ST. JOSEPH'S COLLEGE (AUTONOMOUS), DEVAGIRI, CALICUT

B.Sc. DEGREE PROGRAMME

ST. JOSEPH'S CHOICE BASED CREDIT SEMESTER SYSTEM (SJCBCSSUG - 2019)

MATHEMATICS

(CORE, OPEN & COMPLEMENTARY COURSES)

SYLLABUS

(With effect from 2019 admission onwards)

Syllabus structure

The following courses are compulsory for B.Sc. Mathematics programme.

Sl. No	Code	Name of the course	Semester	No of contact hours/week	Credits	Max. Marks			Ext.Exam dur.(Hrs)
						Internal	External	Total	
1	GMAT1B01T	Basic Logic and Calculus	1	4	4	20	80	100	2.5
2	GMAT2B02T	Calculus and Infinite Series	2	4	4	20	80	100	2.5
3	GMAT3B03T	Geometry and Vector Calculus	3	5	4	20	80	100	2.5
4	GMAT4B04T	Multivariable And Vector Calculus	4	5	4	20	80	100	2.5
5	GMAT5B05T	Abstract Algebra	5	5	4	20	80	100	2.5
6	GMAT5B06T	Real Analysis	5	5	4	20	80	100	2.5
7	GMAT5B07T	Numerical Analysis	5	4	3	15	60	75	2
8	GMAT5B08T	Theory of Equations and Number Theory	5	4	3	15	60	75	2
9	GMAT5B09T	Linear Programming	5	3	3	15	60	75	2
		Project	5	1	Exam at the end of 6th Semester				
10		Open Course (offered by Other Departments)	5	3	3	15	60	75	2
11	GMAT6B10T	Advanced Real Analysis	6	5	5	20	80	100	2.5
12	GMAT6B11T	Complex Analysis	6	5	5	20	80	100	2.5
13	GMAT6B12T	Linear Algebra	6	5	4	20	80	100	2.5
14	GMAT6B13T	Differential Equations	6	5	4	20	80	100	2.5
15		Elective*	6	3	2	15	60	75	2
16	GMAT6B14D	Project	6	2	2	15	60	75	
		Total			58			1450	

*Elective Courses

One of the following four courses can be offered in the sixth semester as an elective course

Sl. No	Code	Name of the course	Semester	No of contact hours/week	Credits	Max. Marks			Exam dur.(Hrs)
						Internal	External	Total	
1	GMAT6E01T	Graph Theory	6	3	2	15	60	75	2
2	GMAT6E02T	Topology of Metric spaces	6	3	2	15	60	75	2
3	GMAT6E03P	Mathematical Programming with Python and Latex	6	3	2	15	60	75	2
4	GMAT6E04T	Introduction to Geometry	6	3	2	15	60	75	2

Open Courses

One of the following four courses can be offered in the fifth semester as an open course for students from other Degree programmmes

Sl. No	Code	Name of the course	Semester	No of contact hours/week	Credits	Max. Marks			Ext exam Dur.(Hrs)
						Internal	External	Total	
1	GMAT5D01T	Applied Calculus	5	3	3	15	60	75	2
2	GMAT5D02T	Discrete Mathematics for Basic and Applied Sciences	5	3	3	15	60	75	2
3	GMAT5D03T	Linear Mathematical Models	5	3	3	15	60	75	2
4	GMAT5D04T	Mathematics for Decision Making	5	3	3	15	60	75	2

Complementary Courses (For Students of other UG Programmes)

Sl. No	Code	Name of the course	Semester	No of contact hours / week	Credits	Max. Marks			External Exam Dur (Hrs)
						Internal	External	Total	
1	GMAT1C01T	Mathematics-1	1	4	3	15	60	75	2
2	GMAT2C02T	Mathematics-2	2	4	3	15	60	75	2
3	GMAT3C03T	Mathematics-3	3	5	3	15	60	75	2
4	GMAT4C04T	Mathematics-4	4	5	3	15	60	75	2

Credit and Mark Distribution of B.Sc. Mathematics Programme

<table>
<tr><th>Sl. No</th><th colspan="2">Course</th><th colspan="2">Credits</th><th colspan="2">Marks</th></tr>
<tr><td>1</td><td colspan="2">English</td><td colspan="2">22</td><td colspan="2">550</td></tr>
<tr><td>2</td><td colspan="2">Additional Language</td><td colspan="2">16</td><td colspan="2">400</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Core Course</td><td>13 Courses</td><td>51</td><td rowspan="3">55</td><td>1225</td><td rowspan="3">1375</td></tr>
<tr><td>1 Elective</td><td>2</td><td>75</td></tr>
<tr><td>Project</td><td>2</td><td>75</td></tr>
<tr><td>4</td><td colspan="2">Complementary course I - Statistics</td><td colspan="2">12</td><td colspan="2">300</td></tr>
<tr><td>5</td><td colspan="2">Complementary course II - Physics</td><td colspan="2">12</td><td colspan="2">400</td></tr>
<tr><td>6</td><td colspan="2">Open Course</td><td colspan="2">3</td><td colspan="2">75</td></tr>
<tr><td></td><td colspan="2">Total</td><td colspan="2">120</td><td colspan="2">3100</td></tr>
</table>

Scheme of Evaluation

The evaluation scheme for each course shall contain two parts:
Internal evaluation and External evaluation.

Internal Evaluation

20% of the total marks in each course are for internal evaluation.

The internal assessment shall be based on a predetermined transparent system involving written test, Class room participation based on attendance.
For the test paper marks, at least one test paper of one hour duration should be conducted. If more test papers are conducted, the mark of the best one should be taken.

Components of Internal Evaluation

Sl No	Components	Marks (For Courses with Max. Marks 75)	Marks (For Courses with Max. Marks 100)
1	Class Room Participation (Attendance)	3	4
2	Assignment	3	4
3	Seminar	3	4
4	Test paper	6	8
	Total	15	20

(a) Percentage of Class Room Participation (Attendance) in a Semester and Eligible Internal Marks

% of Class Room Participation (Attendance)	Out of 3 (Maximum internal marks is 15)	Out of 4 (Maximum internal marks is 20)
50% ≤ CRP < 75%	1	1
75% ≤ CRP < 85%	2	2
85% and above	3	4

CRP means % of class room participation (Attendance)

(b) Percentage of Marks in a Test Paper and Eligible Internal Marks

Range of Marks in test paper (TP)	Out of 6 (Maximum internal marks is 15)	Out of 8 (Maximum internal marks is 20)
Less than 35%	1	1
35% ≤ T P < 45%	2	2
45% ≤ T P < 55%	3	3
55% ≤ T P < 65%	4	4
65% ≤ T P < 85%	5	6
85% ≤ T P ≤ 100%	6	8

Evaluation of Project

1. Evaluation of the Project Report shall be done under Mark System.

2. The evaluation of the project will be done at two stages:

   - Internal Assessment (supervising teachers will assess the project and award internal Marks)
   - External evaluation (external examiner appointed by the College)

3. Grade for the project will be awarded to candidates, combining the internal and external marks.

4. The internal to external components is to be taken in the ratio 1:4.

Assessment of different components may be taken as below.

Internal assessment of Project (15 Marks)

(Supervising Teacher will assess the Project and award internal Marks)

Internal assessment of the project will be based on its content, method of presentation, final conclusion and orientation to research aptitude.

Sl. No.	Components	Internal Marks
1	Originality	3
2	Methodology	3
3	Scheme / Organization of Report	4.5
4	Viva Voce	4.5
	Total	15

External Evaluation of Project (60 Marks)

(To be done by the External Examiner appointed by the College)

Sl. No.	Components	External Marks
1	Relevance of the Topic, Statement of Objectives	12
2	Reference/ Bibliography, Presentation, quality of Analysis/ Use of Statistical Tools.	12
3	Findings and recommendations	18
4	Viva-Voce	18
	Total	60

Pattern of Question Paper for External Examinations

	For Courses with Max. External Marks 80 (2.5Hrs)		For Courses with Max. External Marks 60 (2 Hrs)	
Section A	Short answer type carries 2 marks each - 15 questions	Ceiling - 25	Short answer type carries 2 marks each - 12 questions	Ceiling - 20
Section B	Paragraph/ Problem Type carries 5 marks each - 8 questions	Ceiling - 35	Paragraph/ Problem Type carries 5 marks each - 7 questions	Ceiling - 30
Section C	Essay type carries 10 marks (2 out of 4)	2×10 = 20	Essay type carries 10 marks (1 out of 2)	1×10 = 10
Total		80		60

* Questions are to be evenly distributed over the entire syllabus. At least 20% of questions from each module must be included in each section of the question paper for courses having four modules in the syllabus and 30% for courses having three modules in the syllabus.

Ten point Indirect Grading System

% of Marks (Both Internal & external put together)	Grade	Interpretation	Grade Point Average	Range of Grade points	Class
95 and above	O	Outstanding	10	9.5 - 10	First Class with distinction
85 to below 95	A^+	Excellent	9	8.5 - 9.49	
75 to below 85	A	Very good	8	7.5 – 8.49	
65 to below 75	B^+	Good	7	6.5 – 7.49	First Class
55 to below 65	B	Satisfactory	6	5.5 – 6.49	
45 to below 55	C	Average	5	4.5 – 5.49	Second Class
35 to below 45	P	Pass	4	3.5 – 4.49	Third class
Below 35	F	Failure	0	0	Fail
Incomplete	I	Incomplete	0	0	Fail
Absent	Ab	Absent	0	0	Fail

PSOs	PROGRAMME SPECIFIC OUTCOMES
PSO1	Disciplinary knowledge: (i) Capability of demonstrating comprehensive knowledge of mathematics and understanding of one or more disciplines which form a part of an undergraduate programme of study.
PSO2	Communications skills: (i) Ability to communicate various concepts of mathematics effectively using examples and their geometrical visualizations. (ii) Ability to use mathematics as a precise language of communication in other branches of human knowledge. (iii) Ability to show the importance of mathematics as precursor to various scientific developments since the beginning of the civilization
PSO3	Critical Thinking: (i) Ability to employ critical thinking in understanding the concepts in every area of mathematics.
PSO4	Analytical Reasoning: (ii) Ability to analyze the results and apply them in various problems appearing in different branches of mathematics.
PSO5	Problem solving: (i) Capability to solve problems using concepts of linear algebra. (ii) Capability to solve various models such as growth and decay models, radioactive decay model, LCR circuits and population models using techniques of differential equations. (iii) Ability to solve linear system of equations, linear programming problems and network flow problems. (iv) Ability to provide new solutions using the domain knowledge of mathematics acquired during this programme
PSO6	Research-related skills: (i) Capability for inquiring about appropriate questions relating to the concepts in various fields of mathematics. (ii) To know about the advances in various branches of mathematics.
PSO7	Information/digital literacy: (i) Capability to use appropriate software to solve system of equations and differential equations.
PSO8	Self-directed learning: (i) Ability to work independently and do in-depth study of various notions of mathematics.
PSO9	Lifelong learning: (i) Ability to think, acquire knowledge and skills through logical reasoning and to inculcate the habit of self-learning.
PSO10	Application skills: (i) Ability to apply the acquired knowledge in all aspects.
PSO11	Experimental skills:
PSO12	Moral and ethical awareness/reasoning: (i) Ability to identify unethical behaviour such as fabrication, falsification or misrepresentation of data and adopting objective, unbiased and truthful actions in all aspects

CORE COURSES

FIRST SEMESTER
GMAT1B01T: BASIC LOGIC &CALCULUS

Lecture Hours/ week: 4 **Credits: 4**
Marks: 100(Internal: 20, External: 80) **Examination: 2.5 Hours**

Aims, Objectives and Outcomes

Logic, the study of principles of techniques and reasoning, is fundamental to every branch of learning. Besides, being the basis of all mathematical reasoning, it is required in the field of computer science for developing programming languages and also to check the correctness of the programmes. Electronic engineers apply logic in the design of computer chips. The first module discusses the fundamentals of logic, its symbols and rules. This enables one to think systematically, to express ideas in precise and concise mathematical terms and also to make valid arguments. How to use logic to arrive at the correct conclusion in the midst of confusing and contradictory statements is also illustrated.

