12	Pointwise and uniform convergence	To understand the problem.	Lecture	MA6112.2	

13	Cauchy criterion for uniform convergence	Know the concept of Cauchy criterion for uniform convergence.	Lecture	MA6111.3	
14	Weirstrass M test,	Know the basics of the Weirstrass M test,	Lecture	MA6111.3	
15	Abel and Dirichlet tests for uniform convergence	Know the basics of the Abel and Dirichlet tests for uniform convergence	Lecture	MA6111.3	
16	Abel and Dirichlet tests for uniform convergence	To understand the Abel and Dirichlet tests for uniform convergence.	Lecture	MA6111.3	
17	uniform convergence and continuity	Know the concept of limit of the sequences	Lecture	MA6111.3	
18	uniform convergence and differentiation	Know the basics of limit of a sequences.	Lecture	MA6111.3	
19	uniform convergence and uniqueness theorem	Know the concept of convergence sequences.	Lecture	MA6111.3	
20	uniform convergence and uniqueness theorem	Know the concept of convergence sequences	Lecture	MA6111.3	
21	Abel theorem,	To understand the problem.	Lecture	MA6111.3	
22	Tauber theorem	Know the concept of convergence sequences	Lecture	MA6111.3	
23	Functions of Several Variables: Introductions	Know the concept of convergence sequences	Lecture	MA6111.3	
24	Linear transformations	Know the concept of convergence sequences	Lecture	MA6111.3	
25	Euclidean space Rn	Know the concept of convergence sequences	Lecture	MA6111.3 MA6111.5	
26	derivatives in an open subset of Rn,	To understand the problem.	Lecture	MA6111.3	
27	chain rule	Understand the impulse and reaction turbine	Lecture	MA6111.3	
28	partial derivatives	Understand the concept of monotonic sequences.	Lecture	MA6111.3 MA6111.5	
29	continuously differentiable mapping	Understand the concept of monotonic sequences.	Lecture	MA6111.3	Assignments Class Quiz Mid-Term II End-Term
30	Exercise and doubts	To understand the problem.	Lecture	MA6111.3	
31	Exercise and doubts	Understand the concept of monotonic sequences.	Lecture	MA6111.3 MA6111.5	
32	Young and Schwarz theorems	Understand the concept of subsequences.	Lecture	MA6111.3	
32	Taylor theorem, higher order differentials	To understand the problem.	Lecture	MA6111.3 MA6111.5	
33	Taylor theorem, higher order differentials	Understand the concept of subsequences.	Lecture	MA6111.3	
34	explicit and implicit functions	Understand the concept of infinite series	Lecture	MA6111.4	
35	implicit function theorem	To understand the problem.	Lecture	MA6111.4 MA6111.5	
36	inverse function theorem	Know the basics of the infinite series	Lecture	MA6111.4	
37	change of variables	Know the concept of convergence and divergence series.	Lecture	MA6111.4	
38	extreme values of explicit functions	Know the concept of convergence and divergence series.	Lecture	MA6111.4	Assignments Class Quiz End-Term

39	stationary values of implicit functions	Know the concept of convergence and divergence series	Lecture	MA6111.4	
40	stationary values of implicit functions	Know the concept of convergence and divergence series	Lecture	MA6111.4	
41	stationary values of implicit functions	Know the concept of convergence and divergence series	Lecture	MA6111.4	
42	Lagrange multipliers method	Know the concept of convergence and divergence series	Lecture	MA6111.4	
43	Lagrange multipliers method	Know the concept	Lecture	MA6111.4	
44	Lagrange multipliers method	Know the concept	Lecture	MA6111.4	
45	Doubt class	Know the concept	Lecture	MA6111.4 MA6111.5	
46	Jacobian and its properties.	Know the concept of Jacobian and its properties.	Lecture	MA6111.4	
47	Doubt class	Understand the concept of Jacobian and its properties.	Lecture	MA6111.4	
48	Jacobian and its properties.	Understand the concept of Jacobian and its properties.	Lecture	MA6111.4 MA6111.5	
49	Exercise and doubts	Know the concept of Jacobian and its properties.	Lecture	MA6111.4 MA6111.5	

H. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES							CORRELATION WITH PROGRAM SPECIFIC OUTCOMES			
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PSO 1	PSO 2	PSO 3	
MA6112.1	Describe the concept of RS Integral, vector-valued functions and rectifiable curves	1							2	3	3	
MA6112.2	Describe the concept of Sequence and series of functions	1							3	2		
MA6121.3	Describe the concept the functions of several variables.	1			2				2	2	2	
MA6112.4	Describe the concept in transformations on Lagrange multipliers method, Jacobian	1			2				3	1		
MA6112.5	Evaluate the solution of mathematical problem, which make them employable.	1							1	1	2	

MANIPAL UNIVERSITY JAIPUR

School of Basic Sciences

Department of Mathematics and Statistics

Course Hand-out

Differential Equations | MA 6113 | 3 Credits | 2 1 0 3

Session: Aug. – Feb.

Faculty: Dr. Garima Agarwal

A. **Introduction:** This course is offered by Dept. of Mathematics and Statistics, targeting students who wish to pursue research & development in industries or higher studies. The aim of the department of Mathematics and Statistics is to produce highly, well qualified and motivated graduates possessing fundamental knowledge of mathematics who can provide leadership and service to our nation and world. The main focus of the department of Mathematics and Statistics is to be recognized as a trendsetter of its undergraduate programme through focus on core competencies, multidisciplinary collaborations, and quality in education.

B. **Course Outcomes:** At the end of the course, students will be able

[6113.1]. To understand the concept of approximate solutions of differential equations which makes them employable in the relevant field.

[6113.2]. To solve the initial value problems by different methods

[6113.3]. To understand the concept homogeneous linear system

[6113.4]. To understand the Poincore- Bendixson Theory

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

PROGRAM OUTCOMES

[PO.1]. Critical Thinking: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.

[PO.2]. Effective Communication: Speak, read, write and listen clearly in person and through electronic media in English and in one Indian language, and make meaning of the world by connecting people, ideas, books, media and technology

[PO.3]. Social Interaction: Elicit views of others, mediate disagreements and help reach conclusions in group settings

[PO.4]. Effective Citizenship: Demonstrate empathetic social concern and equity centered national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering.

[PO.5]. Ethics: Recognize different value systems including your own, understand the moral dimensions of your decisions, and accept responsibility for them

[PO.6]. Environment and Sustainability: Understand the issues of environmental contexts and sustainable development.

[PO.7]. Self-directed and Life-long Learning: Acquire the ability to engage in independent and life-long learning in the broadest context socio-technological changes

PROGRAM SPECIFIC OUTCOMES

PSO.1 Describe the basic and advanced Mathematical concepts of Pure and Applied Mathematics.

PSO.2 Apply the Mathematical principles to analyze and solve a variety of real-life as well as industry problems.

PSO.3 To have necessary skills for the research and developments in theoretical and applied science through seminar, project, and publication.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Close Book)	20
	Sessional Exam II (Close Book)	20
	In class Quizzes	10
End Term Exam (Summative)	End Term Exam (Open Book)	50
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	

A. SYLLABUS

Preliminaries: ε-approximate solution, Cauchy-Euler construction of an ε-approximate solution of an initial value problem, Equicontinuous family of functions; Basic Theorems: Ascoli-Arzela lemma, Cauchy-Peano existence theorem, Lipschitz condition, Picards-Lindelof existence and uniqueness theorem for dy/dt=f(t,y), Solution of initial-value problems by picards method; Dependence of Solutions on Initial Conditions: Linear systems, Matrix method for homogeneous first order system of linear differential equations; Fundamental Set of Solutions: Fundamental matrix of solutions, Wronskian of solutions, basic theory of the homogeneous linear system, Abel-Liouville formula, nonhomogeneous linear system. Strum theory, self-adjoint equations of the second order, Abel formula, Strum separation theorem, Strum fundamental comparison theorem, nonlinear differential systems, phase plane, path, critical points; Poincore- Bendixson Theory: Autonomous systems, isolated critical points, path approaching a critical point, Path entering a critical point, types of critical points, enter, saddle points, spiral points, node points, stability of critical points, Asymptotically stable points, unstable points, critical points and paths of linear systems, almost linear systems, nonlinear conservative dynamical system, dependence on a parameter, Liapunov direct method, limit cycles, periodic solutions, Bendixson nonexistence criterion, poincore- Bendixson theorem, index of a critical point, Strum-Liouville problems, orthogonality of characteristic functions.

References:

1. E.A. Coddington and N. Levinson, Theory of Ordinary Differential Equations, Tata McGraw Hill, 2000.
2. S.L. Ross, Differential Equations, John Wiley and Sons Inc., New York, 2004.
3. W.E. Boyce and R.C. Diprima, Elementary Differential Equations and Boundary Value Problems, John Wiley and Sons, Inc., New York, 4th edition, 2012.
4. G.F. Simmon, Differential Equations, Tata McGraw Hill, New Delhi, 2016.

A. Lecture Plan:

S.No	Major Topic	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode of assessing COs
1.	Approximate solutions	Introduction	Understand POS, PSO and COS	Lecture	NA	NA
2.		ε-approximate solution	concept of approximate solutions of differential equations	Lecture	6113.1	Mid Term I quiz and end term
3.		Cauchy-Euler construction	concept of approximate solutions of differential equations	Lecture	6113.1	Mid Term I quiz and end term
4.		Equicontinuous family of functions	concept of approximate solutions of differential equations	Lecture	6113.1	Mid Term I quiz and end term
5.		Ascoli-Arzela lemma	concept of approximate solutions of differential equations	Lecture	6113.1	Mid Term I quiz and end term
6.		Cauchy-Peano existence theorem	concept of approximate solutions of differential equations	Lecture	6113.1	Mid Term I quiz and end term

7.		Lipschitz condition	concept of approximate solutions of differential equations	Lecture	6113.1	Mid Term I quiz and end term
8.		Picards-Lindelof existence and uniqueness theorem	concept of approximate solutions of differential equations	Lecture	6113.1	Mid Term I quiz and end term
9.	Initial value problems	initial-value problems	solve the initial value problems	Lecture	6113.2	Mid Term I quiz and end term
10.		picards method	solve the initial value problems	Lecture	6113.2	Mid Term I quiz and end term
11.		Solutions on Initial Conditions	solve the initial value problems	Lecture	6113.2	Mid Term I quiz and end term
12.		Linear systems	solve the initial value problems	Lecture	6113.2	Mid Term I quiz and end term
13.	Homogeneous linear system	Matrix method for homogeneous first order system of linear differential equations	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
14.		Fundamental matrix of solutions	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
15.		Wronskian of solutions	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
16.		basic theory of the homogeneous linear system	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
17.		Abel-Liouville formula	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
18.		nonhomogeneous linear system	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
19.		Strum theory	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
20.		self-adjoint equations of the second order	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
21.		Abel formula	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
22.		Strum separation theorem	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
23.		Strum fundamental comparison theorem	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
24.		nonlinear differential systems	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term

25.		phase plane	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
26.		critical points	the concept homogeneous linear system	Lecture	6113.3	Mid Term I quiz and end term
27.	Poincore-Bendixson Theory	Poincore- Bendixson Theory	Poincore-Bendixson Theory	Lecture	6113.4	Mid Term II, quiz and end term
28.		Autonomous systems	Poincore-Bendixson Theory	Lecture	6113.4	Mid Term II, quiz and end term
29.		isolated critical points	Poincore-Bendixson Theory	Lecture	6113.4	Mid Term II quiz and end term
30.		Path entering a critical point	Poincore-Bendixson Theory	Lecture	6113.4	Mid Term II quiz and end term
31.		types of critical points	Poincore-Bendixson Theory	Lecture	6113.4	Mid Term II quiz and end term
32.		saddle points	Poincore-Bendixson Theory	Lecture	6113.4	Mid Term II quiz and end term
33.		spiral points	Poincore-Bendixson Theory	Lecture	6113.4	Mid Term II quiz and end term
34.		node points	Poincore-Bendixson Theory	Lecture	6113.4	Mid Term II quiz and end term
35.		stability of critical points	Poincore-Bendixson Theory	Lecture	6113.4	Mid Term II, quiz and end term
36.		Asymptotically stable points	Poincore-Bendixson Theory	Lecture	6113.4	quiz and end term
37.		unstable points	Poincore-Bendixson Theory	Lecture	6113.4	quiz and end term
38.		critical points and paths of linear systems	Poincore-Bendixson Theory	Lecture	6113.4	quiz and end term
39.		nonlinear conservative dynamical system	Poincore-Bendixson Theory	Lecture	6113.4	quiz and end term
40.			Poincore-Bendixson Theory	Lecture	6113.4	quiz and end term
41.		dependence on a parameter	Poincore-Bendixson Theory	Lecture	6113.4	quiz and end term
42.		Liapunov direct method	Poincore-Bendixson Theory	Lecture	6113.4	Mid Term I quiz and end term
43.		limit cycles, periodic solutions	Poincore-Bendixson Theory	Lecture	6113.4	
44.		Bendixson nonexistence criterion	Poincore-Bendixson Theory	Lecture	6113.4	

45.		poincore- Bendixson theorem	Poincore-Bendixson Theory	Lecture	6113.4	
46.		index of a critical point	Poincore-Bendixson Theory	Lecture	6113.4	
47.		Strum-Liouville problems	Poincore-Bendixson Theory	Lecture	6113.4	
48.		orthogonality of characteristic functions	Poincore-Bendixson Theory	Lecture	6113.4	

B. Course Articulation Matrix: (Mapping of COs with POs)

O	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES							CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PSO 1	PSO 2	PSO 3
A 6113.1	To understand the concept of approximate solutions of differential equations	**1**	**3**					**3**		**1**	
A 6113.2	To solve the initial value problems by different methods			**1**				**2**	**1**		**1**
A 6113.3	To understand the concept homogeneous linear system	**3**				**1**				**1**	
A 6113.4	To understand the Poincore- Bendixson Theory		**2**		**1**				**1**		**1**

1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

C. Course Outcome Attainment Level Matrix:

CO	STATEMENT	ATTAINMENT OF PROGRAM OUTCOMES **THRESHOLD VALUE: 40%**									
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	P
MA 6113.1	To understand the concept of approximate solutions										
MA 6113.2	To solve the initial value problems by different methods										
MA 6113.3	To understand the concept homogeneous linear system										
MA 6113.4	To understand the Poincore-Bendixson Theory										

0- No Attainment; 1- Low Attainment; 2- Moderate Attainment; 3- Substantial Attainment

MANIPAL UNIVERSITY JAIPUR

School of Basic Sciences

Department of Mathematics & Statistics
Course Hand-out

Adavanced Complex Analysis | MA 6114 | 4 Credits | 3 1 0 4

Session: July 20–Dec 20 | Faculty: Dr. Ram Naresh Saraswat | Class: M.Sc (Mathematics)/I Sem

A. **Introduction:** This course is offered by Dept. of Mathematics and Statistics for M.Sc. Mathematics students, targeting students who wish to pursue research & development in industries or higher studies in field of Mathematics and Engineering. Offers in depth knowledge of Weierstrass' factorization theorem, Gamma function and its properties, Stirling formula integral version of gamma function, Riemann Zeta function, Analytic Continuation Entire Function: Growth and order of an entire function, an estimate of number of zeros, exponent of convergence, Borel theorem, Bieberbach conjecture and the "1/4 theorem for a better learning.

B. **Course Outcomes:** At the end of the course, students will be able to

[6114.1] Explain the fundamental concepts of complex analysis and their role in modern mathematics and applied contexts.

[6114.2] Demonstrate accurate and efficient use of complex analysis techniques

[6114.3] Demonstrate capacity for mathematical reasoning through analyzing, proving and explaining concepts from complex analysis

[6114.4] Produce counter examples illustrating the mathematical concepts and applications to Employability, Entrepreneurship and Skill Enhancement

PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

PO1	**Critical thinking:** Critically interpret data, write reports and apply the basics of evidence.
PO2	**Effective Communication:** Communicate effectively by writing, connecting people, ideas, books, media, and technology.
PO3	**Social Interaction:** Elicit views of others, mediate disagreements and help reach conclusions in group settings.
PO4	**Effective Citizenship:** Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering.
PO5	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities.
PO6	**Environment and Sustainability:** Understand the issues of environmental contexts and sustainable development.

PO7 **Self-directed and Life-long Learning:** Acquire the ability to engage in independent and life-long learning in the broadest context socio technological changes.

PSO1 Describe the basic and advanced Mathematical concepts of Pure and Applied Mathematics.

PSO2 Apply the Mathematical principles to analyze and solve a variety of real-life as well as industry problems.

PSO3 To have necessary skills for the research and developments in theoretical and applied science through seminar, project, and publication.

C. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Closed Book)	20
	Sessional Exam II (Closed Book)	20
	In class Quizzes and Assignments , Activity feedbacks (Accumulated and Averaged)	20
End Term Exam (Summative)	End Term Exam (Close Book)	40
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	Students who misses a class will have to report to the teacher about the absence. A makeup assignment on the topic taught on the day of absence will be given which has to be submitted within a week from the date of absence. No extensions will be given on this. The attendance for that particular day of absence will be marked blank, so that the student is not accounted for absence. These assignments are limited to a maximum of 5 throughout the entire semester.	
Homework/ Home Assignment/ Activity Assignment (Formative)	There are situations where a student may have to work in home, especially before a flipped classroom. Although these works are not graded with marks. However, a student is expected to participate and perform these assignments with full zeal since the activity/ flipped classroom participation by a student will be assessed and marks will be awarded.	

D. SYLLABUS: MA6114: Advanced Complex Analysis

Integral Functions: Factorization of an integral function, Weierstrass primary factors, Weierstrass' factorization theorem, Gamma function and its properties, Stirling formula integral version of gamma function, Riemann Zeta function, Riemann functional equation, Mittag-Leffler theorem, Runge theorem; Analytic Continuation: Natural boundary, uniqueness of direct analytic continuation, uniqueness of analytic continuation along a curve, power series method of analytic continuation, Schwarz reflection principle, germ of an analytic function, monodromy theorem and its consequences, Harmonic functions on a disk, Poisson kernel, Dirichlet problem for a unit disc, Harnack inequality, Harnack theorem, Dirichlet region, Green function, Canonical product, Jensen formula, Poisson-Jensen formula, Hadamard three circles theorem; Entire Function: Growth and order of an entire function, an estimate of number of zeros, exponent of convergence, Borel theorem, Hadamard factorization theorem, range of an analytic function, Bloch theorem, Schottky theorem, Little Picard theorem, Montel Caratheodory theorem, Great Picard theorem, univalent functions, Bieberbach conjecture and the "1/4 theorem" .

References:

1. S. Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, 2011.
2. 2. J.B. Conway, Functions of one Complex variable, Springer-Verlag, Narosa Publishing House, 2002.

3. H.S. Kasana, Complex Variable Theory and Applications, PHI Learning Private Ltd, 2011.
4. M. J. Ablowitz and A.S. Fokas, Complex Variables: Introduction and Applications, Cambridge University Press, South Asian Edition, 2003.
5. R. V. Churchill and James Ward Brown, Complex Variables and Applications, McGraw-Hill Publishing Company, 2013.
6. L.V. Ahlfors, Complex Analysis, Mc-Graw Hill, 1979.

E. Lecture Plan:

LEC NO	TOPICS	Session Outcome	Mode of Delivery	Corresponding CO	Mode of assessing the outcome
1	Introduction and Complex analysis	Understanding the basics of Complex Analysis	Lecture	MA6114.1	MTE-I Assignment & Quiz Test ETE
2	Integral Function – Introduction	Discuss Introduction of Integral Function	Lecture	MA6114.1	MTE-I Assignment & Quiz Test ETE
3-4	Factorization of an integral function	Describe integra function and problems	Lecture	MA6114.1	MTE-I Assignment & Quiz Test ETE
5-6	Weierstrass primary factors, Weierstrass' factorization theorem	Describe statement of Weierstrass primary factors with problem	Lecture	MA6114.1	MTE-I Assignment & Quiz Test ETE
7	Tutorial				
8-10	Gamma function and its properties, Stirling formula integral version of gamma function	Discuss Gamma function and Stirling formula with examples	Lecture	MA6114.1	MTE-I Assignment & Quiz Test ETE
11-13	Riemann Zeta function, Riemann functional equation	Discuss Riemann Zeta function and equations with examples.	Lecture	MA6114.1	MTE-I Assignment & Quiz Test ETE
14	Tutorial				
15-18	Mittag-Leffler theorem, Runge theorem; Analytic Continuation: Natural boundary, uniqueness of direct analytic continuation	Explain Mittag-Leffler theorem, Runge theorem and Analytic function	Lecture	MA6114.2	MTE-I Assignment & Quiz Test ETE
19-20	Uniqueness of analytic continuation along a curve, power series method of analytic continuation	Describe Uniqueness of analytic and power series	Lecture	MA6114.2	MTE-I Assignment & Quiz Test ETE
21-23	Schwarz reflection principle, germ of an analytic function, monodromy theorem and its consequences,	Describe and examples	Lecture	MA6114.3	MTE-II Assignment & Quiz Test ETE
24	Tutorial				

25-27	Harmonic functions on a disk, Poisson kernel, Dirichlet problem for a unit disc,	Describe Harmonic functions, Poisson kernel, Dirichlet problem	Lecture	MA6114.3	MTE-II Assignment & Quiz Test ETE
28-29	Harnack inequality, Harnack theorem, Dirichlet region, Green function, Canonical product,	Explain Harnack inequality, theorem and green theorem	Lecture	MA6114.4	MTE-II Assignment & Quiz Test ETE
30-33	Jensen formula, Poisson-Jensen formula, Hadamard three circles theorem;	Describe Jensen Poisson formula with theorems and examples	Lecture	MA6114.4	MTE-II Assignment & Quiz Test ETE
34	Tutorial				
35-36	Entire Function: Growth and order of an entire function, an estimate of number of zeros,	Describe Entire Function their propertirs and examples	Lecture	MA6114.4	MTE-II Assignment & Quiz Test ETE
37-38	Exponent of convergence, Borel theorem, Hadamard factorization theorem	Explain convergence, Borel theorem, Hadamard and problems	Lecture	MA6114.4	MTE-II Assignment & Quiz Test ETE
39-40	Range of an analytic function, Bloch theorem, Schottky theorem,	Explain analytic function, Bloch theorem, Schottky theorem, with proof and examples	Lecture	MA6114.4	MTE-II Assignment & Quiz Test ETE
41	Tutorial				
42-43	range of an analytic function, Bloch theorem, Schottky theorem,	Discuss theorems and examples	Lecture	MA6114.4	ETE Assignment & Quiz Test
44-45	Little Picard theorem, Montel Caratheodory theorem	Discuss theorems and examples	Lecture	MA6114.4	ETE Assignment & Quiz Test
46-47	Great Picard theorem, univalent functions, Bieberbach conjecture and the "1/4 theorem" .	Discuss theorems and examples	Lecture	MA6114.4	ETE Assignment & Quiz Test
48	Tutorial				

F. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES							CORRELATION WITH PROGRAM SPECIFIC OUTCOMES			
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PSO 1	PSO 2	PSO 3	PSO 4
[6114.1]	Explain the fundamental concepts of complex analysis and their role in modern mathematics and applied contexts.	2					1		2	2	1	1
[6114.2]	Demonstrate accurate and efficient use of complex analysis techniques	3		1				2	3	2	1	1
[6114.3]	Demonstrate capacity for mathematical reasoning through analyzing, proving and explaining concepts from complex analysis	2				2			3	2	1	1
[6114.4]	Produce counter examples illustrating the mathematical concepts and applications to Employability, Entrepreneurship and Skill Enhancement	2		1		1		1	2	2	1	1

1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Basic Sciences

Department of Mathematics & Statistics

Course Hand-out

Mathematical Statistics| MA6115 | 4 Credits | 3 1 0 4

Session: July20 –Dec 20 | Faculty: Dr. Alok Bhargava | Class: M. Sc (Maths) I Sem

A. Introduction: This course is offered by Dept. of Mathematics and Statistics for M. Sc. (Mathematics) students, targeting students who wish to pursue research & development in industries or higher studies in field of Mathematics and Statistics. This course Offers in depth knowledge of Probability, Random variables, Mathematical Expectations, Moments and Moment generating function, Probability Distributions, Testing of Hypothesis and Tests of Significance. Students are expected to have background knowledge of basic concepts of Probability and functions.

B. Course Outcomes: At the end of the course, students will be able to

[6115.1] Describe the basic concepts of Probability and apply them to solve real world problems which enhance their analytical skills.
[6115.2] Describe the concept and properties of Random variables & Probability functions.
[6115.3] Describe the concept and properties Probability Distributions and their applications.
[6115.4] Describe the concepts and applicability of Testing of Hypothesis, Tests of Significance, and their applications, which enhance their employability skills.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

[PO1] Critical Thinking: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.

[PO2] Effective Communication: Speak, read, write and listen clearly in person and through electronic media in English and in one Indian language, and make meaning of the world by connecting people, ideas, books, media and technology.

[PO3] Social Interaction: Elicit views of others, mediate disagreements and help reach conclusions in group settings.

[PO4] Effective Citizenship: Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering.

[PO5] Ethics: Recognize different value systems including your own, understand the moral dimensions of your decisions, and accept responsibility for them.

[PO6] Environment and Sustainability: Understand the issues of environmental contexts and sustainable development.

[PO7] Self-directed and Life-long Learning: Acquire the ability to engage in independent and life-long learning in the broadest context socio-technological changes

PSO.1 Describe the basic and advanced Mathematical concepts of Pure and Applied Mathematics.
PSO.2 Apply the Mathematical principles to analyze and solve a variety of real-life as well as industry problems.
PSO.3 To have necessary skills for the research and developments in theoretical and applied science through seminar, project, and publication.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I	20
	Sessional Exam II	20
	In class Quizzes and Assignments, Activity feedbacks (Accumulated and Averaged)	20
End Term Exam (Summative)	End Term Exam	40
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	

E. SYLLABUS:

Probability: Definition and various approaches of probability, addition theorem, Boole inequality, conditional probability and multiplication theorem, independent events, mutual and pairwise independence of events, Bayes theorem and its applications; Random Variable and Probability Functions: Definition and properties of random variables, discrete and continuous random variables, probability mass and density functions, distribution function, concepts of bivariate random variable: joint, marginal and conditional distributions, cumulative generating function; Mathematical Expectation: Definition and its properties. variance, covariance, moment generating function- Definitions and their properties; Discrete Distributions: Uniform, Bernoulli, Binomial, Poisson and Geometric distributions with their properties; Continuous Distributions: Uniform, Normal, Exponential, Beta and Gamma distributions with their properties; Testing of Hypothesis: Parameter and statistic, sampling distribution and standard error of estimate, null and alternative hypotheses, simple and composite hypotheses, critical region, Level of significance, one tailed and two tailed tests, two types of errors; Tests of Significance: Large sample tests for single mean, single proportion, difference between two means and two proportions.