The mathematics required for viewing and analyzing the physical world around us is contained in calculus. While Algebra and Geometry provide us very useful tools for expressing the relationship between static quantities, the concepts necessary to explore the relationship between moving/changing objects are provided in calculus. The objective of the course is to introduce students to the fundamental ideas of limit, continuity and differentiability and also to some basic theorems of *differential calculus*. It is also shown how these ideas can be applied in the problem of sketching of curves and in the solution of some optimization problems of interest in real life.

The topics also deal with the other branch of calculus *viz. integral calculus.* Historically, it is motivated by the geometric problem of finding out the area of a planar region. The idea of *definite integral* is defined with the notion of limit. A major result is the *Fundamental Theorem of Calculus,* which not only gives a practical way of evaluating the definite integral but establishes the close connection between the two branches of Calculus.

COs	**COURSE OUTCOMES**
CO1	At the end of the course students get able to be familiar to the language of mathematics and they develop their own way of writing and explaining mathematics
CO2	Students experience the classical way of doing and enjoying mathematics in a much more logical way

Syllabus

Text (1)	Discrete Mathematics with Applications : Thomas Koshy, *Elsever Academic Press(2004) ISBN:0-12-421180-1*
Text:(2)	Calculus: Soo T Tan *Brooks/Cole, Cengage Learning (2010)* *ISBN: 978-0-534-46579-7*

Module-I Text (1) (15 hrs)

1.1: Propositions- *definition*, *Boolean (logic) variables*, Truth Value, Conjunction , *Boolean expression*, Disjunction (*inclusive and exclusive*), Negation, Implication, Converse, Inverse and Contra positive, Biconditional statement, Order of Precedence, Tautology Contradiction and Contingency [‘Switching Networks’ omitted]

1.2: Logical equivalences- *laws of logic* [‘Equivalent Switching Networks’ *‘Fuzzy logic’ & ‘Fuzzy decisions’ omitted*]

1.3: Quantifiers- *universal & existential, predicate logic*

1.4: Arguments- valid and invalid arguments, *inference rules*

1.5: Proof Methods – vacuous proof, trivial proof, direct proof, indirect proof-*contra positive& contradiction*, proof by cases , Existence proof-*constructive & non constructive, counterexample*

Module-II Text (2) (14 hrs)

1.1: Intuitive introduction to Limits- A Real-Life Example, Intuitive Definition of a Limit, One-Sided Limits, Using Graphing Utilities to Evaluate Limits

1.2: Techniques for finding Limits- Computing Limits Using the Laws of Limits, Limits of Polynomial and Rational Functions, Limits of Trigonometric Functions, The Squeeze Theorem.

1.3: Precise Definition of a Limit- $\varepsilon - \delta$definition of limit, A Geometric Interpretation, Some illustrative examples

1.4: Continuous Functions- Continuity at a Number, Continuity at an Endpoint, Continuity on an Interval, Continuity of Composite Functions, Intermediate Value Theorem

2.1: The Derivatives- *Definition* only

2.9: Differentials and Linear Approximations- increments, Differentials, Error Estimates, Linear Approximations, Error in Approximating Δy by dy.

Module-III Text (2) (20 hrs)

3.1: Extrema of Functions -Absolute Extrema of Functions, Relative Extrema of Functions, *Fermat's Theorem***,** Finding the Extreme Values of a Continuous Function on a Closed Interval, An Optimization Problem

3.2: The Mean Value Theorem- Rolle's Theorem, *The Mean Value Theorem***,** Some Consequences of the Mean Value Theorem, Determining the Number of Zeros of a Function

3.3: Increasing and Decreasing Functions- *definition , inferring the behavior of function from sign of derivative*, Finding the Relative Extrema of a Function, *first derivative test*

3.4: Concavity and Inflection points- Concavity, Inflection Points, The Second Derivative Test, The Roles of $f'$and f''in Determining the Shape of a Graph

3.5: Limits involving Infinity; Asymptotes- Infinite Limits, Vertical Asymptotes, Limits at Infinity, Horizontal Asymptotes, Infinite Limits at Infinity, Precise Definitions

3.6: Curve Sketching-The Graph of a Function, Guide to Curve Sketching, Slant Asymptotes, Finding Relative Extrema Using a Graphing Utility

3.7: Optimization Problems – *guidelines for finding absolute extrema*, Formulating Optimization Problems- *application involving several real lifeproblems*

Module-IV Text (2) (15 hrs)

4.1: Anti derivatives, Indefinite integrals, Basic Rules of Integration, *a few basic integration formulas and rules of integration*, Differential Equations, Initial Value Problems

4.3: Area- An Intuitive Look, The Area Problem, Defining the Area of the Region Under the Graph of a Function-*technique of approximation['Sigma Notation' and 'Summation Formulas' Omitted]* An Intuitive Look at Area(Continued), Defining the Area of the Region Under the Graph of a Function-*precise definition*, Area and Distance

4.4: The Definite Integral- Definition of the Definite Integral, Geometric Interpretation of the Definite Integral, The Definite Integral and Displacement, Properties of the Definite Integral , More General Definition of the Definite Integral

4.5: The Fundamental Theorem of Calculus- How Are Differentiation and Integration Related?, The Mean Value Theorem for Definite Integrals, The Fundamental Theorem of Calculus: Part I, *inverse relationship between differentiation and integration,* Fundamental Theorem of Calculus: Part 2,Evaluating Definite Integrals Using Substitution, Definite Integrals of Odd and Even Functions, The Definite Integral as a Measure of Net Change.

References:

1	Susanna S Epp: Discrete Mathematics with Applications(4/e) *Brooks/Cole Cengage Learning(2011) ISBN: 978-0-495-39132-6*
2	Kenneth H. Rosen: Discrete Mathematics and Its Applications(7/e) *McGraw-Hill, NY(2007) ISBN: 978-0-07-338309-5*
3	Joel Hass, Christopher Heil & Maurice D. Weir : Thomas' Calculus(14/e) *Pearson (2018) ISBN 0134438981*
4	Robert A Adams & Christopher Essex : Calculus *Single Variable (8/e)Pearson Education Canada (2013) ISBN:* 0321877403
5	Jon Rogawski & Colin Adams : Calculus *Early Transcendentals* (3/e) *W. H. Freeman and Company(2015) ISBN: 1319116450*
6	Anton, Bivens & Davis : Calculus *Early Transcendentals* (11/e) *John Wiley & Sons, Inc.(2016) ISBN: 1118883764*
7	James Stewart : Calculus (8/e) *Brooks/Cole Cengage Learning(2016) ISBN: 978-1-285-74062-1*
8	Jerrold Marsden & Alan Weinstein : Calculus I and II (2/e*)Springer Verlag NY(1985) ISBN 0-387-90974-5 : ISBN 0-387-90975-3*

SECOND SEMESTER
GMAT2B02T: CALCULUS AND INFINITE SERIES

Lecture Hours/ week: 4 **Credits: 4**
Marks: 100(Internal: 20, External: 80) **Examination: 2.5 Hours**

Aims, Objectives and Outcomes

The notion of definite integral not only solves the area problem but is useful in finding out the arc length of a plane curve, volume and surface areas of solids and so on. The integral turns out to be a powerful tool in solving problems in physics, chemistry, biology, engineering, economics and other fields. Some of the applications are included in the syllabus.

Using the idea of definite integral, the natural logarithm function is defined and its properties are examined. This allows us to define its inverse function namely the *natural exponential function* and also the *general exponential function*. Exponential functions model a wide variety of phenomenon of interest in science, engineering, mathematics and economics. They arise naturally when we model the growth of a biological population, the spread of a disease, the radioactive decay of atoms, and the study of heat transfer problems and so on. We also consider certain combinations of exponential functions namely *hyperbolic functions* that also arise very frequently in applications such as the study of shapes of cables hanging under their own weight.

COs	COURSE OUTCOMES
CO1	The students are introduced to the idea of improper integrals, their convergence and evaluation
CO2	This enables to study a related notion of convergence of a series, which is practically done by applying several different tests such as integral test, comparison test and so on
CO3	As a special case, a study on power series- their region of convergence, differentiation and integration etc., is also done

Syllabus

Text	Calculus: Soo T Tan *Brooks/Cole*, *Cengage Learning (2010)* *ISBN: 978-0-534-46579-7*

Module-I (12 hrs)

(Applications of Definite Integral)

5.1: Areas between Curves- A Real Life Interpretation, The Area Between Two Curves, Integrating with Respect to -*adapting to the shape of the region*, What Happens When the Curves Intertwine?

5.2: Volume – Solids of revolution, *Volume by* Disk Method, *Region revolved about the x-axis*, *Region revolved about the y-axis*, *Volume by the* Method of Cross Sections *[‘ Washer Method’ omitted]*

5.4: Arc Length and Areas of surfaces of revolution- Definition of Arc Length, Length of a Smooth Curve, *arc length formula*, The Arc Length Function, *arc length differentials*, Surfaces of Revolution, *surface area as surface of revolution*

Module-II (20 hrs)

(The Transcendental Functions)

6.1: The Natural logarithmic function- *definition*, The Derivative of $\ln x$, Laws of Logarithms, The Graph of the Natural Logarithmic Function, The Derivatives of Logarithmic Functions, Logarithmic Differentiation, Integration Involving Logarithmic Functions

6.3: Exponential Functions- The number *e*, Defining the Natural Exponential Function, *properties*, The Laws of Exponents, The Derivatives of Exponential Functions, Integration of the Natural Exponential Function

6.4: General Exponential and Logarithmic Functions - Exponential Functions with Base *a*, *laws of exponents*, The Derivatives of a^x and a^u, , Graphs of $y= a^x$, integrating a^x, Logarithmic Functions with Base *a*, *change of base formula*, The Power Rule (General Form), The Derivatives of Logarithmic Functions with Base *a*, The Definition of the Number *e* as a Limit *[‘Compound Interest’ omitted]*

6.6: Hyperbolic functions- The Graphs of the Hyperbolic Functions, Hyperbolic Identities, Derivatives and Integrals of Hyperbolic Functions, Inverse Hyperbolic Functions, *representation in terms of logarithmic function*, Derivatives of Inverse Hyperbolic Functions, An Application

6.7: Indeterminate forms and l'Hˆopital rule- *motivation*, The Indeterminate Forms $\frac{0}{0}$ and $\frac{\infty}{\infty}$, The Indeterminate Forms $\infty - \infty$ and $0.\infty$, The Indeterminate forms 0^0, ∞^0 and 1^{∞}.

7.6: Improper integrals – *definition*, Infinite Intervals of Integration, Improper Integrals with Infinite Discontinuities, A Comparison Test for Improper Integrals

Module-III (20 hrs)

(Infinite Sequences and Series)

9.1: Sequences- *definition, recursive definition,* Limit of a Sequence, *limit laws, squeeze theorem*, Bounded Monotonic Sequences, *definition, monotone convergence theorem (only statement; its proof omitted)*

9.2: Series- *defining the sum*, *convergence and divergence*, Geometric Series, The Harmonic Series, The Divergence Test, Properties of Convergent Series

9.3: The Integral Test – investigation of convergence, integral test, The *p* Series, *its convergence and divergence*

9.4: The Comparison Test- *test series*, The Comparison Test, The Limit Comparison Test

Module-IV (12 hrs)

9.5: Alternating Series- *definition, the alternating series test, its proof, examples,* Approximating the Sum of an Alternating Series by S_n.