References:

1. S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Co., 3rd edition, New Delhi, 2008.
2. V.K. Rohtagi and A.K.M. E Saleh, An Introduction to Probability & Statistics, John Wiley & Sons, 2011.
3. P. L. Meyer, Introductory Probability and Statistical Applications, Addison-Wesley, 2017.
4. W. Feller, An Introduction to Probability Theory and Its Applications, Vol. 1, 3rd edition, John Wiley, 2005.
5. P. Mukhopadhyay, Mathematical Statistics, Books & Allied (P) Ltd., 2009.
6. G. Casella, and R.L. Berger, Statistical Inference, 2nd edition. Thomson Duxbury, 2002.
7. R.V. Hogg, and E.A. Tanis, Probability and Statistical Inference, 9th edition, Macmillan Publishing Co. Inc., 2014.

F. Lecture Plan:

Lec. No.	TOPICS	Session Outcome	Mode of Delivery	Corresponding CO	Mode of assessing the outcome
1	**Introduction to the course and Course Hand-out briefing**	Understanding the course and its importance	Lecture		Interaction
2	**Definition and various approaches of probability**	Knowledge of basic definitions of probability	Lecture	MA6115.1	MTE 1, Assignment, ETE
3	Addition theorem, Boole inequality	Describes the way of calculating probability	Lecture	MA6115.1	MTE 1, Assignment, ETE
4	Conditional probability and	Describes the way of	Lecture	MA6115.1	MTE 1,

	multiplication theorem	calculating probability			Assignment, ETE
5	Mutual and pairwise independence of events	Describes the way of calculating probability	Lecture	MA6115.1	MTE 1, Assignment, ETE
6	Bayes theorem and its applications	Describes the way of calculating probability	Lecture	MA6115.1	MTE 1, Assignment, ETE
7	**Definition and properties of Random variables**	Understand the concept of Random variable	Lecture	MA6115.2	MTE 1, Assignment, ETE
8	Discrete and continuous random variables, probability mass and density functions	Understand the concept of probability mass and density functions	Lecture	MA6115.2	MTE 1, Assignment, ETE
9	Distribution function	Understand the concept of distributive function	Lecture	MA6115.2	MTE 1, Assignment, ETE
10-11	Joint, marginal and conditional distributions	Understand the concept of bivariate random variable	Lecture	MA6115.2	MTE 1, Assignment, ETE
12	Cumulative generating function	Understand the concept of cumulative generating function	Lecture	MA6115.2	MTE 1, Assignment, ETE
13	Mathematical Expectation: Definition and its properties	Understand the concept of Expectation	Lecture	MA6115.2	MTE 1, Assignment, ETE
14	Variance, covariance	Understand the concept of variance and covariance	Lecture	MA6115.2	MTE 1, Assignment, ETE
15	Moment generating function-Definitions and their properties	Understand the concept of moment generating function	Lecture	MA6115.2	MTE 1, Assignment, ETE
16	**Probability Distributions: Discrete and Continuous**	Understand the concept of probability distributions	Lecture	MA6115.3	MTE 2, Assignment, ETE
17	Bernoulli Distribution	Understand the concept of Bernoulli's distribution	Lecture	MA6115.3	MTE 2, Assignment, ETE
18-19	Binomial Distribution	Understand the concept of Binomial distribution	Lecture	MA6115.3	MTE 2, Assignment, ETE
20-21	Poisson Distribution	Understand the concept of Poisson distribution	Lecture	MA6115.3	MTE 2, Assignment, ETE
22	Uniform Distribution (Discrete)	Understand the concept of Uniform distribution	Lecture	MA6115.3	MTE 2, Assignment, ETE
23	Geometric Distribution	Understand the concept of Geometric distribution	Lecture	MA6115.3	MTE 2, Assignment, ETE
24	Uniform Distribution (Continuous)	Understand the concept of Uniform distribution	Lecture	MA6115.3	MTE 2, Assignment, ETE
25 - 28	Normal Distribution	Understand the concept of Normal distribution	Lecture	MA6115.3	MTE 2, Assignment, ETE
29	Exponential distribution	Understand the concept of exponential distribution	Lecture	MA6115.3	MTE 2, Assignment, ETE
30	Beta and Gamma distributions	Understand the concept of Beta and Gamma distributions	Lecture	MA6115.3	MTE 2, Assignment, ETE
31	**Testing of Hypothesis**	Understand the concept of Hypothesis and Testing of Hypothesis	Lecture	MA6115.4	Assignment, ETE
32	Sampling distribution	Understand the concept of Sampling distribution	Lecture	MA6115.4	Assignment, ETE
33	Standard error of estimate	Understand the concept of Standard error of estimate	Lecture	MA6115.4	Assignment, ETE
34	Null and alternative hypotheses	Understand the concept of Null and alternative hypotheses	Lecture	MA6115.4	Assignment, ETE

35-36	Simple and composite hypotheses	Understand the concept of Simple and composite hypotheses	Lecture	MA6115.4	Assignment, ETE
37	Critical region	Understand the concept of Critical region	Lecture	MA6115.4	Assignment, ETE
38	Level of significance	Understand the concept of significance and Level of significance	Lecture	MA6115.4	Assignment, ETE
39-41	One tailed and two tailed tests	Describe the concept of Level of significance	Lecture	MA6115.4	Assignment, ETE
42	Two types of errors	Describe the concept of errors	Lecture	MA6115.4	Assignment, ETE
43	Tests of Significance	Understand the concept of Tests of significance	Lecture	MA6115.4	Assignment, ETE
44-47	Large sample tests for single mean	Describe Large sample tests for single mean	Lecture	MA6115.4	Assignment, ETE
48	Single proportion	Describe the concept of Single proportion	Lecture	MA6115.4	Assignment, ETE
49	Difference between two means and two proportions	Understand the difference between two means and two proportions	Lecture	MA6115.4	Assignment, ETE

G. Course Articulation Matrix: (Mapping of COs with POs)

CO	**STATEMENT**	CORRELATION WITH PROGRAM OUTCOMES							CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PSO 1	PSO 2	PSO 3
MA6115.1	Describe the basic concepts of Probability and apply them to solve real world problems which enhance their analytical skills.	2		1				1	3	3	
MA6115.2	Describe the concept and properties of Random variables & Probability functions.	1						1	3	3	
MA6115.3	Describe the concept and properties Probability Distributions and their applications.	2						1	3	3	2
MA6115.4	Describe the concepts and applicability of Testing of Hypothesis, Tests of Significance, and their applications, which enhance their employability skills.	2		1				1	3	3	2

1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Basic Sciences

Department of Mathematics & Statistics
Course Hand – Out

Topology- I | MA6116 | 3 Credits | 2 1 0 3

Session: Aug-Dec 2020 | Faculty: Dr. Mahesh Kumar Dubey |Class: M. Sc. I Sem

A. Introduction: -

This course is offered by Department of Mathematics & Statistics as a regular course, targeting students who wish to pursue M.Sc., in Mathematics. It offers basic/introductory as well as advanced knowledge of topology and their applications, which are helpful in advanced study of Mathematics and Research. This course deal with general introduction to topological spaces, continuous functions, interior, closure, subspaces, bases, subbases and its constructions. It also includes the properties of general topological spaces like compactness, connectedness and separation axioms. Students are expected to have the deep knowledge of set theoretic concepts, real analysis and metric space.

B. Course Outcomes: At the end of the course, students will be able to

6116.1	Understand the concepts of topological space and their role in mathematics.
6116.2	Understand the basic terms in topology as open sets, closed sets, interior, closure, frontier, boundary point, basis or by a basis of neighbourhoods at each point, and what it means for a function to be continuous.
6116.3	Develop the skills to define topological space in terms of neighbourhood system and Kuratowski closure (interior) operator, relative (induced) topology which make them employable in the relevant field.
6116.4	Understand the definition and properties of connected spaces, locally connected spaces, compact spaces, locally compact spaces and countability of topological space.
6116.5	Enhanced the skill in checking the topological properties like connectedness, compactness and separation axioms

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

[PO1]: Critical thinking: Critically interpret data, write reports and apply the basics of evidence

[PO2]: **Effective Communication**: Communicate effectively by writing, connecting people, ideas, books, media, and technology

[PO3]: **Social Interaction**: Elicit views of others, mediate disagreements and help reach conclusions in group settings

[PO4]: **Effective Citizenship**: Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering

[PO5] Ethics: Apply ethical principles and commit to professional ethics and responsibilities.

[PO6]. Environment and Sustainability: Understand the issues of environmental contexts and sustainable development

[PO7] Self-directed and Life-long Learning: Acquire the ability to engage in independent and life-long learning in the broadest context socio technological changes

[PSO1]: Describe the basic and advanced Mathematical concepts of Pure and Applied Mathematics.

[PSO2]: Apply the Mathematical principles to analyze and solve a variety of real-life as well as industry problems.

[PSO3]: To have necessary skills for the research and developments in theoretical and applied science through seminar, project, and publication.

D. SYLLABUS: -

Basic Concepts: Definition and examples of topological spaces, comparison of topologies on a set, intersection and union of topologies on a set, neighbourhoods, Interior point and interior of a set , closed set as a complement of an open set , adherent point and limit point of a set, closure of a set, derived set, properties of closure operator, boundary of a set , dense subsets, interior, exterior and boundary operators, alternative methods of defining a topology in terms of neighbourhoods system and Kuratowski closure operator, relative (induced) topology, base and subbase for a topology, Base for Neighbourhoods system, continuous functions, open and closed functions, homeomorphism. connectedness and its characterization; Connected Spaces: connected subsets and their properties, continuity and connectedness, components, locally connected spaces; Compact Spaces : Compact spaces and subsets, compactness in terms of finite intersection property, continuity and compact sets, basic properties of compactness, closeness of compact subset and a continuous map from a compact space into a Hausdorff and its consequence, sequentially and countably compact sets, Local compactness and one point compactification; Separation Axioms: First countable, second countable and separable spaces, Hereditary and topological property, countability of a collection of disjoint open sets in separable and second countable spaces, Lindelof theorem, T0, T1, T2 (Hausdorff) separation axioms, their characterization and basic properties.

E. TEXTBOOKS: -

1. K. Chandrasekhara Rao, Topology, Narosa Publishing House Delhi, 2009.
2. K.D. Joshi, Introduction to General Topology, Wiley Eastern Ltd, 2006.

F. REFERENCE BOOKS: -

1. C.W. Patty, Foundation of Topology, Jones & Bertlett, 2009.
2. Fred H. Croom, Principles of Topology, Cengage Learning, 2009.
3. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 1983.
4. J. R. Munkres, Topology, Pearson Education Asia, 2002.
5. W.J. Pervin, Foundations of General Topology, Academic Press Inc. New York, 2014.

G. Lecture Plan:

Lect. No.	Topic	Session Outcome	Mode of delivery	Corresponding CO	Mode of Assessing CO
1	Introduction and Course Hand-out briefing	To acquaint and clear teachers' expectations and understand student expectations	Lecture/ Interaction	--	N/A
2	Introduction of topology and topological spaces with their examples	Understand what topology and topological space is actually	Lecture	MA6116.1	Mid Term-I, Quiz & End Term
3	Problem solving	Problem solving technique	Tutorial	MA6116.1	Mid Term-I, Quiz & End Term
4	Comparison of topologies on a set,	Understand Set theoretic operations of topological space	Lecture	MA6116.1	Mid Term-I, Quiz & End Term

	intersection and union of topologies on a set				
5	Introduction of open set, closed set, interior and closure points.	Understand what open set, closed set, interior and closure points. is actually	Lecture	MA6116.1 & MA6116.2	Mid Term-I, Quiz & End Term
6	Problem solving	Problem solving technique	Tutorial	MA6116.1 & MA6116.2	Mid Term-I, Quiz & End Term
7	Introduction of adherent point and limit point of a set, closure of a set, derived set,	Understand the concepts of adherent point and limit point of a set, closure of a set, derived set.	Lecture	MA6116.1& MA6116.2	Mid Term-I, Quiz & End Term
8	boundary of a set, dense subsets, interior, exterior and boundary points of a set	Understand the concepts of boundary of a set, dense subsets, interior, exterior and boundary points of a set	Lecture	MA6116.1& MA6116.2	Mid Term-I, Quiz & End Term
9	Problem solving	Problem solving technique	Tutorial	MA6116.1 & MA6116.2	Mid Term-I, Quiz & End Term
10	neighbourhoods, Interior point and interior of a set	Understand the concepts of neighbourhoods, Interior point and interior of a set	Lecture	MA6116.1& MA6116.2	Mid Term-I, Quiz & End Term
11	Base and subbase of topological space	Understand the concepts of Base and subbase of topological space	Lecture	MA6116.1& MA6116.2	Mid Term-I, Quiz & End Term
12	Problem solving	Problem solving technique	Tutorial	MA6116.1 & MA6116.2	Mid Term-I, Quiz & End Term
13	Interior (closure) operator, exterior and boundary operators,	Understand Principles of Interior (closure) operator, exterior and boundary operators	Lecture	MA6116.1& MA6116.3	Mid Term-I, Quiz & End Term
14	Defining a topology in terms of neighbourhood system and Kuratowski closure (Interior) operator, relative (induced) topology	Understand and implementation of topology in terms of neighbourhood system and Kuratowski closure (Interior) operator, relative (induced) topology	Lecture	MA6116.1& MA6116.3	Mid Term-I, Quiz & End Term
15	Problem solving	Problem solving technique	Tutorial	MA6116.1 & MA6116.3	Mid Term-I, Quiz & End Term
			FIRST SESSIONAL EXAM		
16	continuous functions, open and closed functions, homeomorphism of topological spaces	Understand the concepts of continuous functions, open and closed functions, homeomorphism of topological spaces	Lecture	MA6116.1& MA6116.3	Mid Term-II, Quiz & End Term
17	Connected Spaces: connected subsets and their properties	Understand the concepts of Connected Spaces: connected subsets and their properties	Lecture	MA6116.1, MA6116.4 & MA6116.5	Mid Term-II, Quiz & End Term