9.6: Absolute Convergence- *definition*, *conditionally convergent*, The Ratio Test, The Root Test, Summary of Tests for Convergence and Divergence of Series, Rearrangement of Series

9.7: Power Series- *definition,* Interval of Convergence, *radius of convergence,* Differentiation and Integration of Power Series

9.8: Taylor and Maclaurin Series- *definition, Taylor and Maclaurin series of functions,* Techniques for Finding Taylor Series

References:

1	Joel Hass, Christopher Heil & Maurice D. Weir : Thomas' Calculus(14/e) *Pearson (2018) ISBN 0134438981*
2	Robert A Adams & Christopher Essex : Calculus *Single Variable (8/e) Pearson Education Canada (2013) ISBN:* 0321877403
3	Jon Rogawski & Colin Adams : Calculus *Early Transcendentals* (3/e) *W. H. Freeman and Company(2015) ISBN: 1319116450*
4	Anton, Bivens & Davis : Calculus *Early Transcendentals* (11/e) *John Wiley & Sons, Inc.(2016) ISBN: 1118883764*
5	James Stewart : Calculus (8/e) *Brooks/Cole Cengage Learning(2016) ISBN: 978-1-285-74062-1*
6	Jerrold Marsden & Alan Weinstein : Calculus I and II (2/e*) Springer Verlag NY (1985) ISBN 0-387-90974-5 : ISBN 0-387-90975-3*

THIRD SEMESTER
GMAT3B03T: GEOMETRY AND VECTOR CALCULUS

Lecture Hours/ week: 5 **Credits: 4**
Marks: 100(Internal: 20, External: 80) **Examination: 2.5 Hours**

Aims, Objectives and Outcomes

Geometry is, basically, the study concerned with questions of shape, size, and relative position of planar and spatial objects. The classical Greek geometry, also known as *Euclidean geometry* after the work of Euclid, was once regarded as one of the highest points of rational thought, contributing to the thinking skills of logic, deductive reasoning and skills in problem solving.

In the early 17 th century, the works of Rene Descartes and Pierre de Fermat put the foundation stones for the creation of *analytic geometry* where the idea of a coordinate system was introduced to simplify the treatment of geometry and to solve a wide variety of geometric problems.

A detailed study of plane and space curves is then taken up. The students get the idea of parametrization of curves; they learn how to calculate the arc length, curvature etc. using parametrization and also the area of surface of revolution of a parametrized plane curve. Students are introduced into other coordinate systems which often simplify the equation of curves and surfaces and the relationship between various coordinate systems are also taught. This enables them to directly calculate the arc length and surface areas of revolution of a curve whose equation is in polar form. At the end of the course, the students will be able to handle *vectors* in dealing with the problems involving geometry of lines, curves, planes and surfaces in space and have acquired the ability to sketch curves in plane and space given in vector valued form.

The intention of the course is to extend the immensely useful ideas and notions such as limit, continuity, derivative and integral seen in the context of function of single variable to function of several variables. The corresponding results will be the higher dimensional analogues of what we learned in the case of single variable functions. The results we develop in the course of calculus of multivariable are extremely useful in several areas of science and technology as many functions that arise in real life situations are functions of multivariable.

COs	**COURSE OUTCOMES**
CO1	Recall several basic facts about parabola, hyperbola and ellipse (conics) such as their equation in standard form, focal length properties, and reflection properties, their tangents and normal
CO2	Recognise and classify conics

CO3	Explain several contexts of appearance of multivariable functions and their representation using graph and contour diagrams
CO4	Formulate and work on the idea of limit and continuity for functions of several variables
CO5	Explain the notion of partial derivative, their computation and interpretation
CO6	Explain chain rule for calculating partial derivatives
CO7	Get the idea of directional derivative, its evaluation, interpretation, and relationship with partial derivatives
CO8	Explain the concept of gradient, a few of its properties, application and interpretation

Syllabus

Text	Calculus: Soo T Tan *Brooks/Cole, Cengage Learning (2010)* *ISBN: 978-0-534-46579-7*

Module-I (30 hrs)

10.1: Conic Sections- Parabola, Reflective property of the parabola, Ellipses, Reflective property of the ellipse, Eccentricity of an ellipse, Hyperbola, Shifted Conics

10.2: Plane Curves and Parametric Equations- Why We Use Parametric Equations, Sketching Curves Defined by Parametric Equations

10.3: The Calculus of parametric equations- Tangent Lines to Curves Defined by Parametric Equations, Horizontal and Vertical Tangents,
Finding $\frac{d^2y}{dx^2}$ from Parametric Equations, The Length of a Smooth Curve, The Area of a Surface of Revolution

10.4: Polar coordinates-The Polar Coordinate System, Relationship between Polar and Rectangular Coordinates, Graphs of Polar Equations, Symmetry, Tangent Lines to Graphs of Polar Equations

10.5: Areas and Arc Lengths in polar coordinates-Areas in Polar Coordinates, *area bounded by polar curves*, Area Bounded by Two Graphs, Arc Length in Polar Coordinates, Area of a Surface of Revolution, Points of Intersection of Graphs in Polar Coordinates

Module-II (20 hrs)

11.5: Lines and Planes in Space-Equations of Lines in Space, *parametric equation, symmetric equation of a line,* Equations of Planes in Space, *standard equation,* Parallel and Orthogonal Planes, The Angle Between Two Planes, The Distance Between a Point and a Plane

11.6: Surfaces in Space- Traces, Cylinders, Quadric Surfaces, *Ellipsoids, Hyperboloids of One Sheet, Hyperboloids of Two Sheets, Cones, Paraboloids, Hyperbolic Paraboloids*

11.7: Cylindrical and Spherical Coordinates-The Cylindrical Coordinate System, *converting cylindrical to rectangular and vice versa*, The Spherical Coordinate System, *converting spherical to rectangular and vice versa*

Module-III (20 hrs)

12.1: Vector Valued functions and Space Curves- *definition of vector function*, Curves Defined by Vector Functions, *['Example 7' omitted]* Limits and Continuity

12.2: Differentiation and Integration of Vector-Valued Function- The Derivative of a Vector Function, Higher-Order Derivatives, Rules of Differentiation, Integration of Vector Functions,

12.3: Arc length and Curvature- Arc Length *of a space curve*, Smooth Curves, Arc Length Parameter, *arc length function,* Curvature, *formula for finding curvature,* Radius of Curvature

12.4: Velocity and Acceleration- Velocity, Acceleration, and Speed; Motion of a Projectile

12.5: Tangential and Normal Components of Acceleration- The Unit Normal, *principal unit normal vector***,** Tangential and Normal Components of Acceleration *[The subsections ' Kepler's Laws of Planetary Motion ', and `Derivation of Kepler's First Law' omitted]*

Module-IV (10 hrs)

13.1: Functions of two or more variables- Functions of Two Variables, Graphs of Functions of Two Variables, Level Curves, Functions of Three Variables and Level Surfaces

13.2: Limits and continuity-An Intuitive Definition of a Limit, *existence and non existence of limit*, Continuity of a Function of Two Variables, Continuity on a Set, *continuity of polynomial and rational functions*, *continuity of composite functions*, Functions of Three or More Variables, The Definition of a Limit

13.3: Partial Derivatives- Partial Derivatives of Functions of Two Variables, *geometric interpretation*, Computing Partial Derivatives, Implicit Differentiation, Partial Derivatives of Functions of More Than Two Variables, Higher-Order Derivatives, *Clairaut theorem*, *harmonic functions*

13.4: Differentials- Increments, The Total Differential, *interpretation*, Error in Approximating Δz by *[only statement of theorem1 required; proof omitted]* Differentiability of a Function of Two Variables, *criteria*, Differentiability and Continuity, Functions of Three or More Variables

References:

1	Joel Hass, Christopher Heil & Maurice D. Weir : Thomas' Calculus (14/e) *Pearson(2018) ISBN 0134438981*
2	Robert A Adams & Christopher Essex : Calculus *Single Variable (8/e) Pearson Education Canada (2013) ISBN:* 0321877403
3	Jon Rogawski & Colin Adams : Calculus *Early Transcendentals* (3/e) W. H. Freeman and Company(2015) *ISBN: 1319116450*
4	Anton, Bivens & Davis : Calculus *Early Transcendentals* (11/e) *John Wiley & Sons, Inc.(2016) ISBN: 1118883764*
5	James Stewart : Calculus (8/e) *Brooks/Cole Cengage Learning(2016) ISBN: 978-1-285-74062-1*
6	Jerrold Marsden & Alan Weinstein : Calculus I and II (2/e*) Springer Verlag NY(1985) ISBN 0-387-90974-5 : ISBN 0-387-90975-3*

FOURTH SEMESTER
GMAT4B04T: MULTIVARIABLE AND VECTOR CALCULUS

Lecture Hours/ week: 5 **Credits: 4**
Marks: 100(Internal: 20, External: 80) **Examination: 2.5 Hours**

Aims, Objectives and Outcomes

The intention of the course is to extend the immensely useful ideas and notions such as limit, continuity, derivative and integral seen in the context of function of single variable to function of several variables. The corresponding results will be the higher dimensional analogues of what we learned in the case of single variable functions. The results we develop in the course of calculus of multivariable are extremely useful in several areas of science and technology as many functions that arise in real life situations are functions of multivariable.

COs	COURSE OUTCOMES
CO1	Understand the use of partial derivatives in getting information of tangent plane and normal line
CO2	Calculate the maximum and minimum values of a multivariable function using second derivative test and Lagrange multiplier method
CO3	Find a few real life applications of Lagrange multiplier method in optimization problems
CO4	Extend the notion of integral of a function of single variable to integral of functions of two and three variables
CO5	Address the practical problem of evaluation of double and triple integral using Fubini's theorem and change of variable formula
CO6	Realize the advantage of choosing other coordinate systems such as polar, spherical, cylindrical etc. in the evaluation of double and triple integrals
CO7	See a few applications of double and triple integral in the problem of finding out surface area, mass of lamina, volume, centre of mass and so on
CO8	Understand the notion of a vector field, the idea of curl and divergence of a vector field, their evaluation and interpretation
CO9	Understand the idea of line integral and surface integral and their evaluations
CO10	Learn three major results viz. Green's theorem, Gauss's theorem and Stokes' theorem of multivariable calculus and their use in several areas and directions

Syllabus

Text	Calculus: Soo T Tan *Brooks/Cole, Cengage Learning (2010) ISBN 0-534-46579-X)*

Module-I (20 hrs)

13.5: The Chain rule- The Chain Rule for Functions Involving One Independent Variable, The Chain Rule for Functions Involving Two Independent Variables, The General Chain Rule, Implicit Differentiation

13.6: Directional Derivatives and Gradient vectors - The Directional Derivative, The Gradient of a Function of Two Variables, Properties of the Gradient, Functions of Three Variables

13.7: Tangent Planes and Normal Lines- Geometric Interpretation of the Gradient, Tangent Planes and Normal Lines, Using the Tangent Plane of f to approximate the Surface z=f(x, y)

13.8: Extrema of Functions of two variables - Relative and Absolute Extrema, Critical Points—Candidates for Relative Extrema, The Second Derivative Test for Relative Extrema, Finding the Absolute Extremum Values of a Continuous Function on a Closed Set

13.9: Lagrange Multipliers- Constrained Maxima and Minima, The Method of Lagrange Multipliers, *Lagrange theorem*, Optimizing a Function Subject to Two Constraints

Module-II (30 hrs)

14.1: Double integrals- An Introductory Example, Volume of a Solid between a Surface and a Rectangle, The Double Integral over a Rectangular Region, Double Integrals over General Regions, Properties of Double Integrals

14.2: Iterated Integrals-Iterated Integrals over Rectangular Regions, Fubini's Theorem for Rectangular Regions, Iterated Integrals over Nonrectangular Regions, *- simple and - simple regions, advantage of changing the order of integration*

14.3: Double integrals in polar coordinates- Polar Rectangles, Double Integrals over Polar Rectangles, Double Integrals over General Regions, r-simple region, method of evaluation

14.5: Surface Area- Area of a Surface $z=(x,y)$, Area of Surfaces with Equations $y=g(x,z)$ and $x=h(y,z)$

14.6: Triple integrals- Triple Integrals Over a Rectangular Box, *definition, method of evaluation as iterated integrals,* Triple Integrals Over General Bounded Regions in Space, Evaluating Triple Integrals Over General Regions, *evaluation technique*

14.7: Triple Integrals in cylindrical and spherical coordinates- *evaluation of integrals in* Cylindrical Coordinates, Spherical Coordinates

14.8: Change of variables in multiple integrals- Transformations, Change of Variables in Double Integrals *[only the method is required; derivation omitted],* illustrations, Change of Variables in Triple Integrals

Module-III (30 hrs)

15.1: Vector Fields- *V.F. in two and three dimensional space,* Conservative Vector Fields

15.2: Divergence and Curl- *Divergence- idea and definition*, Curl- *idea and definition*

15.3: Line Integrals- *Line integral w.r.t. arc length-motivation, basic idea and definition,* Line Integrals with Respect to Coordinate Variables, *orientation of curve* Line Integrals in Space, Line Integrals of Vector Fields

15.4: Independence of Path and Conservative Vector Fields-*path independence through example, definition, fundamental theorem for line integral,* Line Integrals Along Closed Paths, *work done by conservative vector field,* Independence of Path and Conservative Vector Fields, Determining Whether a Vector Field Is Conservative, *test for conservative vector field* Finding a Potential Function, Conservation of Energy

15.5: Green's Theorem- Green's Theorem for Simple Regions, *proof of theorem for simple regions, finding area using line integral,* Green's Theorem for More General Regions, Vector Form of Green's Theorem

15.6: Parametric Surfaces-Why We Use Parametric Surfaces, Finding Parametric Representations of Surfaces, Tangent Planes to Parametric Surfaces, Area of a Parametric Surface *[derivation of formula omitted]*

15.7: Surface Integrals-Surface Integrals of Scalar Fields, *evaluation of surface integral for surfaces that are graphs, [derivation of formula omitted; only method required]* Parametric Surfaces, *evaluation of surface integral for parametric surface*, Oriented Surfaces, Surface Integrals of Vector Fields-*definition, flux integral*, *evaluation of surface integral for graph [method only],* Parametric Surfaces, *evaluation of surface integral of a vector field for parametric surface [method only]*

15.8: The Divergence Theorem-*divergence theorem for simple solid regions* (*statement only*), *illustrations*, Interpretation of Divergence

15.9: Stokes Theorem-*generalization of Green's theorem –Stokes Theorem, illustrations,* Interpretation of Curl

References:

1	JoelHass, Christopher Heil & Maurice D. Weir : Thomas' Calculus(14/e) *Pearson(2018) ISBN 0134438981*
2	Robert A Adams & Christopher Essex : Calculus: *A complete Course (8/e) Pearson Education Canada (2013) ISBN:* 032187742X
3	Jon Rogawski: Multivariable Calculus *Early Transcendentals* (2/e) W. H. Freeman and Company(2012) *ISBN: 1-4292-3187-4*
4	Anton, Bivens & Davis : Calculus *Early Transcendentals* (10/e) John Wiley & Sons, Inc.(2012) ISBN: 978-0-470-64769-1
5	James Stewart : Calculus (8/e) *Brooks/Cole Cengage Learning(2016) ISBN: 978-1-285-74062-1*
6	Jerrold E. Marsden & Anthony Tromba :Vector Calculus (6/e) *W. H. Freeman and Company ,New York(2012) ISBN: 978-1-4292-1508-4*
7	Arnold Ostebee & Paul Zorn: Multivariable Calculus (2/e) *W. H. Freeman Custom Publishing, N.Y.(2008)ISBN: 978-1-4292-3033-9*

FIFTH SEMESTER
GMAT5B05T: ABSTRACT ALGEBRA

Lecture Hours/ week: 5 — **Credits: 4**

Marks: 100(Internal: 20, External: 80) — **Examination: 2.5 Hours**

Aims, Objectives and Outcomes

Credit goes to the brilliant mathematician Evariste Galois for proving this fact and he developed an entire theory that connected the solvability by radicals of a polynomial equation with the *permutation group* of its roots. The theory now known as *Galois theory* solves the famous problem of *insolvability of quintic.* A study on *symmetric functions* now becomes inevitable. One can now observe the connection emerging between classical algebra and modern algebra. The four modules are therefore devoted to the discussion on basic ideas and results of abstract algebra. Students understand the abstract notion of a group, learn several examples, are taught to check whether an *algebraic system* forms a group or not and are introduced to some fundamental results of group theory. The idea of structural similarity, the notion of cyclic group, permutation group , various examples and very fundamental results in the areas are also explored.

COs	**COURSE OUTCOMES**
CO1	At the end of the course students explain the general way in which algebraic structures are introduced and studied in an abstract fashion
CO2	Students enjoy the construction of algebraic structures and they begin to develop new algebraic structures by generalizing the well known examples

Syllabus

Text	Abstract Algebra(3/e):John A Beachy and William D Blair *Waveland Press, Inc.(2006) ISBN: 1-57766-443-4*

Module-I (15 hrs)

1.4: Integers modulo n- congruence class modulo n, addition and multiplication, divisor of zero, multiplicative inverse

2.2: Equivalence relations-basic idea, definition, equivalence class, factor set, partition and equivalence relation, examples and illustrations

2.3: Permutations- definition, cycles, product of cycles, permutation as product of disjoint cycles, order of cycles, transposition, even and odd transpositions

Module-II (25 hrs)

3.1: Definition of Group-binary operation, uniqueness of identity and inverse, definition and examples of groups, properties, Abelian group, finite and infinite groups, general linear groups

3.2: Subgroups-the notion of subgroup, examples, conditions for a subgroup, cyclic subgroups, order of an element, Lagrange theorem, Euler's theorem

3.3: constructing examples- groups with order up to 6, multiplication table, product of subgroups, direct products, Klein four group as direct product, subgroup generated by a subset

3.4: Isomorphism – definition, consequences, structural properties, method of showing that groups are not isomorphic, isomorphic and non-isomorphic groups.

Module-III (25 hrs)

3.5: Cyclic groups- subgroups of cyclic groups, characterisation, generators of a finite cyclic group, structure theorem for finite cyclic group, exponent of a group, characterisation of cyclic groups among finite abelian groups.

3.6: Permutation groups- definition, Cayley's theorem, rigid motions of n-gons, dihedral group, alternating group

3.7: Homomorphism - basic idea, examples, definition, properties, kernel, normal subgroups, subgroups related via homomorphism

3.8: Cosets- left and right cosets, normal subgroups and factor groups, fundamental homomorphism theorem, simple groups, examples and illustrations of concepts

Module-IV (15 hrs)

4.1: Fields; Roots of polynomials

7.1: (Structure of Groups) Isomorphism theorems; Automorphism- first isomorphism theorem, second isomorphism theorem, inner automorphism (Statements Only)

5.1: Commutative Rings ; Integral Domains- definition, examples, subring, criteria to be a subring, divisor of zero, integral domain, finite integral domain.

References:

1	Joseph A. Gallian : Contemporary Abstract Algebra(9/e) *Cengage Learning, Boston(2017) ISBN: 978-1-305-65796-0*
2	John B Fraleigh : A First Course in Abstract Algebra(7/e) *Pearson Education LPE(2003) ISBN 978-81-7758-900-9*
3	David Steven Dummit, Richard M. Foote: Abstract Algebra(3/e) *Wiley, (2004) ISBN: 8126532289*
4	Linda Gilbert and Jimmie Gilbert: Elements of Modern Algebra (8/e) *Cengage Learning, Stamford(2015) ISBN: 1-285-46323-4*
5	John R. Durbin : Modern Algebra: An Introduction(6/e) *Wiley(2015) ISBN: 1118117611*
6	Jeffrey Bergen: A Concrete Approach to Abstract Algebra- From the integers to Insolvability of Quintic *Academic Pres [Elsever](2010)ISBN: 978-0-12-374941-3*

FIFTH SEMESTER
GMAT5B06T : REAL ANALYSIS

Lecture Hours/ week: 5 **Credits: 4**
Marks: 100(Internal: 20, External: 80) **Examination: 2.5 Hours**

Aims, Objectives and Outcomes

In this course, basic ideas and methods of real and complex analysis are taught. Real analysis is a theoretical version of single variable calculus. So many familiar concepts of calculus are reintroduced but at a much deeper and more rigorous level than in a calculus course. At the same time there are concepts and results that are new and not studied in the calculus course but very much needed in more advanced courses. The aim is to provide students with a level of mathematical sophistication that will prepare them for further work in mathematical analysis and other fields of knowledge, and also to develop their ability to analyze and prove statements of mathematics using logical arguments. The course will enable the students

COs	COURSE OUTCOMES
CO1	To learn and deduce rigorously many properties of real number system by assuming a few fundamental facts about it as axioms. In particular they will learn to prove Archimedean property, density theorem, existence of a positive square root for positive numbers and so on and the learning will help them to appreciate the beauty of logical arguments and embolden them to apply it in similar and unknown problems
CO2	To know about sequences ,their limits, several basic and important theorems involving sequences and their applications . For example, they will learn how monotone convergence theorem can be used in establishing the divergence of the harmonic series, how it helps in the calculation of square root of positive numbers and how it establishes the existence of the transcendental number e (Euler constant)
CO3	To understand some basic topological properties of real number system such as the concept of open and closed sets, their properties, their characterization and so on
CO4	To get a rigorous introduction to algebraic, geometric and topological structures of complex number system, functions of complex variable, their limit and continuity and so on. Rich use of geometry, comparison between real and complex calculus-areas where they agree and where they differ, the study of mapping properties of a few important complex functions exploring the underlying geometry etc. will demystify student's belief that complex variable theory is incomprehensible

Syllabus

Text	Introduction to Real Analysis (4/e): Robert G Bartle, Donald R Sherbert *John Wiley & Sons(2011)ISBN 978-0-471-43331-6*

Module-I (12 hrs)

Chapter 1: Preliminaries

1.3: Finite and Infinite Sets

Chapter 2: The Real Numbers

2.1: The Algebraic and Order Properties of $\mathbb{R}$
2.2: Absolute Value and the Real Line

Module-II (25 hrs)

2.3: The Completeness Property of $\mathbb{R}$
2.4: Applications of the Supremum Property
2.5: Intervals

Chapter 3: Sequences and Series

3.1: Sequences and Their Limits
3.2: Limit Theorems
3.3: Monotone Sequences

Module-III (25 hrs)