18	Problem solving	Problem solving technique	Tutorial	MA6116.1, MA6116.4 & MA6116.5	Mid Term-II, Quiz & End Term
19-20	Continuity and connectedness, components, locally connected spaces;	Understand Continuity and connectedness, components, locally connected spaces;	Lecture	MA6116.1, MA6116.4 & MA6116.5	Mid Term-II, Quiz & End Term
21	Problem solving	Problem solving technique	Tutorial	MA6116.1 & MA6116.4	Mid Term-II, Quiz & End Term
22-23	Compact spaces and subsets, compactness in terms of finite intersection property, continuity and compact sets	Understand the notion of Compact topological space	Lecture	MA6116.1, MA6116.4 & MA6116.5	Mid Term-II, Quiz & End Term
24	Problem solving	Problem solving technique	Tutorial	MA6116.1, MA6116.4 & MA6116.5	Mid Term-II, Quiz & End Term
25-26	basic properties of compactness, closeness of compact subset and a continuous map of compact space	Understand the basic properties of compactness	Lecture	MA6116.1, MA6116.4 & MA6116.5	Mid Term-II, Quiz & End Term
27	Problem solving	Problem solving technique	Tutorial	MA6116.1, MA6116.4 & MA6116.5	Mid Term-II, Quiz & End Term
28-29	sequentially and countably compact sets, Local compactness and one-point compactification;	Understand the sequentially and countably compact sets, Local compactness and one-point compactification	Lecture	MA6116.1, MA6116.4 & MA6116.5	Mid Term-II, Quiz & End Term
30	Problem solving	Problem solving technique	Tutorial	MA6116.1, MA6116.4 & MA6116.5	Mid Term-II, Quiz & End Term
		SECOND SESSIONAL EXAM			
31-32	First countable, second countable and separable spaces	Understand countable axioms in topological space	Lecture	MA6116.1, MA6116.4 & MA6116.5	Quiz & End Term
33	Problem solving	Problem solving technique	Tutorial	MA6116.1, MA6116.4 & MA6116.5	Quiz & End Term
34-35	Lindelof theorem, Hereditary and topological property, countability of a collection of disjoint open sets in separable	Understand countable axioms in topological space	Lecture	MA6116.1, MA6116.4 & MA6116.5	Quiz & End Term
36	Problem solving	Problem solving technique	Tutorial	MA6116.1, MA6116.4 & MA6116.5	Quiz & End Term

37-38	Separation Axioms: T0, T1 space	Understand Separation axioms in topological space	Lecture	MA6116.1, MA6116.4 & MA6116.5	Quiz & End Term
39-40	T2 (Hausdorff) separation axioms, their characterization and basic properties.	Understand Separation axioms in topological space	Lecture	MA6116.1, MA6116.4 & MA6116.5	Quiz & End Term
END TERM EXAM					

H. Course Articulation Matrix: (Mapping of COs with POs and PSOs): -

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOME									
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PSO 1	PSO 2	PSO 3
MA6116.1	Understand the concepts of topological space and their role in mathematics.	**2**			**2**			**3**	**2**	**2**	
MA6116.2	Understand the basic terms in topology as open sets, closed sets, interior, closure, frontier, boundary point, basis or by a basis of neighbourhoods at each point, and what it means for a function to be continuous.		**2**	**3**		**2**			**2**		
MA6116.3	Develop the skills to define topological space in terms of neighbourhood system and Kuratowski closure (interior) operator, relative (induced) topology	2		**3**			**1**		**1**		
MA6116.4	Understand the definition and properties of connected spaces, locally connected spaces, compact spaces, locally compact spaces and countability of topological space.		**3**		**2**			**3**	**1**		
MA6116.5	Enhanced the skill in checking the topological properties like connectedness, compactness and separation axioms	**2**		**2**			**2**		**1**		

1: -Low Correlation; 2:-Moderate Correlation; 3:- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Basic Sciences

Department of Mathematics and Statistics

Course Hand-out

Partial Differential Equations | MA6201 | 4 Credits | 3 1 0 4

Session: March 2021– May 2021| Faculty: Dr Reema Jain| Class: M.Sc. II Sem (Mathematics)

A. INTRODUCTION: This course will focus on the formulation of first and second order partial differential equations (PDEs) for three basic types of hyperbolic, parabolic and elliptic equations. It will provide some familiarity with different types of equations occurring in physics, particularly in mechanics involving Laplace Equation, Diffusion Equation and Wave Equation. Students will gain an understanding of the properties of different solutions in general, as well as some knowledge about initial and boundary value problems for PDEs of first and second order.

B. COURSE OUTCOMES: After completion of this course, the students will be able to

[6201.1] Learn the basic concepts of solution of PDE and their classification.
[6201.2] Solve the first order linear and nonlinear PDEs using various methods.
[6201.3] Identify and utilize the methods to solve higher order PDEs.
[6201.4] Understand and solve the given Boundary value problems and Equipotential surfaces.
[6201.5] Solve the PDEs which include heat, wave and Laplace' s equation that arise in various physical systems which make them employable in relevant area.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

[PO.1]. **Critical thinking:** Critically interpret data, write reports and apply the basics of evidence.
[PO.2]. **Effective Communication:** Communicate effectively by writing, connecting people, ideas, books, media and technology.
[PO.3]. **Social Interaction:** Elicit views of others, mediate disagreements and help reach conclusions in group settings.
[PO.4]. **Effective Citizenship:** Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering**.**
[PO.5]. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities.
[PO.6]. **Environment and Sustainability:** Understand the issues of environmental contexts and sustainable development.
[PO.7]. **Self-directed and Life-long Learning:** Acquire the ability to engage in independent and life-long learning in the broadest context socio technological changes.

[PSO.1]. Describe the basic and advanced Mathematical concepts of Pure and Applied Mathematics.
[PSO.2]. Apply the Mathematical principles to analyze and solve a variety of real-life as well as industry problems.
[PSO.3]. To have necessary skills for the research and developments in theoretical and applied science through seminar, project, and publication.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I	20
	Sessional Exam II	20
	Quizzes and Assignments	20
End Term Exam (Summative)	End Term Exam	40
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Homework/ Home Assignment/ Activity Assignment (Formative)	There are situations where a student may have to work in home, especially before an online class session Although these works are not graded with marks. However, a student is expected to participate and perform these assignments with full zeal since the activity/ online classroom participation by a student will be assessed and marks will be awarded.	

E. SYLLABUS

Partial Differential Equations(PDE): Definition of PDE, origin of first-order PDE, determination of integral surfaces of linear first order partial differential equations passing through a given curve, surfaces orthogonal to given system of surfaces, non-linear PDE of first order, Cauchy's method of characteristic, compatible system of first order PDE, Charpit's method of solution, origin of second order PDE, linear second order PDE with constant coefficients, linear second order PDE with variable coefficients, characteristic curves of the second order PDE, Monge's method of solution of non-linear PDE of second order, separation of variables in a PDE, Higher Order Partial Differential Equations: Laplace's equation, elementary solutions of Laplace's equations, families of equipotential surfaces, wave equation, the occurrence of wave equations, elementary solutions of one dimensional wave equation, diffusion equation, resolution of boundary value problems for diffusion equation, elementary solutions of diffusion equation, separation of variables.

References:

1. I. N. Sneddon, Elements of Partial Differential Equation, 3rd edition, Dove Publication, 2006.
2. M. D. Raisinghania, Ordinary and Partial Differential Equations, S. Chand & Sons, 2010.
3. E. T. Copson, Partial Differential Equations, Cambridge University Press, 1995.
4. L. C. Evans, Partial Differential Equations, Vol. 19, AMS, 2010.
5. J. R. Buchanan and Z. Shao, A First Course of Partial Differential Equation, World Scientific Publishing, 2017.

F. LECTURE PLAN

Lecture Number	Topic	Session Outcome	Mode of Delivery	Corresponding CO	Mode of Assessing CO
1	Introduction of the Course	Develop the understanding about the course	Lecture, Discussion & Examples	NA	NA
2	Definition of PDE	Students will get the acquaintance with the basic concept of PDEs	Lecture, Discussion & Examples	6201.1	Quiz, Sessional & End Term Exam.

3, 4	Origin of PDEs	Learn about the origin of PDEs	Lecture, Discussion & Examples	6201.1	Quiz, Sessional & End Term Exam.
5, 6	Classification of PDEs	Understand the Classification of PDEs	Lecture, Discussion & Examples	6201.1	Quiz, Sessional & End Term Exam.
7, 8	Solution of linear PDEs of first order	Learn about solution of linear PDEs	Lecture, Discussion & Examples	6201.2	Quiz, Sessional & End Term Exam.
9, 10	Determination of integral surfaces of linear first order PDEs	Learn about integral surfaces	Lecture, Discussion & Examples	6201.2	Quiz, Sessional & End Term Exam.
11	Non-linear PDEs of first order	Understand the concepts of non-linear PDEs	Discussion & Examples	6201.2	Quiz, Sessional & End Term Exam.
12, 13	Solution of non-linear PDE of first order	Learn about solution of non-linear PDEs of first order	Lecture, Discussion & Examples	6201.2	Quiz, Sessional & End Term Exam.
14, 15	Cauchy's method of characteristic	Understand the Cauchy's method	Lecture, Discussion & Examples	6201.2	Quiz, Sessional & End Term Exam.
16	Compatible system of first order PDE	Develop the understanding of Compatible system	Lecture, Discussion & Examples	6201.2	Quiz, Sessional & End Term Exam.
17, 18	Charpit's method of solution	Understand the Charpit's method	Lecture, Discussion & Examples	6201.2	Quiz, Sessional & End Term Exam.
19	Origin of second order PDEs	Understand the concept of second order PDEs	Lecture, Discussion & Examples	6201.3	Quiz, Sessional & End Term Exam.
20, 21	Linear second order PDEs with constant coefficients	Solve the PDEs with constant coefficients	Discussion & Examples	6201.3	Quiz, Sessional & End Term Exam.
22, 23	Linear second order PDEs with variable coefficients	Understand the concept of PDEs with variable coefficients	Lecture, Discussion & Examples	6201.3	Quiz, Sessional & End Term Exam.
24, 25	Characteristic curves of the second order PDEs	Get the knowledge of Characteristic curves	Lecture, Discussion & Examples	6201.3	Quiz, Sessional & End Term Exam.
26, 27, 28	Monge's method of solution of non-linear PDE of second order	Develop the notion of non-linear PDE of second order and Monge's method	Lecture, Discussion & Examples	6201.4	Quiz, Sessional & End Term Exam.
29, 30, 31	Separation of variables in a PDE	Understand the method of Separation of variables	Lecture, Discussion & Examples	6201.4	Quiz, Sessional & End Term Exam.
32, 33	Families of equipotential surfaces	Elaborate the notion of Families of	Lecture, Discussion & Examples	6201.4	Quiz, Sessional & End Term Exam.

		equipotential surfaces			
34, 35	Higher Order Partial Differential Equations: Laplace equation	Understand the concept of Laplace equation	Lecture, Discussion & Examples	6201.5	Quiz, Sessional & End Term Exam.
36, 37	Elementary solutions of Laplace equations	Solve Laplace equations	Lecture, Discussion & Examples	6201.5	Quiz, Sessional & End Term Exam.
38	Wave equation	Get the knowledge of Wave equations	Lecture, Discussion & Examples	6201.5	Quiz, Sessional & End Term Exam.
39	The occurrence of wave equations	Get the idea of occurrence of Wave equations	Discussion & Examples	6201.5	Quiz, Sessional & End Term Exam.
40, 41	Elementary solutions of one-dimensional Wave equation	Find the solution of one -dimensional Wave equation	Lecture, Discussion & Examples	6201.5	Quiz, Sessional & End Term Exam.
42	Diffusion equation	Get the knowledge of Diffusion equations	Lecture, Discussion & Examples	6201.5	Quiz, Sessional & End Term Exam.
43, 44	Resolution of boundary value problems for diffusion equation	Understand the concept of boundary value problems	Lecture, Discussion & Examples	6201.5	Quiz, Sessional & End Term Exam.
45, 46	Elementary solutions of diffusion equation	Understand the Elementary solutions	Lecture, Discussion & Examples	6201.5	Quiz, Sessional & End Term Exam.
47, 48	Separation of variables	Apply the Separation of variables	Lecture, Discussion & Examples	6201.5	Quiz, Sessional & End Term Exam.

G. COURSE ARTICULATION MATRIX (MAPPING OF COs WITH POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES							CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PSO 1	PSO 2	PSO 3
MA6201.1	Learn the basic concepts of solution of PDE and their classification.	3	2	1	2	1	2	3	3	2	1
MA6201.2	Solve the first order linear and nonlinear PDEs using various methods.	3	2	1	2	1	1	3	3	1	2
MA6201.3	Identify and utilize the methods to solve higher order PDEs.	3	2	1	2	1	1	3	3	1	1
MA6201.4	Understand and solve the given Boundary value problems and Equipotential surfaces.	3	2	1	2	1	2	3	2	2	2
MA6201.5	Solve the PDEs which include heat, wave and Laplace' s equation that arise in various physical systems.	3	2	1	2	1	2	3	3	3	2

Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Basic Sciences

Department of Mathematics & Statistics

Course Hand-out

OPTIMIZATION THEORY AND TECHNIQUES | MA6202| 4 Credits | 3 1 0 4

Session: March 2021–June 2021 | Faculty: Dr Pooja Sharma | Class: M.Sc. II SEM

A. Introduction: This course is offered by Dept. of Mathematics & Statistics as a regular course to make the students acquainted with the subject of Optimization Theory and Techniques at the higher level. Optimization Theory is a collection of mathematical principles and methods used for solving quantitative problems in many disciplines, including physics, biology, engineering, economics, and business. The subject grew from a realization that quantitative problems in manifestly different disciplines have important mathematical elements in common. Because of this commonality, many problems can be formulated and solved by using the unified set of ideas and methods that make up the field of optimization. In this course, students will expand their knowledge of different optimization techniques in many field of applications.

B. Course Outcomes: After completing this course, the students will be able to

[6202.1] Implement the various methods to solve the one dimensional and multidimensional problems of unconstraint optimization related to real word problem

[6202.2] Understand the key concept of Non Linear Programming to develop the skill of applying the various solution methodologies

[6202.3] To develop and implement the concept of Kuhun-Tucker conditions for solving the Non Linear programming problems at different level

[6202.4] Comprehend the concept of Quadratic Programming Problems which will enhance the analytical skills.

[6202.5] Apply the convex programming techniques to solve the linear and non -linear constrained problems which make them employable in relevant field.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Programme Outcomes

PO1 **Critical thinking:** Critically interpret data, write reports and apply the basics of evidence.

PO2 **Effective Communication:** Communicate effectively by writing, connecting people, ideas, books, media, and technology.

PO3 **Social Interaction:** Elicit views of others, mediate disagreements and help reach conclusions in group settings.

PO4 **Effective Citizenship:** Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering.

PO5	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities.
PO6	**Environment and Sustainability:** Understand the issues of environmental contexts and sustainable development.
PO7	**Self-directed and Life-long Learning:** Acquire the ability to engage in independent and life-long learning in the broadest context socio technological changes.

Programme Specific Outcomes

PSO1	Describe the basic and advanced Mathematical concepts of Pure and Applied Mathematics.
PSO2	Apply the Mathematical principles to analyze and solve a variety of real-life as well as industry problems.
PSO3	To have necessary skills for the research and developments in theoretical and applied science through seminar, project, and publication.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I	20
	Sessional Exam II	20
	Quizzes and Assignments	20
End Term Exam (Summative)	End Term Exam	40
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Homework/ Home Assignment/ Activity Assignment (Formative)	There are situations where a student may have to work in home, especially before an online class session Although these works are not graded with marks. However, a student is expected to participate and perform these assignments with full zeal since the activity/ online classroom participation by a student will be assessed and marks will be awarded.	

E. SYLLABUS

Unconstrained Optimization: Fibonacci golden section and quadratic interpolation methods for one dimensional problems, steepest descent, conjugate gradient and variable metric methods for multidimensional problems; Nonlinear Programming: Generalized convexity, quasi and psuedo convex functions and their properties, general nonlinear programming problem, difficulties introduced by nonlinearity, Kuhun-Tucker necessary conditions for optimality, insufficiency of K-T conditions, sufficiency conditions for optimality, solution of simple NLPP using K-T conditions; Quadratic Programming: Beale's method, restricted basis entry method (Wolfe's method), proof of termination for the definite case, resolution of the semi definite case, duality in quadratic programming; Convex Programming: Methods of feasible directions, Zoutendijk's method, Rozen's gradient projection method for linear constraints, Kelly's cutting plane method to deal with nonlinear constraints.

References:

1. S.S. Rao, Optimization Theory and Applications, Wiley Eastern, 2009.

2. G. Hadley, Nonlinear and Dynamic Programming, Addison Wesley, 2018.

3. M. Bazara and Shetty, Nonlinear Programming: Theory and Algorithms, 3rd edition, John Wiley, 2006.

4. H.S. Kasana, Introductory Operation Research: Theory and Applications, Springer Verlag, 2005.

5. R. L. Rardin, Optimization in Operations research, Pearson Education, 2005.

F. LECTURE PLAN

Lecture Number	Topic	Session Outcome	Mode of Delivery	Corresponding CO	Mode of Assessing CO
1.	Introduction of the Course	Develop the understanding about the course	Lecture, Discussion	NA	NA
2.	Concept of Fibonacci golden section	Students will get the acquaintance with the basic concept of Fibonacci & golden section	Lecture, Discussion & Examples	6202.1	Quiz, Sessional & End Term Exam.
3.	Unconstrained Optimization: Fibonacci methods for one dimensional problems,	Understand the Fibonacci method	Lecture, Discussion & Examples	6202.1	Quiz, Sessional & End Term Exam.
4.	Unconstrained Optimization: Fibonacci methods for one dimensional problems,	Understand the Fibonacci method	Lecture, Discussion & Examples	6202.1	Quiz, Sessional & End Term Exam.
5.	Unconstrained Optimization: golden section methods for one dimensional problems	Understand the golden section method	Lecture, Discussion & Examples	6202.1	Quiz, Sessional & End Term Exam.
6.	Unconstrained Optimization: golden section methods for one dimensional problems	Understand the golden section method	Lecture, Discussion & Examples	6202.1	Quiz, Sessional & End Term Exam.
7.	Tutorial-Problem Solving Session	Apply the concepts in real world problems	Discussion & Examples	6202.1	Quiz, Sessional & End Term Exam.
8.	steepest descent, methods for multidimensional problems	Learn about Random Variable	Lecture, Discussion & Examples	6202.1	Quiz, Sessional & End Term Exam.
9.	steepest descent, methods for multidimensional problems	Understand the steepest descent, method	Lecture, Discussion & Examples	6202.1	Quiz, Sessional & End Term Exam.
10.	conjugate gradient methods for multidimensional problems	Understand the steepest descent, method	Lecture, Discussion & Examples	6202.1	Quiz, Sessional & End Term Exam.
11.	Quadratic interpolation methods	Understand the variable metric methods	Lecture, Discussion & Examples	6202.1	Quiz, Sessional & End Term Exam.
12.	variable metric methods for multidimensional problems	Understand the variable metric methods	Lecture, Discussion & Examples	6202.1	Quiz, Sessional & End Term Exam.
13.	Tutorial-Problem Solving Session	Apply the concepts in real world problems	Discussion & Examples	6202.1	Quiz, Sessional & End Term Exam.
14.	Nonlinear Programming: Generalized convexity	Learn the concept of Nonlinear Programming	Lecture, Discussion & Examples	6202.2	Quiz, Sessional & End Term Exam.
15.	Nonlinear Programming: Generalized convexity	Learn the concept of Nonlinear Programming and Generalized convexity	Lecture, Discussion & Examples	6202.2	Quiz, Sessional & End Term Exam.
16.	Quasi and psuedo convex functions and their properties,	Get the knowledge of Quasi and psuedo convex functions	Lecture, Discussion & Examples	6202.2	Quiz, Sessional & End Term Exam.

17.	Quasi and psuedo convex functions and their properties	Get the knowledge of Quasi and psuedo convex functions	Lecture, Discussion & Examples	6202.2	Quiz, Sessional & End Term Exam.
18.	Tutorial-Problem Solving Session	Apply the concepts in real world problems	Discussion & Examples	6202.2	Quiz, Sessional & End Term Exam.
19.	general nonlinear programming problem, difficulties introduced by nonlinearity	Understand the difficulties introduced by nonlinearity in NLPP	Lecture, Discussion & Examples	6202.2	Quiz, Sessional & End Term Exam.
20.	general nonlinear programming problem, difficulties introduced by nonlinearity	Understand the difficulties introduced by nonlinearity in NLPP	Lecture, Discussion & Examples	6202.2	Quiz, Sessional & End Term Exam.
21.	Kuhun-Tucker necessary conditions for optimality	Understand the Kuhun-Tucker necessary conditions for optimality	Lecture, Discussion & Examples	6202.2	Quiz, Sessional & End Term Exam.
22.	Kuhun-Tucker necessary conditions for optimality	Understand the Kuhun-Tucker necessary conditions for optimality	Lecture, Discussion & Examples	6202.3	Quiz, Sessional & End Term Exam.
23.	insufficiency of K-T conditions, sufficiency conditions for optimality	Understand the properties of KT conditions	Discussion & Examples	6202.3	Quiz, Sessional & End Term Exam.
24.	insufficiency of K-T conditions, sufficiency conditions for optimality	Understand the properties of KT conditions	Lecture, Discussion & Examples	6202.3	Quiz, Sessional & End Term Exam.
25.	Tutorial-Problem Solving Session	Apply the concepts in real world problems	Lecture, Discussion & Examples	6202.3	Quiz, Sessional & End Term Exam.
26.	Solution of simple NLPP using K-T conditions;	Apply the KT conditions for optimization	Lecture, Discussion & Examples	6202.3	Quiz, Sessional & End Term Exam.
27.	Solution of simple NLPP using K-T conditions;	Apply the KT conditions for optimization	Lecture, Discussion & Examples	6202.3	Quiz, Sessional & End Term Exam.
28.	Quadratic Programming: Beale's method	Understand the concept of Quadratic Programming: Beale's method	Lecture, Discussion & Examples	6202.4	Quiz, Sessional & End Term Exam.
29.	Quadratic Programming: Beale's method,	Understand the concept of Quadratic Programming: Beale's method	Lecture, Discussion & Examples	6202.4	Quiz, Sessional & End Term Exam.
30.	Quadratic Programming: restricted basis entry method (Wolfe's method)	Develop the concept of restricted basis entry method (Wolfe's method)	Lecture, Discussion & Examples	6202.4	Quiz, Sessional & End Term Exam.
31.	Quadratic Programming: restricted basis entry method (Wolfe's method)	Develop the concept of restricted basis entry method (Wolfe's method)	Lecture, Discussion & Examples	6202.4	Quiz, Sessional & End Term Exam.
32.	Tutorial-Problem Solving Session	Understand the concept and properties of QPP	Discussion & Examples	6202.4	Quiz, Sessional & End Term Exam.
33.	proof of termination for the definite case, resolution of the semi definite case	Understand the concept and properties of QPP	Lecture, Discussion & Examples	6202.4	Quiz, Sessional & End Term Exam.
34.	proof of termination for the definite case, resolution of the semi definite case	Understand the concept and properties of QPP	Lecture, Discussion & Examples	6202.4	Quiz, Sessional & End Term Exam.
35.	duality in quadratic programming	Understand the basics of duality in quadratic programming	Lecture, Discussion & Examples	6202.4	Quiz, Sessional & End Term Exam.

36.	Convex Programming: Methods of feasible directions,	Understand the basics Convex Programming:	Lecture, Discussion & Examples	6202.5	Quiz, Sessional & End Term Exam.
37.	Convex Programming: Methods of feasible directions	Understand the basics Convex Programming:	Lecture, Discussion & Examples	6202.5	Quiz, Sessional & End Term Exam.
38.	Convex Programming: Methods of feasible directions	Understand the basics Convex Programming:	Lecture, Discussion & Examples	6202.5	
39.	Tutorial-Problem Solving Session	Apply the concepts in real world problems	Discussion & Examples	6202.5	Quiz, Sessional & End Term Exam.
40.	Zoutendijk's method	Apply the Zoutendijk's method	Lecture, Discussion & Examples	6202.5	Quiz, Sessional & End Term Exam.
41.	Zoutendijk's method	Apply the Zoutendijk's method	Lecture, Discussion & Examples	6202.5	Quiz, Sessional & End Term Exam.
42.	Rozen's gradient projection method for linear constraints,	Apply the Rozen's gradient projection method	Lecture, Discussion & Examples	6202.5	Quiz, Sessional & End Term Exam.
43.	Rozen's gradient projection method for linear constraints,	Apply the Rozen's gradient projection method	Discussion & Examples	6202.5	Quiz, Sessional & End Term Exam.
44.	Rozen's gradient projection method for linear constraints,	Apply the Rozen's gradient projection method	Lecture, Discussion & Examples	6202.5	Quiz, Sessional & End Term Exam.
45.	Tutorial-Problem Solving Session	Apply the concepts in real world problems	Discussion & Examples	6202.5	Quiz, Sessional & End Term Exam.
46.	Kelly's cutting plane method to deal with nonlinear constraints.	Apply the Kelly's cutting plane method	Lecture, Discussion & Examples	6202.5	Quiz, Sessional & End Term Exam.
47.	Kelly's cutting plane method to deal with nonlinear constraints.	Apply the Kelly's cutting plane method	Lecture, Discussion & Examples	6202.5	Quiz, Sessional & End Term Exam.
48.	Tutorial-Problem Solving Session	Apply the concepts in real world problems	Lecture, Discussion & Examples	6202.5	Quiz, Sessional & End Term Exam.

G. COURSE ARTICULATION MATRIX (MAPPING OF COs WITH POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES									
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PSO 1	PSO 2	PSO 3
MA6202.1	Implement the various methods to solve the one dimensional and multidimensional problems of unconstraint optimization related to real word problem	2	0	0	1	0	3	3	3	3	1
MA6202.2	Understand the key concept of Non Linear Programming to develop the skill of applying the various solution methodologies	2	0	0	1	0	3	3	3	3	1
MA6202.3	To develop and implement the concept of Kuhun-Tucker conditions for solving the Non Linear programming problems at different level	2	0	0	1	0	3	3	3	3	1
MA6202.4	Comprehend the concept of Quadratic Programming Problems which will enhance the analytical skills.	2	0	0	1	0	3	3	3	3	1
MA6202.5	Apply the convex programming techniques to solve the linear and non - linear constrained problems	2	0	0	1	0	3	3	3	3	1

1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Basic Sciences

Department of Mathematics & Statistics
Course Hand-out

Functional Analysis | MA6203 | 4 Credits | 3 1 0 4

Session: Jan 2021– June 2021 | Class: M.Sc. Mathematics III Sem. | Course Coordinator : Dr. Virendra Singh Chouhan

A. Introduction:

Dept. of Mathematics & Statistics offer the course Functional Analysis for M.Sc. Mathematics students. The aim of this course to motivate students to develop research ability in students by theoretical approach and create interest in pure mathematics. The course will develop a depth understanding of Functional Analysis by some concept of Functional Analysis like Normed linear spaces, Banach spaces, Hahn-Banach extension, open mapping and closed graph theorem, Compact operator theory. The course will motivate students to think problems conceptually.