3.4: Subsequences and the Bolzano-Weierstrass Theorem
3.5: The Cauchy Criterion
3.6: Properly divergent sequences
3.7: Introduction to Infinite Series

Module-IV (18 hrs)

Chapter 11: A Glimpse into topology

11.1: Open and Closed sets in $\mathbb{R}$
Appendix B: Finite and countable sets

References:

1	Charles G. Denlinger: Elements of Real Analysis *Jones and Bartlett Publishers Sudbury, Massachusetts (2011) ISBN:0-7637-7947-4 [Indian edition: ISBN-9380853157]*
2	David Alexander Brannan: A First Course in Mathematical Analysis *Cambridge University Press, US(2006) ISBN: 9780521684248*
3	John M. Howie: Real Analysis *Springer Science & Business Media(2012) [Springer Undergraduate Mathematics Series] ISBN: 1447103416*
4	James S. Howland: Basic Real Analysis *Jones and Bartlett Publishers Sudbury, Massachusetts (2010) ISBN:0-7637-7318-2*
5	James Ward Brown, Ruel Vance Churchill: Complex variables and applications(8/e) *McGraw-Hill Higher Education, (2009) ISBN: 0073051942*
6	Alan Jeffrey: Complex Analysis and Applications(2/e) *Chapman and Hall/CRC Taylor Francis Group(2006)ISBN:978-1-58488-553-5*
7	Saminathan Ponnusamy, Herb Silverman: Complex Variables with Applications *Birkhauser Boston(2006) ISBN:0-8176-4457-4*

FIFTH SEMESTER
GMAT5B07T: NUMERICAL ANALYSIS

Lecture Hours/ week: 4 **Credits: 3**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

Aims, Objectives and Outcomes

The goal of numerical analysis is to provide techniques and algorithms to find *approximate numerical solution* to problems in several areas of mathematics where it is impossible or hard to find the actual/closed form solution by analytical methods and also to make an *error analysis* to ascertain the accuracy of the *approximate solution.* The subject addresses a variety of questions ranging from the approximation of functions and integrals to the approximate solution of algebraic, transcendental, differential and integral equations, with particular emphasis on the stability, accuracy, efficiency and reliability of numerical algorithms. The course enables the students to

COs	**COURSE OUTCOMES**
CO1	Understand several methods such as bisection method, fixed point iteration method, regula falsi method etc. to find out the approximate numerical solutions of algebraic and transcendental equations with desired accuracy
CO2	Understand the concept of interpolation and also learn some well known interpolation techniques
CO3	Understand a few techniques for numerical differentiation and integration and also realize their merits and demerits
CO4	Find out numerical approximations to solutions of initial value problems and also to understand the efficiency of various methods

Syllabus

Text	Numerical Analysis (10/e): *Richard L. Burden, J Douglas Faires, Annette M. Burden, Brooks Cole Cengage Learning(2016)* *ISBN:978-1-305-25366-7*

Module-I (14 hrs)

Solutions of Equations in One Variable

Note: Students should be familiar with concepts and definitions such as 'round off error', 'rate of convergence' etc. discussed in sections 1.2 and 1.3

Introduction

2.1: The Bisection Method

2.2: Fixed-Point Iteration

2.3: Newton's Method and Its Extensions- *Newton's Method (Newton-Raphson method), Convergence using Newton's Method, The Secant Method, The Method of False Position*

[derivation of formula omitted in each case]

[Algorithms are omitted]

Module-II (14hrs)

Interpolation and Polynomial Approximation

Introduction

3.1: Interpolation and the Lagrange Polynomial- *motivation*, Lagrange Interpolating Polynomials, *error bound*

3.3: Divided Differences- k^{th} *divided difference*, *Newton's divided difference formula,* Forward Differences, Newton Forward-Difference Formula, Backward Differences, Newton Backward–Difference Formula, Centered Differences, *Stirling's formula.*

[derivation of formula omitted in each case]

[Algorithms are omitted]

Module-III (18 hrs)

Numerical Differentiation and Integration

Introduction

4.1: Numerical Differentiation- *approximation of first derivative by forward difference formula, backward difference formula, Three-Point Formulas, Three-Point Endpoint Formula, Three-Point Midpoint Formula [Five-Point Formulas, Five-Point Endpoint Formula, Five-*

Point Midpoint Formula omitted] Second Derivative Midpoint Formula *to approximate second derivative,* Round-Off Error Instability

4.3: Elements of Numerical Integration-*numerical quadrature,* The Trapezoidal Rule, Simpson's Rule, Measuring Precision, Closed Newton-Cotes Formulas, Simpson's Three-Eighths rule, Open Newton-Cotes Formulas

[derivation of formula omitted in each case]
[Algorithms are omitted]

Module-IV (18 hrs)
Initial-Value Problems for Ordinary Differential Equations
Introduction
5.1 The Elementary Theory of Initial-Value Problems

5.2: Euler's Method- *derivation using Taylor formula,* Error bounds for Euler Method

5.3: Higher-Order Taylor Methods- *local truncation error, Taylor method of order n and order of local truncation error*

5.4: Runge-Kutta Methods- *only* Mid Point Method, Modified Euler's Method and Runge-Kutta Method of Order Four are required.
[derivation of formula omitted in each case]
[Algorithms are omitted]

References:

1	Kendall E. Atkinson, Weimin Han: Elementary Numerical Analysis(3/e) *John Wiley & Sons(2004) ISBN:0-471-43337-3[Indian Edition by Wiley India ISBN: 978-81-265-0802-0]*
2	James F. Epperson: An Introduction to Numerical Methods and Analysis(2/e) *John Wiley & Sons(2013)ISBN: 978-1-118-36759-9*
3	Timothy Sauer: Numerical Analysis(2/e) *Pearson (2012) ISBN: 0-321-78367-0*
4	S S Sastri : Introductory Methods of Numerical Analysis(5/e) *PHI Learning Pvt. Ltd.(2012) ISBN:978-81-203-4592-8*
5	Ward Cheney,David Kincaid : Numerical Mathematics and Computing (6/e) *Thomson Brooks/Cole(2008) ISBN: 495-11475-8*

FIFTH SEMESTER
GMAT5B08T: THEORY OF EQUATIONS AND NUMBER THEORY

Lecture Hours/ week: 4 **Credits: 3**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

Aims, Objectives and Outcomes

Theory of equations is an important part of traditional algebra course and it mainly deals with polynomial equations and methods of finding their *algebraic solution* or *solution by radicals*. This means we seek a formula for solutions of polynomial equations in terms of coefficients of polynomials that involves only the operations of addition, subtraction, multiplication, division and taking roots. A well knitted formula for the solution of a quadratic polynomial equation is known to us from high school classes and is not difficult to derive. However, there is an increasing difficulty to derive such a formula for polynomial equations of third and fourth degree. One of our tasks in this learning process is to derive formulae for the solutions of *third* and *fourth* degree polynomial equations given by Carden and Ferrari respectively. In the meantime, we shall find out the relationship between the roots and coefficients of an n^{th} degree polynomial and an upper and lower limit for the roots of such a polynomial. This often helps us to locate the region of solutions for a general polynomial equation. Methods to find out integral and rational roots of a general n^{th} degree polynomial with rational coefficients are also devised. However, all efforts to find out an *algebraic solution* for general polynomial equations of degree higher than fourth failed or didn't work. This was not because one failed to hit upon the right idea, but rather due to the disturbing fact that there was no such formula.

The classical number theory is introduced and some of the very fundamental results are discussed. It is hoped that the method of writing a formal proof, using proof methods discussed in the first module, is best taught in a concrete setting, rather than as an abstract exercise in logic. Number theory, unlike other topics such as geometry and analysis, doesn't suffer from too much abstraction and the consequent difficulty in conceptual understanding. Hence, it is an ideal topic for a beginner to illustrate how mathematicians do their normal business. By the end of the course, the students will be able to enjoy and master several techniques of problem solving such as recursion, induction etc., the importance of pattern recognition in mathematics, the art of conjecturing and a few applications of number theory. Enthusiastic students will have acquired knowledge to read and enjoy on their own a few applications of number theory in the field of art, geometry and coding theory.

COs	COURSE OUTCOMES
CO1	At the end of the course students get used to different ways of solving equations and they begin to prove many properties in their own way regarding numbers
CO2	In fact the number theory course attracts students more towards pure mathematics and student enjoy mathematics as they enjoy poetry and they believe that they are poets

Syllabus

Text	**1.**Theory of Equations : J V Uspensky *McGraw Hill Book Company, Inc.(1948) ISBN:07-066735-7* **2.**Elementary Number Theory(2/e): Underwood Dudley, W.H.Freeman and company

Module-I (16hrs)
(Theory of Equations)
Chapter II (Text 1)

II.1 Integral rational functions or polynomials.
II.2 Multiplication of polynomials.
II.3 Division of polynomials
II.4 The remainder theorem
II.5 Synthetic Division
II.6 Horner's process
II.7 Taylor formula
II.8 Highest common divisor of two polynomials

Chapter III(Text 1)

III.1 Algebraic equations
III.2 Identity theorem
III.3 The Fundamental theorem of Algebra (*statement only)*
III.4 Imaginary roots of equations with real coefficients
III.5 Relations between roots and coefficients
III.6 Discovery of multiple roots

Chapter IV (Text 1)
IV.1 Limits of roots
IV.2 Method to find upper limit of positive roots
IV.3 Limit for moduli of roots [*only the method to find out upper limit from the auxiliary equation is required; derivation omitted*]
IV.4 Integral roots
IV.5 Rational roots

Module-II (16 hrs)
(Theory of Equations)

Chapter V (Text 1)
V.1 What is the solution of an equation?
V.2 *Cardan's* formulas
V.3 Discussion of solution
V.4 Irreducible case
V.5 Trigonometric solution
V.6 Solutions of biquadratic equations, *Ferrari method[example2 omitted]*

Chapter VI(Text 1)
VI.1 Object of the Chapter
VI.2 The sign of a polynomial for small and large values of variables-*locating roots of polynomial between two numbers having values of opposite sign-geometric illustration only-[rigorous reasoning in the starred section omitted]*
VI.4 Corollaries- *roots of odd and even degree polynomial, number of roots in an interval counted according to their multiplicity*
VI.5 Examples
VI.6 An important identity and lemma *[derivation not needed]*
VI.7 Rolle 's Theorem *[proof omitted]*, *use in separating roots*
VI.10 Descarte's rule of signs-*only statement and illustrations are required*

Module-III(16 hrs)
Number Theory
(Text 2)
Section 1: Integers
Section 2: Unique Factorization
Section 3: Linear Diophantine Equations

Module-IV (16 hrs)
Number Theory
(Text 2)
Section 4: Congruences
Section 5: Linear Congruences
Section 6: Fermat's and Wilson's Theorems

References:

1	Dickson L.E: Elementary Theory of Equations *John Wiley and Sons,Inc. NY(1914)*
2	Turnbull H.W: Theory of Equations(4/e) *Oliver and Boyd Ltd. Edinburg(1947)*
3	Todhunter I: An Elementary Treatise on the Theory of Equations(3/e) *Dublin Macmillan and Co. London(1875*)
4	William Snow Burnside and Arthur William Panton: The Theory of Equations *with* An Introduction to Binary Algebraic Forms *University Press Series(1881)*
5	Joseph A. Gallian : Contemporary Abstract Algebra(9/e) *Cengage Learning, Boston(2017) ISBN: 978-1-305-65796-0*
6	John B Fraleigh : A First Course in Abstract Algebra(7/e) *Pearson Education LPE(2003) ISBN 978-81-7758-900-9*
7	David Steven Dummit, Richard M. Foote: Abstract Algebra(3/e) *Wiley, (2004) ISBN: 8126532289*
8	Linda Gilbert and Jimmie Gilbert: Elements of Modern Algebra (8/e) *Cengage Learning, Stamford(2015) ISBN: 1-285-46323-4*
9	John R. Durbin : Modern Algebra: An Introduction(6/e) *Wiley(2015) ISBN: 1118117611*