B. Course Outcomes: At the end of the course, students will be able to

[6203.1] Develop their skill to understand normed linear space with different inequalities.

[6203.2] Analyse the Banach Space in context of vector space on real field and complex field.

[6203.3] Enhance bounded linear transformations, Riesz representation theorem, Hahn-Banach extension, second conjugate spaces which enhance their problem solving skills.

[6203.4] Apply their skill to study open mapping and closed graph theorem, weak and strong convergence.

[6203.5] Study of compact operator and its relationship with continuous operator.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

[PO.1]. Critical thinking: Critically interpret data, write reports and apply the basics of evidence.
[PO.2]. Effective Communication: Communicate effectively by writing, connecting people, ideas, books, media and technology.
[PO.3]. Social Interaction: Elicit views of others, mediate disagreements and help reach conclusions in group settings.
[PO.4]. Effective Citizenship: Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering.
[PO.5]. Ethics: Apply ethical principles and commit to professional ethics and responsibilities.
[PO.6]. Environment and Sustainability: Understand the issues of environmental contexts and sustainable development.
[PO.7]. Self-directed and Life-long Learning: Acquire the ability to engage in independent and life-long learning in the broadest context socio technological changes.
[PSO.1]. Describe the basic and advanced Mathematical concepts of Pure and Applied Mathematics.
[PSO.2]. Apply the Mathematical principles to analyze and solve a variety of real-life as well as industry problems. [PSO.3]. To have necessary skills for the research and developments in theoretical and applied science through seminar, project, and publication.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Closed Book)	20
	Sessional Exam II (Closed Book)	20
	In class Quizzes and Assignments , Activity feedbacks (Accumulated and Averaged)	20
End Term Exam (Summative)	End Term Exam (Closed Book)	40
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Homework/ Home Assignment/ Activity Assignment (Formative)	There are situations where a student may have to work in home, especially before a flipped classroom. Although these works are not graded with marks. However, a student is expected to participate and perform these assignments with full zeal since the activity/ flipped classroom participation by a student will be assessed and marks will be awarded.	

E. SYLLABUS MA6203

Normed Linear Spaces: Metric on normed linear spaces, completion of a normed space; Banach Spaces: Introduction, subspace of a Banach space, Holder and Minkowski inequality, completeness of quotient spaces of normed linear spaces, completeness of lp, Lp, Rn, Cn and C[a,b], incomplete normed spaces, finite dimensional normed linear spaces and subspaces, bounded linear transformation, equivalent formulation of continuity, spaces of bounded linear transformations, continuous linear functional, conjugate spaces, Hahn-Banach extension theorem (real and complex form), Riesz representation theorem for bounded linear functionals on Lp and C[a,b], second conjugate spaces, reflexive space, uniform boundedness principle and its consequences, open mapping theorem and its application, projections, closed graph theorem equivalent norms, weak and strong convergence, their equivalence in finite dimensional spaces, weak sequential compactness, solvability of linear equations in Banach spaces; Compact Operator Theory: Compact operator and its relation with continuous operator, compactness of linear transformation on a finite dimensional space, properties of compact operators, compactness of the limit of the sequence of compact operators.

F. References:

1. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 2003.
2. E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley, 2007.
3. A. H. Siddiqi, Khalil Ahmad and P. Manchanda, Introduction to Functional Analysis with Applications, Anamaya Publishers, New Delhi, 2006
4. K.C. Rao, Functional Analysis, Narosa Publishing House, 2nd edition, 2006

G. Lecture Plan:

Lec No	**Topics**	**Session Objective**	**Mode of Delivery**	**Corres-ponding CO**	**Mode of Assessing the Outcome**
1	Normed Linear Spaces	Learn About Normed Linear Spaces	Lecture	6203.1	By examination/ Assignment
2	Metric on normed linear spaces	Idea of Metric on normed linear spaces	Lecture	6203.1	By examination/ Assignment
3	completion of a normed space	completion of a normed space	Lecture	6203.1	By examination/ Assignment
4	Holder and Minkowski inequality	Know about inequality	Tutorial	6203.1	By examination/ Assignment
5	completeness of quotient spaces of normed linear spaces	Information about completeness of quotient space	Lecture	6203.1	By examination/ Assignment
6	finite dimensional normed linear spaces and subspaces	Learn about finite dimensional normed linear spaces	Lecture	6203.1	By examination/ Assignment
7	incomplete normed spaces	Idea about incomplete normed spaces	Lecture	6203.1	By examination/ Assignment
8	Reisz Lemma	Get idea about the Reisz Lemma	Tutorial	6203.1	By examination/ Assignment
9	Banach spaces	Get idea about the Banach spaces	Lecture	6203.2	By examination/ Assignment
10	subspace of a Banach space	Get idea about the Banach spaces	Lecture	6203.2	By examination/ Assignment
11	completeness of R	Understand the concept of completeness	Lecture	6203.2	By examination/ Assignment
12	completeness of C	Understand the concept of completeness	Tutorial	6203.2	By examination/ Assignment
13	completeness of l infinity,	Understand the concept of completeness	Lecture	6203.2	By examination/ Assignment
14	completeness of l^p,	Understand the concept of completeness	Lecture	6203.2	By examination/ Assignment
15	completeness of R^n	Learn usefulness of completeness	Lecture	6203.2	By examination/ Assignment
16	completeness of C^n	Get idea about the completeness	Tutorial	6203.2	By examination/ Assignment
17	completeness of C[a,b],	Understand the concept of completeness	Lecture	6203.2	By examination/ Assignment
18	bounded linear transformation	Understand the concept of bounded linear transformation	Lecture	6203.3	By examination/ Assignment
19	equivalent formulation of continuity	Get idea about the equivalent formulation of continuity	Lecture	6203.3	By examination/ Assignment
20	spaces of bounded linear transformations	Learn about spaces of bounded linear transformations	Tutorial	6203.3	By examination/ Assignment
21	spaces of bounded linear transformations	Learn about spaces of bounded linear transformations	Lecture	6203.3	By examination/ Assignment
22	continuous linear functional	Get idea about the concept	Lecture	6203.3	By examination/ Assignment
23	continuous linear functional	Get idea about the concept	Lecture	6203.3	By examination/ Assignment
24	conjugate spaces	Understand the concept of conjugate spaces	Tutorial	6203.3	By examination/ Assignment
25	Hahn-Banach extension theorem (real and complex	Get idea about Hahn-Banach extension	Lecture	6203.3	By examination/ Assignment

	form),				
26	Hahn-Banach extension theorem (real and complex form),	Get idea about Hahn-Banach extension	Lecture	6203.3	By examination/ Assignment
27	Riesz representation theorem for bounded linear functionals on Lp and C[a,b]	Get idea about the theorem	Lecture	6203.3	By examination/ Assignment
28	second conjugate spaces	Get idea about the concept	Tutorial	6203.3	By examination/ Assignment
29	reflexive space	Get idea about the concept	Lecture	6203.4	By examination/ Assignment
30	uniform boundedness principle and its consequences	Understand the concept of uniform boundedness principle	Lecture	6203.4	By examination/ Assignment
31	Open mapping	Understand the concept of Open mapping	Lecture	6203.4	By examination/ Assignment
32	open mapping theorem and its application	Understand the concept of open mapping theorem	Tutorial	6203.4	By examination/ Assignment
33	projections	Understand the concept of projections	Lecture	6203.4	By examination/ Assignment
34	closed graph	Understand the concept of closed graph	Lecture	6203.4	By examination/ Assignment
35	closed graph theorem equivalent norms	Get idea about the closed graph theorem	Lecture	6203.4	By examination/ Assignment
36	closed graph theorem equivalent norms	Get idea about the closed graph theorem	Tutorial	6203.4	By examination/ Assignment
37	weak and strong convergence	Learn about weak and strong convergence	Lecture	6203.4	By examination/ Assignment
38	equivalence in finite dimensional spaces	Get idea about the concept	Lecture	6203.4	By examination/ Assignment
39	weak sequential compactness	Understand the concept weak sequential compactness	Lecture	6203.4	By examination/ Assignment
40	solvability of linear equations in Banach spaces	Get idea about the solvability of linear equations	Tutorial	6203.4	By examination/ Assignment
41	Compact Operator Theory	Learn about Compact operator theory	Lecture	6203.5	By examination/ Assignment
42	Compact Operator Theory	Learn about Compact operator theory	Lecture	6203.5	By examination/ Assignment
43	Compact operator and its relationship with continuous operator	Get idea about the concept	Lecture	6203.5	By examination/ Assignment
44	Compact operator and its relationship with continuous operator	Get idea about the concept	Tutorial	6203.5	By examination/ Assignment
45	compactness of linear transformation on a finite dimensional space	Get idea about the compactness of linear transformation	Lecture	6203.5	By examination/ Assignment
46	compactness of linear transformation on a finite dimensional space	Learn about compactness of linear transformation	Lecture	6203.5	By examination/ Assignment
47	properties of compact operators	Learn about properties of compact operators	Lecture	6203.5	By examination/ Assignment
48	compactness of the limit of the sequence of compact operators	Get idea about the concept	Tutorial	6203.5	By examination/ Assignment

H. Course Articulation Matrix: (Mapping of COs with POs and PSOs):-

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOME							CORRELATION WITH PROGRAM SPECIFIC OUTCOME			
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PSO 1	PSO 2	PSO 3	PSO 4
[MA6203.1]	Develop their skill to understand normed linear space with different inequalities.	**3**	**2**				**2**	**3**				
[MA6203.2]	Analyse the Banach Space in context of vector space on real field and complex field.		**2**	**2**			**1**	**2**				
[MA6203.3]	Enhance bounded linear transformations, Riesz representation theorem, Hahn-Banach extension, second conjugate spaces.	2			**2**	**2**			**2**			
[MA6203.4]	Apply their skill to study open mapping and closed graph theorem, weak and strong convergence.	**3**		**1**	**1**				**3**			
[MA6203.5]	Study of compact operator and its relationship with continuous operator.				**1**	**2**	**3**	**3**				

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1:-Low Correlation; 2:-Moderate Correlation; 3:- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Basic Sciences

Department of Mathematics & Statistics
Course Hand-out

Measure Theory and Integration| MA 6204 | 4 Credits | 4 0 0 4

Session: JAN, 2021- MAY, 2021| Class: M.Sc. Mathematics | Course Coordinator: Dr. Ashok Kumar Pal

A. Introduction: Dept. of Mathematics & Statistics offer the course Measure Theory and Integration for M.Sc. Mathematics Students. The aim of this course to motivate students to develop research ability in students by theoretical approach and create interest in pure mathematics. The course will develop a depth understanding of measure theory by some concept of Measurable sets, functions, lebesgue measure and lebesgue integration. The course will develop mental ability in the Mesure theory and lebesgue integartion problem and their solutions.

B. Course Outcomes: At the end of the course, students will be able to

[MA6204.1] Describe the concept of Measurable Sets, outer measure and Lebesgue measure of a set of real numbers.
[MA6204.2]. Describe the concept of Borel set, open, closed, and non-measurable sets.
[MA6204.3] Describe the concept the measurable functions and their equivalent formulations.
[MA6204.4] Describe the concept in Lebesgue Integral.
[MA6204.5] Evaluate the solution of mathematical problem, which make them employable.

C. Program Outcomes and Program Specific Outcomes

[PO.1]. **Critical thinking:** Critically interpret data, write reports and apply the basics of evidence.
[PO.2]. **Effective Communication:** Communicate effectively by writing, connecting people, ideas, books, media and technology.
[PO.3]. **Social Interaction:** Elicit views of others, mediate disagreements and help reach conclusions in group settings.
[PO.4]. **Effective Citizenship:** Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering**.**
[PO.5]. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities.
[PO.6]. **Environment and Sustainability:** Understand the issues of environmental contexts and sustainable development.
[PO.7]. **Self-directed and Life-long Learning:** Acquire the ability to engage in independent and life-long learning in the broadest context socio technological changes.

PROGRAM SPECIFIC OUTCOMES:

[PSO.1]. Describe the basic and advanced Mathematical concepts of Pure and Applied Mathematics.
[PSO.2]. Apply the Mathematical principles to analyze and solve a variety of real-life as well as industry problems.
[PSO.3]. To have necessary skills for the research and developments in theoretical and applied science through seminar, project, and publication.

D. Assessment Rubrics:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Close Book)	20
	Sessional Exam II (Close Book)	20
	Quizzes and Assignment	20
End Term Exam (Summative)	End Term Exam (Close Book)	40
	Total	100

Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.
Quizzes	3 Quizzes (Close Book)

E. Syllabus

Measurable Sets: Set functions, intuitive idea of measure, elementary properties of measure, measurable sets and their fundamental properties, Lebesgue measure of a set of real numbers, algebra of measurable sets, Borel set, equivalent formulation of measurable sets in terms of open, closed, non-measurable sets, measurable functions and their equivalent formulations, properties of measurable functions, approximation of a measurable function by a sequence of simple functions, measurable functions as nearly continuous functions, Egoroff theorem, Lusin theorem, convergence in measure and F. Riesz theorem, almost uniform convergence;

Measureable Function and Lebesgue Integral: Shortcomings of Riemann integral, Lebesgue integral of a bounded function over a set of finite measure and its properties, Lebesgue integral as a generalization of Riemann integral, bounded convergence theorem, Lebesgue theorem regarding points of discontinuities of Riemann integrable functions, integral of non-negative functions, Fatou lemma, monotone convergence theorem, general Lebesgue integral, Lebesgue convergence theorem, Vitali covering lemma, differentiation of monotonic functions, function of bounded variation and its representation as difference of monotonic functions, differentiation of indefinite integral, Fundamental theorem of calculus, absolutely continuous functions and their properties..