FIFTH SEMESTER
GMAT5B09T: LINEAR PROGRAMMING

Lecture Hours/ week: 3 **Credits: 3**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

Aims, Objectives and Outcomes

Linear programming problems are having wide applications in mathematics, statistics, computer science, economics, and in many social and managerial sciences. For mathematicians it is a sort of mathematical modelling process, for statisticians and economists it is useful for planning many economic activities such as transport of raw materials and finished products from one place to another with minimum cost and for military heads it is useful for scheduling the training activities and deployment of army personnel. The emphasis of this course is on nurturing the linear programming skills of students *via*. the algorithmic solution of small-scale problems, both in the general sense and in the specific applications where these problems naturally occur. On successful completion of this course, the students will be able to

COs	COURSE OUTCOMES
CO1	Solve linear programming problems geometrically
CO2	Understand the drawbacks of geometric methods
CO3	Solve LP problems more effectively using Simplex algorithm via. the use of condensed tableau of A.W. Tucker
CO4	Convert certain related problems, not directly solvable by simplex method, into a form that can be attacked by simplex method
CO5	Understand duality theory, a theory that establishes relationships between linear programming problems of maximization and minimization
CO6	Solve transportation and assignment problems by algorithms that take advantage of the simpler nature of these problems

Syllabus

Text	Linear Programming and Its Applications: James K. Strayer *Undergraduate Texts in Mathematics Springer (1989) ISBN: 978-1-4612-6982-3*

Module-I **(20 hrs)**

Chapter1 Geometric Linear Programming: Profit Maximization and Cost Minimization, *typical motivating examples*, *mathematical formulation*, Canonical Forms for Linear Programming Problems, *objective functions, constraint set*, *feasible solution, optimal solution* , Polyhedral Convex Sets, *convex set, extreme point, theorems asserting existence of optimal solutions*, The Two Examples Revisited, *graphical solutions to the problems*, A Geometric Method for Linear Programming, *the difficulty in the method*, Concluding Remarks

Chapter2 The Simplex Algorithm:- Canonical Slack Forms for Linear Programming Problems; Tucker Tableaus, *slack variables, Tucker tableaus*, *independent variables* or *non basic variables, dependent variables* or *basic variables,* .An Example: Profit Maximization, *method of solving a typical canonical maximization problem*, The Pivot Transformation, *The Pivot Transformation for Maximum and Minimum Tableaus,* An Example: Cost Minimization, *method of solving a typical canonical minimization problem*, The Simplex Algorithm for Maximum Basic Feasible Tableaus, The Simplex Algorithm for Maximum Tableaus, Negative Transposition; The Simplex Algorithm for Minimum Tableaus, Cycling, Simplex Algorithm Anti cycling Rules, Concluding Remarks

Module-II **(10 hrs)**

Chapter 4 Duality Theory :- Duality in Canonical Tableaus, The Dual Simplex Algorithm, *The Dual Simplex Algorithm for Minimum Tableaus*, *The Dual Simplex Algorithm for Maximum Tableaus*, Matrix Formulation of Canonical Tableaus ,The Duality Equation, The Duality theorem , Concluding Remarks

Module-III **(18 hrs)**

Chapter 6 Transportation and Assignment Problems :- The Balanced Transportation Problem, The Vogel Advanced-Start Method (VAM), The Transportation Algorithm, Another Example, Unbalanced Transportation Problems, The Assignment Problem, *The Hungarian Algorithm*, Concluding Remarks, *The Minimum-Entry Method, The Northwest-Corner Method*

References:

1 Robert J.Vanderbei:LinearProgramming:Foundations and Extensions
(2/e) Springer Science+Business Media LLC(2001) ISBN: 978-1-4757-5664-7

2 Frederick S Hiller, Gerald J Lieberman: Introduction to Operation Research(10/e) *McGraw-Hill Education, 2 Penn Plaza, New York(2015)ISBN: 978-0-07-352345-3*

3 Paul R. Thie, G. E. Keough : An Introduction to Linear Programming and
Game Theory(3/e) *John Wiley and Sons,Ins.(2008)ISBN: 978-0-470-23286-6*

4 Louis Brickman: Mathematical Introduction to Linear Programming and Game Theory *UTM,Springer Verlag,NY(1989)ISBN:0-387-96931-4*

5 Jiri Matoušek, Bernd Gartner: Understanding and Using Linear Programming
Universitext, Springer-Verlag Berlin Heidelberg (2007)ISBN: 978-3-540-30697-9

SIXTH SEMESTER
GMAT6B10T: ADVANCED REAL ANALYSIS

Lecture Hours/ week: 5 **Credits: 5**
Marks: 100(Internal: 20, External: 80) **Examination: 2.5 Hours**

Aims, Objectives and Outcomes

The course is built upon the foundation laid in Basic Analysis course of fifth semester. The course thoroughly exposes one to the rigour and methods of an analysis course. One has to understand definitions and theorems of text and study examples well to acquire skills in various problem solving techniques. The course will teach one how to combine different definitions, theorems and techniques to solve problems one has never seen before. One shall acquire ability to realise when and how to apply a particular theorem and how to avoid common errors and pitfalls. The course will prepare students to formulate and present the ideas of mathematics and to communicate them elegantly.

On successful completion of the course, students will be able to

COs	COURSE OUTCOMES
CO1	State the definition of continuous functions, formulate sequential criteria for continuity and prove or disprove continuity of functions using this criteria
CO2	Understand several deep and fundamental results of continuous functions on intervals such as boundedness theorem, maximum-minimum theorem, intermediate value theorem, preservation of interval theorem and so on
CO3	Realise the difference between continuity and uniform continuity and equivalence of these ideas for functions on closed and bounded interval
CO4	Understand the significance of uniform continuity in continuous extension theorem
CO5	Develop the notion of Riemann integrability of a function using the idea of tagged partitions and calculate the integral value of some simple functions using the definition
CO6	Understand a few basic and fundamental results of integration theory
CO7	Formulate Cauchy criteria for integrability and a few applications of it. In particular they learn to use Cauchy criteria in proving the non integrability of certain functions
CO8	Understand classes of functions that are always integrable
CO9	Understand two forms of fundamental theorem of calculus and their significance in the practical problem of evaluation of an integral

CO10	Find a justification for 'change of variable formula' used in the practical problem of evaluation of an integral
CO11	Prove convergence and divergence of sequences of functions and series
CO12	Understand the difference between point wise and uniform convergence of sequences and series of functions
CO13	Answer a few questions related to interchange of limits
CO14	Learn and find out examples/counter examples to prove or disprove the validity of several mathematical statements that arise naturally in the process/context of learning
CO15	Understand the notion of improper integrals, their convergence, principal value and evaluation

Syllabus

Text(1)	Introduction to Real Analysis(4/e) : Robert G Bartle, Donald R Sherbert *John Wiley & Sons(2011) ISBN 978-0-471-43331-6*
Text(2)	Improper Riemann Integrals*:* Ioannis M. Roussos, *CRC Press by Taylor & Francis Group, LLC(2014) ISBN: 978-1-4665-8808-0*

Module-I Text 1 (20 hrs)

5.1: Continuous Functions
5.3: Continuous Functions on Intervals
5.4: Uniform Continuity-[Weierstrass Approximation Theorem -*only statement]*
5.6: Monotone and Inverse Functions

Module-II Text 1 (20 hrs)

7.1: Riemann Integral
7.2: Riemann Integrable Functions
7.3: The Fundamental Theorem

Module-III Text 1 (15 hrs)

8.1: Pointwise and Uniform Convergence
8.2: Interchange of Limits- *[only statement of theorem 8.2.3 required; proof omitted]*, *[*Bounded convergence theorem -statement only]
[8.2.6 Dini's theorem omitted]
9.4: Series of Functions – *(A quick review of series of real numbers of section 3.7 without proof) (only up to and including 9.4.6)*

Module-IV Text 2 (25 hrs)

Improper Riemann Integrals
1.1: Definitions and Examples
1.2: Cauchy Principal Value
1.3: Some Criteria of Existence
2.1: Calculus Techniques [‘2.1.1 Applications’ Omitted]
2.2: Integrals Dependent on Parameters- *upto and including example 2.2.4*
2.6: The Real Gamma and Beta Functions- *upto and including example 2.6.18*

References:

1	Charles G. Denlinger: Elements of Real Analysis *Jones and Bartlett Publishers Sudbury, Massachusetts (2011) ISBN:0-7637-7947-4 [Indian edition: ISBN- 9380853157]*
2	David Alexander Brannan: A First Course in Mathematical Analysis *Cambridge University Press,US(2006) ISBN: 9780521684248*
3	John M. Howie: Real Analysis *Springer Science & Business Media(2012)[Springer Undergraduate Mathematics Series] ISBN: 1447103416*
4	James S. Howland: Basic Real Analysis *Jones and Bartlett Publishers Sudbury, Massachusetts (2010) ISBN:0-7637-7318-2*
5	Terrace Tao: Analysis 1(3/e) *TRIM 37 Hindustan book agency(2016)*
6	Richard R Goldberg: Methods of Real Analysis *Oxford and IBH Publishing Co.Pvt.Ltd. NewDelhi(1970)*

SIXTH SEMESTER
GMAT6B11T: COMPLEX ANALYSIS

Lecture Hours/ week: 5 **Credits: 5**
Marks: 100(Internal: 20, External: 80) **Examination: 2.5 Hours**

Aims, Objectives and Outcomes

The course is aimed to provide a thorough understanding of complex function theory. It is intended to develop the topics in a fashion analogous to the calculus of real functions. At the same time differences in both theories are clearly emphasized. When real numbers are replaced by complex numbers in the definition of derivative of a function, the resulting *complex differentiable functions* (more precisely *analytic functions)* turn out to have many remarkable properties not possessed by their real analogues. These functions have numerous applications in several areas of mathematics such as differential equations, number theory etc. and also in science and engineering. The focus of the course is on the study of analytic functions and their basic behavior with respect to the theory of complex calculus.

The course enables students

COs	COURSE OUTCOMES
CO1	To understand the difference between differentiability and analyticity of a complex function and construct examples
CO2	To understand necessary and sufficient condition for checking analyticity.
CO3	To know of harmonic functions and their connection with analytic functions
CO4	To know a few elementary analytic functions of complex analysis and their properties.
CO5	To understand definition of complex integral, its properties and evaluation.
CO6	To know a few fundamental results on contour integration theory such as Cauchy's theorem, Cauchy- Goursat theorem and their applications.
CO7	To understand and apply Cauchy's integral formula and a few consequences of it such as Liouville's theorem, Morera's theorem and so forth in various situations.
CO8	To see the application of Cauchy's integral formula in the derivation of power series expansion of an analytic function.
CO9	To know a more general type of series expansion analogous to power series expansion *viz.Laurent's series expansion* for functions having *singularity*.
CO10	To understand how Laurent's series expansion lead to the concept of *residue,* which in turn provide another fruitful way to evaluate complex integrals and, in some cases, even real integrals.
CO11	To see another application of residue theory in locating the region of zeros of an analytic function

Syllabus

Text	Complex Analysis: John M. Howie, *Springer International Edtion ,* *ISBN 978-81-8128-296-5*

Module I (20 hours)

Chapter 2: Complex Numbers

2.1: Are complex numbers necessary?
2.2: Basic properties of complex numbers

Chapter 3: Prelude to complex analysis

3.1: Why is complex analysis possible?
3.2: Some useful terminology
3.3: Functions and continuity

Chapter 4: Differentiation

4.1: Differentiability *[only statement of theorem 4.3 required; proof omitted]*
4.2: Power series *[only statements of theorem 4.17 and 4.19 required; proofs omitted]*
4.3: Logarithms
4.5: Singularities

Module II (20 hours)

Chapter 5: Complex Integration

5.1: The Heine-Borel theorem *[only statements of theorem 5.1 and 5.3 required; proofs omitted]*
5.2: Parametric representation
5.3: Integration
5.4: Estimation
5.5: Uniform convergence

Module III (20 hours)

Chapter 6: Cauchy's theorem

6.1: Cauchy's theorem: A first approach *[only statement of theorem 6.2 required; proof omitted]*
6.3: Deformation

Chapter 7: Some consequences of Cauchy's theorem

7.1: Cauchy's integral formula *[only statement of theorem 7.5 required; proof omitted]*
7.2: The fundamental theorem of algebra
7.4: Taylor series

Module IV (20 hours)

Chapter 8: Laurent series and Residue theorem

8.1: Laurent series
8.2: Classification of singularities *[only statements of theorems required; proofs omitted]*
8.3: The residue theorem

Chapter 9: Applications of Contour Integration

9.1: Real integrals: semicircular contours
9.2: Integrals involving circular functions

References:

1	James Ward Brown, Ruel Vance Churchill: Complex variables and applications(8/e) *McGraw-Hill Higher Education, (2009) ISBN: 0073051942*
2	John B. Conway, Functions of one complex variable (2nd edn.), Springer international student edition, 1973
3	Alan Jeffrey: Complex Analysis and Applications(2/e) *Chapman and Hall/CRC Taylor Francis Group (2006) ISBN:978-1-58488-553-5*
4	Saminathan Ponnusamy, Herb Silverman: Complex Variables with Applications *Birkhauser Boston (2006) ISBN:0-8176-4457-4*
5	John H. Mathews & Russell W. Howell: Complex Analysis for Mathematics and Engineering (6 /e)
6	H A Priestly: Introduction to Complex Analysis(2/e) *Oxford University Press (2003) ISBN: 0 19 852562 1*
7	Jerrold E Marsden, Michael J Hoffman: Basic Complex Analysis(3/e) *W.H Freeman,N.Y.(1999) ISBN:0-7167- 2877- X*

SIXTH SEMESTER
GMAT6B12T: LINEAR ALGEBRA

Lecture Hours/ week: 5 **Credits: 4**
Marks: 100(Internal: 20, External: 80) **Examination: 2.5 Hours**

Aims, Objectives and Outcomes

An introductory treatment of linear algebra with an aim to present the fundamentals in the clearest possible way is intended here. Linear algebra is the study of linear systems of equations, vector spaces, and linear transformations. Virtually every area of mathematics relies on or extends the tools of linear algebra. Solving systems of linear equations is a basic tool of many mathematical procedures used for solving problems in science and engineering. A number of methods for solving a system of linear equations are discussed. In this process, the student will become competent to perform matrix algebra. Another advantage is that the student will come to understand the modern view of a matrix as a linear transformation. The discussion necessitates the introduction of central topic of linear algebra namely the concept of a *vector space*. Several examples and general properties of vector spaces are studied. The idea of a subspace, spanning vectors, basis and dimension are discussed and fundamental results in these areas are explored.

COs	COURSE OUTCOMES
CO1	Linear maps are introduced. The key result here is that for a linear map T, the dimension of the null space of T plus the dimension of the range of T equals the dimension of the domain of T.
CO2	The part of the theory of polynomials that will be needed to understand linear operators is presented.
CO3	The idea of studying a linear operator by restricting it to small subspaces to eigenvectors. The highlight is a simple proof that on complex vector spaces, eigenvalues always exist. This result is then used to show that each linear operator on a complex vector space has an upper-triangular matrix with respect to some basis. Similar techniques are used to show that every linear operator on a real vector space has an invariant subspace of dimension 1 or 2. This result is used to prove that every linear operator on an odd-dimensional real vector space has an eigenvalue. All this is done without defining determinants or characteristic polynomials.
CO4	Inner-product spaces are defined and their basic properties are developed along with standard tools such as orthonormal bases.
CO5	The novel approach of not relying on the concept of determinants leads the students to achieve the central goal of linear algebra: understanding the structure of linear operators on vector spaces

Text(1)	Frank Ayres JR: Matrices, Schaum's Outline Series, TMH Edition.
Text(2)	Linear Algebra Done Right : Sheldon Axler, Second Edition, Springer

Module-I **(20 hrs.)**

(Relevant sections from Text 1).
Rank of a Matrix, Row Canonical form or Echelon form of a matrix, Normal form.
Systems of Linear equations: Homogeneous and Non Homogeneous Equations,
Characteristic equation of a matrix; Characteristic roots and characteristic vectors.
Statement of Cayley Hamilton Theorem and simple applications.

Module-II **(20 hrs.)**

Chapter1 (Text2)
Vector Spaces:
Complex Numbers, Definition of Vector Space, Properties of Vector Spaces, Subspaces, Sums and Direct Sums

Chapter 2 (Text2)
Finite-Dimensional Vector Spaces:
Span and Linear Independence, Bases, Dimension

Module-III **(20 hrs.)**

Chapter 3 (Text2)
Linear Maps:
Definitions and Examples, Null Spaces and Ranges, The Matrix of a Linear Map, Invertibility (Proof of Proposition 3.17 omitted)

Module-IV **(20 hrs.)**

Chapter 5 (Text2)
Eigenvalues and Eigenvectors:
Invariant Subspaces, Polynomials Applied to Operators, Upper-Triangular Matrices, (Proofs of Proposition 5.16 and Proposition 5.17 omitted.)
Diagonal Matrices (only Up to 5.21) (Proof of Proposition 5.21 omitted.),

Chapter 6 (Text2)
Inner-Product Spaces:
Definition and Examples of Inner Products (Up to 6.2)

References:

1	Jim DeFranza, Daniel Gagliardi: Introduction to Linear Algebra with Applications *Waveland Press, Inc(2015)ISBN: 1-4786-2777-8*
2	Otto Bretscher: Linear Algebra with Applications(5/e) Pearson Education, Inc (2013) ISBN: 0-321-79697-7
3	Ron Larson, Edwards, David C Falvo : Elementary Linear Algebra(6/e) *Houghton Mifflin Harcourt Publishing Company(2009) ISBN: 0-618-78376-8*
4	David C. Lay, Steven R. Lay, Judi J. McDonald: Linear Algebra and its Application (5/e) *Pearson Education, Inc(2016) ISBN: 0-321-98238-X*
5	Martin Anthony, Michele Harvey: Linear Algebra: Concepts and Methods *Cambridge University Press(2012) ISBN: 978-0-521-27948-2*
6	Jeffrey Holt: Linear Algebra with Applications *W. H. Freeman and Company (2013) ISBN: 0-7167-8667-2*

SIXTH SEMESTER
GMAT6B13T: DIFFERENTIAL EQUATIONS

Lecture Hours/ week: 5 **Credits: 4**
Marks: 100(Internal: 20, External: 80) **Examination: 2.5 Hours**

Aims, Objectives and Outcomes

Differential equations model the physical world around us. Many of the laws or principles governing natural phenomenon are statements or relations involving rate at which one quantity changes with respect to another. The mathematical formulation of such relations (*modeling*) often results in an equation involving derivative (*differential equations*). The course is intended to find out ways and means for solving differential equations and the topic has wide range of applications in physics, chemistry, biology, medicine, economics and engineering.

On successful completion of the course, the students shall acquire the following skills/knowledge.

COs	COURSE OUTCOMES
CO1	Students could identify a number of areas where the modeling process results in a differential equation
CO2	They will learn what an ODE is, what it means by its solution, how to classify DEs, what it means by an IVP and so on.
CO3	They will learn to solve DEs that are in linear, separable and in exact forms and also to analyze the solution.
CO4	They will realize the basic differences between linear and nonlinear DEs and also basic results that guarantee a solution in each case.
CO5	They will learn a method to approximate the solution successively of a first order IVP
CO6	They will become familiar with the theory and method of solving a second order linear homogeneous and nonhomogeneous equation with constant coefficients
CO7	They will learn to find out a series solution for homogeneous equations with variable coefficients near ordinary points
CO8	Students acquire the knowledge of solving a differential equation using Laplace method which is especially suitable to deal with problems arising in engineering field
CO9	Students learn the technique of solving partial differential equations using the method of separation of variables

Syllabus

Text	Elementary Differential Equations and Boundary Value Problems (11/e): William E Boyce, Richard C Diprima And Douglas B Meade *John Wiley & Sons(2017) ISBN: 1119169879*

Pre-Requisites

1.1: Some Basic Mathematical Models; Direction Fields
1.2: Solutions of some Differential equations
1.3: Classification of Differential Equations

Module-I (22 hrs)

2.1: Linear Differential Equations; Method of Integrating Factors
2.2: Separable Differential Equations
2.3: Modeling with First Order Differential Equations
2.4: Differences between Linear and Nonlinear Differential Equations
2.6: Exact Differential Equations and Integrating Factors
2.8: The Existence and Uniqueness Theorem *(proof omitted)*

Module-II (23 hrs)

3.1: Homogeneous Differential Equations with Constant Coefficients
3.2: Solutions of Linear Homogeneous Equations; the Wronskian
3.3: Complex Roots of the Characteristic Equation
3.4: Repeated Roots; Reduction of Order
3.5: Nonhomogeneous Equations; Method of Undetermined Coefficients
3.6: Variation of Parameters
5.2: Series solution near an ordinary point, part1
5.3: Series solution near an ordinary point, part2

Module-III (15 hrs)

6.1: Definition of the Laplace Transform
6.2: Solution of Initial Value Problems
6.3: Step Functions
6.5: Impulse Functions
6.6: The Convolution Integral

Module-IV (20 hrs)

10.1: Two-Point Boundary Value Problems
10.2: Fourier Series

10.3: The Fourier Convergence Theorem
10.4: Even and Odd Functions
10.5: Separation of Variables; Heat Conduction in a Rod
10.7: The Wave Equation: Vibrations of an Elastic String

References:

1	Dennis G Zill &Michael R Cullen: Differential Equations with Boundary Value Problems(7/e):*Brooks/Cole Cengage Learning(2009)ISBN: 0-495-10836-7*
2	R Kent Nagle, Edward B. Saff & Arthur David Snider: Fundamentals of Differential Equations(8/e) *Addison-Wesley(2012) ISBN: 0-321-74773-9*
3	C. Henry Edwards &David E. Penney: Elementary Differential Equations (6/e) *Pearson Education, Inc. New Jersey (2008) ISBN 0-13-239730-7*
4	John Polking, Albert Boggess & David Arnold : Differential Equations with Boundary Value Problems(2/e) *Pearson Education, Inc New Jersey(2006) ISBN 0-13-186236-7*
5	Henry J. Ricardo: A Modern Introduction to Differential Equations(2/e*) Elsevier Academic Press(2009)ISBN: 978-0-12-374746-4*
6	James C Robinson: An Introduction to Ordinary Differential Equations *Cambridge University Press (2004)ISBN: 0-521-53391-0*