F. Reference Book:

W. Rudin, Principles of Mathematical Analysis, 3rd edition, McGraw-Hill, Kogakusha, 2017.
H.L. Royden, Real Analysis, Macmillan Pub. Co., Inc. 4th edition, New York, 1993.
P. K. Jain and V. P. Gupta, Lebesgue Measure and Integration, New Age International (P) Limited Published, New Delhi,2012.
De Barra, Measure Theory and Integration, Wiley Eastern Ltd., 2003.
R.R. Goldberg, Methods of Real Analysis, Oxford & IBH Pub. Co. Pvt. Ltd, 2012.
R. G. Bartle, The Elements of Real Analysis, Wiley International Edition, 2011.
R. R. Goldberg, Methods of Real Analysis, John Wiley & Sons, 2012.

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G. Lecture Plan:

Lec No	Topics	Session Objective	Mode of Delivery (Online/Classroom)	Corresponding CO	Mode of Assessing the Outcome
1	Introduction, aims and objectives of the course and elementary fundamentals of Measure theory	Know the basics of the course and understand its applications	Lecture	MA6204.1	Assignments Class Quiz Mid-Term I End-Term
2	Measurable Sets: Set functions	Recall of vector space, basis,	Lecture	MA6204.1	
3	intuitive idea of measure	Understand the dimension and related properties.	Lecture	MA6204.1	
4	elementary properties of measure,	Understand the algebra of linear transformations.	Lecture	MA6204.1	
5	measurable sets and their fundamental properties	Know the doubts	Lecture	MA6204.2	
6	Lebesgue measure of a set of real numbers	Know the basics of the linear transformation	Lecture	MA6204.2	
7	algebra of measurable sets	Understand the concept of dimension of space of linear transformations.	Lecture	MA6204.2	
8	Borel set,	Understand the concept of dimension of the space.	Lecture	MA6204.2	
9	equivalent formulation of measurable sets in terms of open	Know the concept of change of basis and transition matrices	Lecture	MA6204.2	
10	closed, non-measurable sets,	basics of the linear functional, dual basis.	Lecture	MA6204.2	
11	measurable functions and their equivalent formulations,	To understand the concept of dual basis.	Lecture	MA6204.2	
12	measurable functions and their equivalent formulations,	To understand the problem.	Lecture	MA6204.2	
13	Doubt class	Know the concept of annihilator.	Lecture	MA6204.3	
14	properties of measurable functions	Know the basics of the second dual space	Lecture	MA6204.3	
15	approximation of a measurable function by a sequence of simple functions	Know the basics of the dual transformations	Lecture	MA6204.3	
16	approximation of a measurable function by a sequence of simple functions	To understand the Inner-Product Spaces.	Lecture	MA6204.3	
17	approximation of a measurable function by a sequence of simple functions	Know the concept of limit of the sequences	Lecture	MA6204.3	
18	measurable functions as nearly continuous functions,	Know the basics of limit of a sequences.	Lecture	MA6204.3	

19	Egoroff theorem	Know the concept of convergence sequences.	Lecture	MA6204.3	
20	Lusin theorem	Know the concept of convergence sequences	Lecture	MA6204.3	
21	convergence in measure	To understand the problem.	Lecture	MA6204.3	
22	F. Riesz theorem	Know the concept of convergence sequences	Lecture	MA6204.3	
23	almost uniform convergence	Know the concept of convergence sequences	Lecture	MA6204.3	
24	Measureable Function and Lebesgue Integral:	Know the concept of convergence sequences	Lecture	MA6204.3	
25	Shortcomings of Riemann integral	Know the concept of convergence sequences	Lecture	MA6204.3 MA6204.5	
26	Lebesgue integral of a bounded function over a set of finite measure and its properties	To understand the problem.	Lecture	MA6204.3	
27	Lebesgue integral of a bounded function over a set of finite measure and its properties	Understand the impulse and reaction turbine	Lecture	MA6204.3	
28	Lebesgue integral of a bounded function over a set of finite measure and its properties	Understand the concept of monotonic sequences.	Lecture	MA6204.3 MA6204.5	
29	Lebesgue integral as a generalization of Riemann integral,	Understand the concept of monotonic sequences.	Lecture	MA6204.3	Assignments Class Quiz Mid-Term II End-Term
30	bounded convergence theorem	To understand the problem.	Lecture	MA6204.3	
31	Lebesgue theorem regarding points of discontinuities of Riemann integrable functions	Understand the concept of monotonic sequences.	Lecture	MA6204.3 MA6204.5	
32	Lebesgue theorem regarding points of discontinuities of Riemann integrable functions	Understand the concept of subsequences.	Lecture	MA6204.3	
32	integral of non-negative functions,	To understand the problem.	Lecture	MA6204.3 MA6204.5	
33	Fatou lemma	Understand the concept of subsequences.	Lecture	MA6204.3	
34	monotone convergence theorem	Understand the concept of infinite series	Lecture	MA6204.4	
35	general Lebesgue integral	To understand the problem.	Lecture	MA6204.4 MA6204.5	
36	Doubt Class	Know the basics of the infinite series	Lecture	MA6204.4	
37	Lebesgue convergence theorem,	Know the concept of convergence and divergence series.	Lecture	MA6204.4	

38	Vitali covering lemma	Know the concept of convergence and divergence series.	Lecture	MA6204.4	Assignments Class Quiz End-Term
39	differentiation of monotonic functions	Know the concept of convergence and divergence series	Lecture	MA6204.4	
40	function of bounded variation and its representation as difference of monotonic functions,	Know the concept of convergence and divergence series	Lecture	MA6204.4	
41	function of bounded variation and its representation as difference of monotonic functions,	Know the concept of convergence and divergence series	Lecture	MA6204.4	
42	function of bounded variation and its representation as difference of monotonic functions,	Know the concept of convergence and divergence series	Lecture	MA6204.4	
43	differentiation of indefinite integral	Know the concept of convergence and divergence series	Lecture	MA6204.4	
44	Fundamental theorem of calculus	Know the concept of convergence and divergence series	Lecture	MA6204.4	
45	Fundamental theorem of calculus	Know the concept of convergence and divergence series	Lecture	MA6204.4 MA6204.5	
46	Doubt Class	Know the concept of convergence and divergence series	Lecture	MA6204.4	
47	absolutely continuous functions and their properties	Understand the concept of Alternating series	Lecture	MA6204.4	
48	Fundamental theorem of calculus	Understand the concept of Alternating series	Lecture	MA6204.4 MA6204.5	
49	Fundamental theorem of calculus	Know the concept of convergence and divergence of Alternating series	Lecture	MA6204.4 MA6204.5	

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES							CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PSO 1	PSO 2	PSO 3
MA6111.1	Describe the concept of Measurable Sets, outer measure and Lebesgue measure of a set of real numbers.	1							2	3	3
MA6111.2	Describe the concept of Borel set, open, closed, and non-measurable sets	1							3	2	

MA6111.3	Describe the concept the measurable functions and their equivalent formulations	1			2				2	2	2
MA6111.4	Describe the concept in Lebesgue Integral	1			2				3	1	
MA6111.5	Evaluate the solution of mathematical problem, which make them employable	1							1	1	2

H. Course Articulation Matrix: (Mapping of COs with POs)

MANIPAL UNIVERSITY JAIPUR

School of Basic Sciences

DEPARTMENT OF MATHEMATICS & STATISTICS

Course Hand-Out

Research Methodology and Technical Writing | MA6205 | 3 Credits | 2 1 0 3

Session: Jan 21– May 21 | Faculty: Dr. Ram Naresh Saraswat | Class: M.SC. Mathematics

A. Introduction: This course is offered by Dept. of Mathematics and Statistics for postgraduate students. This course is designed as a basic course of research methodology and technical writing for students of under postgraduate program. Mainly the course is divided in two part one is research methodology and other is study of technical writing. We will begin with a general overview of research methodology. It offers in depth knowledge of foundations of research, understanding the language of research, research process; features of a good research design; statistical techniques and tools; paper writing, ethical issues related to publishing of a research paper, plagiarism. Further, we will study the LATEX and MATLAB. So, the objective of this course is to provide a research methodology and technical writing knowledge of scientific research problem.

B. Course Outcomes: At the end of the course, students will be able to:

[MA 6205.1]. Describe and analysis of scientific research problem.
[MA 6205.2]. Describe the concepts of research designs which enhance their interpretation skills.
[MA 6205.3]. Describe the concepts of classification of data and their measurement in research.
[MA 6205.4]. Describe the concept of statistical tools, estimation and hypothesis testing to choose the appropriate analytical tools which enhance their problem solving skills and make them employable.
[MA 6205.5]. Write and interpret a research paper and describe ethical issues related to publishing of paper.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

[PO.1]. **Critical Thinking:** Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational and personal) from different perspectives.

[PO.2]. **Effective Communication:** Speak, read, write and listen clearly in person and through electronic media in English and in one Indian language, and make meaning of the world by connecting people, ideas, books, media and technology.

[PO.3]. **Social Interaction:** Elicit views of others, mediate disagreements and help reach conclusions in group settings.

[PO.4]. **Effective Citizenship:** Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering.

[PO.5]. **Ethics:** Recognize different value systems including your own, understand the moral dimensions of your decisions, and accept responsibility for them.

[PO.6]. **Environment and Sustainability:** Understand the issues of environmental contexts and sustainable development.

[PO.7]. **Self-directed and Life-long Learning:** Acquire the ability to engage in independent and life-long learning in the broadest context socio-technological changes.

[PSO.1]. To understand fundamental principles of molecular biology, molecular cell biology and bioinformatics

[PSO.2]. Modern approaches in biotechnology: the 'omics technologies including proteomics, transcriptomic, metabolomics and bioprocessing

[PSO.3]. Management and communication skills, including problem definition, project design, data collection and interpretation using statistical tools, decision processes, teamwork, written and oral reports, scientific publications

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Closed Book)	20
	Sessional Exam II (Closed Book)	20
	In class Quizzes and Assignments, Activity feedbacks (Accumulated and Averaged)	20
End Term Exam (Summative)	End Term Exam (Closed Book)	40
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	Students who misses a class will have to report to the teacher about the absence. A makeup assignment on the topic taught on the day of absence will be given which has to be submitted within a week from the date of absence. No extensions will be given on this. The attendance for that particular day of absence will be marked blank, so that the student is not accounted for absence. These assignments are limited to a maximum of 5 throughout the entire semester.	
Homework/ Home Assignment/ Activity Assignment (Formative)	There are situations where a student may have to work in home, especially before a flipped classroom. Although these works are not graded with marks. However, a student is expected to participate and perform these assignments with full zeal since the activity/ flipped classroom participation by a student will be assessed and marks will be awarded.	

E. SYLLABUS

Foundations of Research: Meaning, objectives, motivation, utility, empiricism, deductive and inductive theory, characteristics of scientific method , understanding the language of research; **Research Process:** Problem identification & formulation, research question, investigation question, measurement issues, hypothesis, qualities of a good hypothesis, types of hypothesis; **Research Design:** Concept and importance in research, features of a good research design, exploratory research design, descriptive research designs, experimental research design; **Types of Data:** Classification of data, uses, advantages, disadvantages, sources; **Measurement:** Concept of measurement, problems in measurement in research, validity and reliability, levels of measurement; **Statistical Techniques and Tools:** Introduction of statistics, functions, limitations, graphical representation, measures of central tendency, measure of dispersion, skewness, kurtosis, correlation, regression, tests of significance based on t, F, Chi-square, Z and ANOVA test; **Paper Writing:** Layout of a research paper, Scopus/Web of Science journals, impact factor of journals, when and where to publish, ethical issues related to publishing, plagiarism and self-plagiarism. Introduction to LATEX and MATLAB.

F. REFERENCE BOOKS

1. C.R. Kothari, Research Methodology Methods & Techniques, New Age International Publishers, Reprint 2008.
2. R. Singh, Research Methodology, Saga Publication, 4th edition, 2014.
3. J. Anderson and M. Poole, Thesis and Assignment Writing, Wiley India 4th edition, 2011.
4. Mukul Gupta and Deepa Gupta, Research Methodology, PHI Learning Private Ltd., New Delhi, 2011.
5. S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons, New Delhi, 1999.