ELECTIVE COURSES

SIXTH SEMESTER (Elective)
GMAT6E01T: GRAPH THEORY

Lecture Hours/ week: 3 **Credits: 2**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

COs	COURSE OUTCOMES
CO1	Understand and apply the fundamental concepts in graph theory
CO2	Apply graph theory based tools in solving practical problems
CO3	Improve the proof writing skills.
CO4	Analyze properties of graphs
CO5	Understand trees and their properties
CO6	Distinguish between Eulerian and Hamiltonian graphs
CO7	Analyze planar graphs

Text	A First Look at Graph Theory: John Clark & Derek Allan Holton, *Allied Publishers, First Indian Reprint 1995*

Module-I **(16 hrs)**

1.1 Definition of a graph
1.2 Graphs as models
1.3 More definitions
1.4 Vertex degrees
1.5 Sub graphs
1.6 Paths and Cycles
1.7 Matrix representation of a graph *[up to Theorem 1.6; proof of Theorem1.5 is omitted]*

Module-II **(16 hrs)**

2.1 Definitions and Simple Properties
2.2 Bridges [*Proof of Theorem 2.6 and Theorem 2.9 are omitted]*
2.3 Spanning Trees
2.6 Cut Vertices and Connectivity *[Proof of Theorem 2.21omitted]*

Module-III (16 hrs)

3.1 Euler Tour *[up to Theorem 3.2, proof of Theorem 3.2 omitted]*
3.3: Hamiltonian Graphs *[Proof of Theorem 3.6 omitted]*
5.1: Plane and Planar graphs *[Proof of Theorem 5.1 omitted]*
5.2 Euler's Formula *[Proofs of Theorems 5.3 and Theorem 5.6 omitted]*

References:

1. R.J. Wilson: Introduction to Graph Theory, 4th ed., *LPE, Pearson Education*
2. J.A. Bondy& U.S.R. Murty : Graph Theory with Applications
3. J. Clark & D.A. Holton: A First Look at Graph Theory, *Allied Publishers*
4. N. Deo : Graph Theory with Application to Engineering and Computer Science, *PHI.*

SIXTH SEMESTER (Elective)
GMAT6E02T: TOPOLOGY OF METRIC SPACES

Lecture Hours/ week: 3 **Credits: 2**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

COs	COURSE OUTCOMES
CO1	The student will be able to perform simple theoretical analysis involving sets in metric and topological spaces and maps between these spaces
CO2	The students will be able to apply these concepts to other areas of mathematics

Text	Metric Spaces: *Mícheál Ó Searcóid Undergraduate Mathematics Series Springer-Verlag London Limited (2007) ISBN: 1-84628-369-8*

Module-I **(18 hrs)**

Chapter 1:**Metrics**
1.1: Metric Spaces
1.3: Metric Subspaces and Metric Superspaces
1.4: Isometries
1.6: Metrics on Products
1.7: Metrics and Norms on Linear Spaces-*[example1.7.8 omitted]*

Chapter 2: **Distance**
2.1: Diameter
2.2: Distances from Points to Sets
2.3: Inequalities for Distances
2.4: Distances to Unions and Intersections
2.5: Isolated Points
2.6: Accumulation Points
2.7: Distances from Sets to Sets

Chapter 3 **Boundary**
3.1: Boundary Points
3.2: Sets with Empty Boundary
3.3: Boundary Inclusion
3.6: Closure and Interior
3.7: Inclusion of Closures and Interiors

Module-II **(15 hrs)**

Chapter 4 **Open, Closed and Dense subsets :**

4.1: Open and Closed Subsets
4.2: Dense Subsets
4.3: Topologies
4.4: Topologies on Subspaces and Super spaces
4.5: Topologies on Product Spaces

Chapter 5 **Balls**

5.1: Open and Closed Balls
5.2: Using Balls

Module-III **(15hrs)**

Chapter 6 **Convergence**

6.1: Definition of Convergence for Sequences
6.2: Limits
6.4: Convergence in Subspaces and Superspaces
6.6: Convergence Criteria for Interior and Closure
6.7: Convergence of Subsequences
6.8: Cauchy Sequences

Chapter 7 **Bounds**

7.1: Bounded Sets
7.4: Spaces of Bounded Functions
7.6: Convergence and Boundedness
7.7: Uniform and Pointwise Convergence

References:

1	E.T.Copson: Metric Spaces *Cambridge University Press(1968)ISBN:0 521 35732 2*
2	Irving Kaplansky: Set Theory and Metric Spaces *Allyn and Bacon,Inc. Boston(1972)*
3	S. Kumaresan: Topology of Metric Spaces *Alpha Science International Ltd.(2005) ISBN: 1-84265-250-8*
4	Wilson A Sutherland: Introduction to Metric and Topological Spaces(2/e) *Oxford University Press(2009)ISBN:978-0-19-956308-1*
5	Mohamed A. Khamsi and William A. Kirk: An Introduction to Metric Spaces and Fixed Point Theory *John Wiley & Sons, Inc(2001) ISBN 0-471-41825-0*

SIXTH SEMESTER (Elective)
GMAT6E03P: MATHEMATICAL PROGRAMMING WITH PYTHON AND LATEX

Lecture Hours/ week: 3 **Credits: 2**
Marks: 75(Internal: 15, External: 60 (Practical Exam)) **Examination: 2 Hours**

COs	COURSE OUTCOMES
CO1	Understand basis of Python programming, apply Python programming in plotting mathematical functions, apply Python programming in numerical analysis, understands typesetting using Latex and apply Latex in writing equations

Text	Python for Education - Learning Maths and Physics using Python: Ajith Kumar B.P *Inter University Accelerator Centre 2010*

Course Contents

The course has Theory Part (*Internal evaluation*) and Practical Part (*for internal and external evaluation*). A student has to maintain a practical record of the work.

Module-I **(15hrs)**

Basics of Python Programming

Chapter 2 Programming in Python: Two modes of using Python, Interpreter Variables and Data Types, Operators and their Precedence, Python Strings, Slicing, Python Lists, Mutable and Immutable Types, Input from the Keyboard, Iteration: while and for loops, Python Syntax, Colon & Indentation, Syntax of ‘for loops’, Conditional Execution: if, else if and else,

Modify loops : break and continue, Line joining, Functions, Scope of variables, Optional and Named Arguments, More on Strings and Lists, split and join, Manipulating Lists, Copying Lists, Python Modules and Packages, Different ways to import, Packages, File Input/Output, The pickle module, Formatted Printing, Exception Handling, Turtle Graphics.

Chapter 3 Arrays and Matrices: The NumPy Module Vectorized Functions.
(sec. 2.1 to 2.19, 3.1 to 3.2)

Module-II (20 hrs)

Applications of Python Programming

Chapter 4 Data visualization: The Matplotlib Module, Plotting mathematical functions, Famous Curves, Power Series, Fourier Series, 2D plot using colors, Meshgrids, 3D Plots, Mayavi, 3D visualization, .

Chapter 6 Numerical methods: Numerical Differentiation, Numerical Integration, Ordinary Differential Equations, Polynomials, Finding roots of an equation, System of Linear Equations, Least Squares Fitting, Interpolation.

(sec. 4.1 to 4.6, 4.8 to 4.10, 6.1 to 6.8)

Module-III (13 hrs)

Latex

Chapter 5 Typesetting using LATEX: Document classes, Modifying Text, Dividing the document, Environments, Typesetting Equations, Arrays and matrices, Floating bodies, Inserting Images, Example, Application

(sec. 5.1 to 5.8)

External Examination (Practical)

The external examination is a practical examination of 2 hr duration.

The Practical Examinations will be conducted by 2 examiners(One External and One Internal).

The Practical examination has 3 sections ; 2 python programmes(from the list given below) and 1 latex document preparation(based on the syllabus).

A practical examination, based on following topics, should be conducted for the external evaluation.

Python Programmes

1. Bisection Method
2. Newton-Raphson Method
3. Numerical differentiation
4. Trapezoidal rule
5. Simpson’s rule
6. Euler Method to solve ODE
7. Second order RK Method to solve ODE
8. Fourth order RK Method to solve ODE
9. Lagrange Interpolation

10. Newton’s Interpolation
11. Matrix inversion
12. Gauss elimination
13. Gauss-Siedel Method

One document to be prepared using Latex.

References:

1	Saha, Amit: Doing Math with Python: Use Programming to Explore Algebra, Statistics, Calculus, and More*!*. *No Starch Press, 2015*.
2	Nunez-Iglesias, Juan, Stefan van der Walt, and Harriet Dashnow: "Elegant SciPy: The Art of Scientific Python." (2017).
3	Stewart, John M.: Python for scientists. *Cambridge University Press, 2017*.
4	Kinder, Jesse M., and Philip Nelson: A student's guide to Python for physical modeling. *Princeton University Press, 2018*.
5	McGreggor, Duncan :. Mastering matplotlib. *Packt Publishing Ltd, 2015*
6	Lamport, Leslie. LaTeX: A Document Preparation System(2/e) *Pearson Education India, 1994.*
7	Grätzer, George: Math into LATEX. *Springer Science & Business Media, 2013*
8	Hahn, Jane: LATEX for Everyone. *Prentice Hall PTR, 1993*

SIXTH SEMESTER (Elective)
GMAT6E04T: INTRODUCTION TO GEOMETRY

Lecture Hours/ week: 3 **Credits: 2**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

COs	COURSE OUTCOMES
CO1	At the end of the course students develop rational thought, contributing to the thinking skills of logic, deductive reasoning and skills in problem solving

Text	Geometry(2/e): David A Brannan, Mathew F Espen, Jeremy J Gray *Cambridge University Press(2012) ISBN: 978-1-107-64783-1*

Module-I **(10 hrs)**

Conics
1.1.1: Conic Sections
1.1.3: Focus-Directrix Definition of the Non-Degenerate Conics-*definition***,** *parabola in standard form, ellipse in standard form, hyperbola in standard form,* Rectangular Hyperbola, Polar Equation of a Conic
1.1.4: Focal Distance Properties of Ellipse and Hyperbola-*Sum of Focal Distances of Ellipse, Difference of Focal Distances of Hyperbola*
1.2: Properties of Conics**-** Tangents, *equation of tangents to ellipse, hyperbola, and parabola , polar of a point w.r.t. unit circle, normal*, Reflections, *The Reflection Law,* Reflection Property of the Ellipse, Reflection Property of the Hyperbola, Reflection Property of the Parabola, Conics as envelopes of tangent families
1.3: Recognizing Conics- *equation of conic in general form, identifying a conic*

Module-II **(20 hrs)**

Affine Geometry
2.1: Geometry and Transformations - What is Euclidean Geometry?
*Isometry, Euclidean properties, Euclidean transformation***,** Euclidean Congruence
2.2: Affine Transformations and Parallel Projections- Affine Transformations, *Basic Properties of Affine Transformations***,** Parallel Projections, *Basic Properties of Parallel Projections***,** Affine Geometry, *Midpoint Theorem, Conjugate Diameters Theorem, Affine Transformations and Parallel Projections, affine transformations as composite of two parallel projections*

2.3: Properties of Affine Transformations-Images of Sets Under Affine Transformations, The Fundamental Theorem of Affine Geometry, Proofs of the Basic Properties of Affine Transformations
2.4: Using the Fundamental Theorem of Affine Geometry-The Median Theorem, Ceva's Theorem, *converse*, Menelaus' Theorem, *converse[subsection "2.4.4. Barycentric Coordinates" omitted]*
2.5: Affine Transformations and Conics-Classifying Non-Degenerate Conics in Affine Geometry, *A few affine properties*, Applying Affine Geometry to Conics

Module-III (18 