G. Lecture Plan:

Class Number	Topics	Session Outcome	Mode of Delivery	Corresponding Course Outcome	Mode of Assessing the Outcome
1	Introduction and Course Hand-out briefing of Research Methodology and Technical Writing	To understand basics about Research Methodology and Technical Writing	Lecture Interaction	-	NA
2	Foundations of Research: Meaning, objectives	To develop understanding of the basic framework of research process	Lecture	CO I	In Class Quiz Home Assignment
3	Foundations of Research: Motivation, utility, empiricism	To develop understanding of the basic framework of research process	Lecture	CO I	In Class Quiz Home Assignment
4	Deductive and inductive theory	To develop understanding of the basic framework of research process	Lecture	CO I	In Class Quiz Home Assignment
5	Characteristics of scientific method	To develop understanding of the basic framework of research process	Lecture	CO I	In Class Quiz Home Assignment
6	Understanding the language of research	To develop understanding of the basic framework of research process	Lecture	CO I	In Class Quiz Home Assignment
7	Research Process: Problem identification & formulation	To develop understanding of the basic framework of research process	Lecture	CO I	In Class Quiz Home Assignment
8	Research question, Investigation question, measurement issues	To develop understanding of the basic framework of research process	Lecture	CO I	In Class Quiz Home Assignment
9	Hypothesis, qualities of a good hypothesis	To develop understanding of the basic framework of research process.	Lecture	CO I	In Class Quiz Home Assignment
10	Types of hypothesis	To develop understanding of the basic framework of research process	Lecture	CO I	In Class Quiz Home Assignment
11	Research Design: Concept and importance in research	To develop an understanding of various research designs and techniques	Lecture	CO II	In Class Quiz Home Assignment
12	Features of a good research design	To develop an understanding of various research designs and techniques	Lecture	CO II	In Class Quiz Home Assignment
13	Exploratory research design, descriptive research designs, experimental research design	To develop an understanding of various research designs and techniques	Lecture	CO II	In Class Quiz Home Assignment
14	Types of Data: Classification of data, uses	To develop an understanding of various research designs and techniques	Lecture	CO III	In Class Quiz Home Assignment
15	Types of Data: Advantages, disadvantages, sources	To develop an understanding of various research designs and techniques	Lecture	CO III	In Class Quiz Home Assignment
16	Measurement: Concept of measurement, problems in measurement in research	To develop an understanding of various research designs and techniques	Lecture	CO III	In Class Quiz Home Assignment
17	Measurement: Validity and reliability, levels of measurement	To develop an understanding of various research designs and techniques	Lecture	CO III	In Class Quiz Home Assignment
18	Statistical Techniques and Tools: Introduction of statistics, functions, limitations	To understand basics about statistical techniques and tools	Lecture	CO IV	In Class Quiz Home Assignment

19	Graphical representation, measures of central tendency, measure of dispersion	To understand conceptual framework of Statistical Inference	Lecture	CO IV	In Class Quiz Home Assignment
20	Skewness, kurtosis	To understand conceptual framework of Statistical Inference	Lecture	CO IV	In Class Quiz Home Assignment
21	Correlation	To understand conceptual framework of Statistical Inference	Lecture	CO IV	In Class Quiz Home Assignment
22	Regression	To understand conceptual framework of Statistical Inference	Lecture	CO IV	In Class Quiz Home Assignment
FIRST SESSIONAL EXAM					
23	Tests of significance based on t	To understand conceptual framework of Statistical Inference	Lecture	CO IV	In Class Quiz Home Assignment
24	Problem Solving Class	To understand conceptual framework of Statistical Inference	Lecture	CO IV	In Class Quiz Home Assignment
25	Tests of significance based on F	To understand conceptual framework of Statistical Inference	Lecture	CO IV	In Class Quiz Home Assignment
26	Tests of significance based on Chi-square	To understand conceptual framework of Statistical Inference	Lecture	CO IV	In Class Quiz Home Assignment
27	Problem Solving Class	To understand conceptual framework of Statistical Inference	Lecture	CO IV	In Class Quiz Home Assignment
28	Tests of significance based on Z-test	To understand conceptual framework of Statistical Inference	Lecture	CO IV	In Class Quiz Home Assignment
29	ANOVA test	To understand conceptual framework of Statistical Inference	Lecture	CO IV	In Class Quiz Home Assignment
30	Problem Solving Class	To understand conceptual framework of Statistical Inference	Lecture	CO IV	In Class Quiz Home Assignment
31	Paper Writing: Layout of a research paper	To understand basics about the components of writing and evaluate quality research	Lecture	CO IV	In Class Quiz Home Assignment
32	Paper Writing: Scopus/Web of Science journals, impact factor of journals	To understand basics about the components of writing and evaluate quality research	Lecture	CO V	In Class Quiz Home Assignment
33	Paper Writing: Technical Sections Examples of reports, Journal papers, Conference papers	To understand basics about the components of writing and evaluate quality research	Lecture	CO V	In Class Quiz Home Assignment
34	When and where to publish, ethical issues related to publishing	To understand basics about the components of writing and evaluate quality research	Lecture	CO V	In Class Quiz Home Assignment
35	Brief information about Plagiarism and self-plagiarism	To understand basics about the components of writing and evaluate quality research	Lecture	CO V	In Class Quiz Home Assignment
36	How to avoid Plagiarism and self-plagiarism	To understand basics about the components of writing and evaluate quality research	Lecture	CO V	In Class Quiz Home Assignment

SECOND SESSIONAL EXAM					
37	Introduction to LATEX	To understand basics about LATEX	Lecture	CO V	In Class Quiz Home Assignment
38	Practical Class of LATEX	To understand basics about LATEX	Lecture	CO V	In Class Quiz Home Assignment
39	Practical Class of LATEX	To understand basics about LATEX	Lecture	CO V	In Class Quiz Home Assignment
40	Introduction to MATLAB	To understand basics about MATLAB	Lecture	CO V	In Class Quiz Home Assignment
41	Practical Class of MATLAB	To understand basics about MATLAB	Lecture	CO V	In Class Quiz Home Assignment
42	Practical Class of MATLAB	To understand basics about MATLAB	Lecture	CO V	In Class Quiz Home Assignment
END TERM EXAM					

H. Course Articulation Matrix: (Mapping of COs with POs & PSOs)

CO	**STATEMENT**	Correlation with Program Outcomes **(POs)**							Correlation with Program Specific Outcomes (**PSOs)**		
		PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PSO 1**	**PSO 2**	**PSO 3**
[MA6205.1]	Describe and analysis of scientific research problem	**3**						**2**			**3**
[MA6205.2]	Describe the concepts of research designs which enhance their interpretation skills	**3**									**2**
[MA6205.3]	Describe the concepts of classification of data and their measurement in research	**3**		**2**							**2**
[MA6205.4]	Describe the concept of statistical tools, estimation and hypothesis testing to choose the appropriate analytical tools	**3**									**3**
[MA6205.5]	Write and interpret a research paper and describe ethical issues related to publishing of paper	**3**	**3**								**3**

1.Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Basic Sciences

Department of Mathematics & Statistics
Course Hand-out

LAB ON OPTIMIZATION THEORY AND TECHNIQUES | MA6230 | 1 Credits | 0 0 1 2

Session: Jan. – May. 2021| Faculty: Dr. Mohammad Rizwanullah | Class: M.Sc.

A. Introduction: This course is designed as a foundation lab course of optimization techniques. We will begin with a general overview of Optimization techniques, its classification and then go into more detail about different Optimization techniques use in decision-making process in Engineering and management. Since Optimization techniques are like a water molecule which is known as universal solvent. Same as water molecule, the application of optimization techniques are use in every field of engineering, science, commerce, management etc. The course's objective is to provide a theoretical & practical knowledge of different opt. techniques used in engineering, business and industry for optimal decision making.

B. Course Outcomes: At the end of the course, students will be able to

[6230.1] understand the basic concepts of Optimization Techniques,
[6230.2] to understand the concept of various software using for optimization,
[6230.3] apply Fibonacci golden section and quadratic interpolation methods for one dimensional problems,
[6230.4] to apply Kuhun-Tucker necessary conditions for optimality, solution of simple NLPP using K-T conditions, Beale's method, restricted basis entry method (Wolfe's method) to help in employability.
[6230.5] Rozen's gradient projection method for linear constraints
[6230.6] to skills enhance the application of Kelly's cutting plane method to deal with nonlinear constraints

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

PO.1	to teach a wide range of Mathematics & Statistics at a basic level and stimulate the interest of students in Mathematics & Statistics
PO.2	producing graduates who are well grounded in the fundamentals of Mathematics & Statistics and acquisition of the necessary skills, in order to use their knowledge in Mathematics & Statistics in a wide range of practical application.
PO.3	To acquire discipline – based skills in pure Mathematics, applied Mathematics, Mathematical Statistics and Operations research.
PO.4	To analyse situations, search for truth and extract information, formulate and solve problems in a systematic and logical manner.
PO.5	Graduates of the program will continue to learn and to adapt in a world of constantly evolving and innovative technology
PO.6	Function on multidisciplinary teams by working cooperatively, creatively and responsibly as a member of a team
PO.7	Pursue for Master's program in Mathematics, Statistics and Operations Research.
PSO.1	to understand the basic Mathematical & Statistical principles and to explain them clearly.
PSO.2	to apply these principles both in simple exercises and in more complex problems of advanced Mathematics & Statistics
PSO.3	to develop creative thinking and the power of imagination.
PSO.4	to expose the graduates in research in academia and industry for broader applications

D. Assessment Plan:

Criteria	Description	Maximum Marks
Lab	Practical Lab Exam	40
	Day to Day Assessment	60
	Total	100

Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.
Homework/ Home Assignment/ Activity Assignment (Formative)	There are situations where a student may have to work in home, especially before a flipped classroom. Although these works are not graded with marks. However, a student is expected to participate and perform these assignments with full zeal since the activity/ flipped classroom participation by a student will be assessed and marks will be awarded.

E. SYLLABUS

Fibonacci golden section and quadratic interpolation methods for one dimensional problems, Kuhun-Tucker necessary conditions for optimality, solution of simple NLPP using K-T conditions, Beale's method, restricted basis entry method (Wolfe's method), duality in quadratic programming, Methods of feasible directions, Zoutendijk's method, Rozen's gradient projection method for linear constraints, Kelly's cutting plane method to deal with nonlinear constraints. Reference:

Text-Book:

1. **Hadley, G.,** Linear Programming, Narosa Publishing House, 1995.
2. **Sharma, J.K.** (2001). **Fundamentals of Operations Research**. *Macmillan India Ltd.*, New Delhi.
3. **N.D. Vohra (2009). Quantitative Techniques in Management**, 4/e, TMH, New Delhi.
4. M.W. Carter and Camille C, Operation Research: A Practical Introduction, CRC Press, 1st edition, 2000.

Recommended Reference Books:

1. **Levin, R.I.** and **Rubin, D.S:** (2000). **Statistics for Management**, *Prentice Hall of India*, New Delhi.
2. **K.K. Chawla, B.K. Sharma**; *Operational Research & Quantitative Analysis for Management*, Kalyani Publications. (2011).
3. **Taha H**.A., *Operations Research: An Introduction* – 9/e, PHI.
4. **Sharma, S.D. Operations Research: Theory, Methods and Application**, Kedar Nath, Ram Nath & Co.
5. **Kapoor, V.K.** (1999). **Operations Research**. *Sultan Chand and Sons*, New Delhi.

I. Lecture Plan:

LEC NO	TOPICS	Session Outcome	Mode of Deliver	Corresponding CO	Mode of assessing the outcome
1	Graphical Method to solve LPP: Problem based on Maximization Case	To learn Graphical solution method of solve LPP: Maximization and Minimization case using software	Demonstration	6230.1	Quiz I, Viva voce & End Term
2	General Linear Programming Problem (General L.P.P):	To understand the Basics of LPP in general form	Demonstration	6230.2	Quiz I, Viva voce & End Term
3	Simplex Method to solve LPP: Concepts & Terminologies used and Application	To learn concept and application of Simplex method and its terminologies	Demonstration	6230.4	Quiz I, Viva voce & End Term
4	Degeneracy in LPP Numerical Problems	To learn the breaking of degeneracy cases in LPP	Demonstration	6230.4	Quiz I, Viva voce & End Term
5	Fibonacci golden section	To learn the concept of Fibonacci golden section	Demonstration	6230.4	Quiz I, Viva voce & End Term
6	The Two-Phase method: Basic Concept	To understand the concept of Two phase Method to solve LPP and it algorithm	Demonstration	6230.4	Quiz I, Viva voce & End Term
7	quadratic interpolation methods for one dimensional problems	To understand the concept of quadratic interpolation methods for one dimensional problems	Demonstration	6230.4	Quiz I, Viva voce & End Term
8	Kuhun-Tucker necessary conditions for optimality	To learn method Kuhun-Tucker necessary conditions for optimality	Demonstration	6230.5	Quiz II, Viva voce & End Term
9	solution of simple NLPP using K-T conditions	To learn the concept of solution of simple NLPP using K-T conditions	Demonstration	6230.5	Quiz II, Viva voce & End Term
10	Beale's method	To learn the concept of Beale's method	Demonstration	6230.5	Quiz II, Viva voce & End Term

11	restricted basis entry method (Wolfe's method): Basis Concepts Steps to find optimization solution	To learn restricted basis entry method (Wolfe's method),	Demonstration	6230.5	Quiz II, Viva voce & End Term
12	duality in quadratic programming, Methods of feasible directions, Zoutendijk's method, Rozen's gradient projection method for linear constraints	To understand the duality in quadratic programming, Methods of feasible directions, Zoutendijk's method, Rozen's gradient projection method for linear constraints	Demonstration	6230.5	Quiz II, Viva voce & End Term
13	Kelly's cutting plane method to deal with nonlinear constraints.	To understand the concept of Kelly's cutting plane method to deal with nonlinear constraints.	Demonstration	6230.6	Quiz II, Viva voce & End Term

2. **Course Articulation Matrix: (Mapping of COs with POs)**

CO	STATEMENT	CORRELATION WITH PROGRAM SPECIFIC OUTCOMES							CORRELATION WITH PROGRAM SPECIFIC OUTCOMES			
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PSO 1	PSO 2	PSO 3	PSO 4
MA6230.1	understand the basic concepts of Optimization Techniques,		2		2				2			
MA6230.2	to understand the concept of various software using for optimization,	2	1		2					2		
MA6230.3	apply Fibonacci golden section and quadratic interpolation methods for one dimensional problems,			3		3	2	2			2	
MA6230.4	to apply Kuhun-Tucker necessary conditions for optimality, solution of simple NLPP using K-T conditions, Beale's method, restricted basis entry method (Wolfe's method) to help in employability.	2				3	2	2			2	
MA6230.5	Rozen's gradient projection method for linear constraints	1	2	2		3	2	2			2	
MA6230.6	to skills enhance the application of Kelly's cutting plane method to deal with nonlinear constraints	3		2	2	3	2	2				2

1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation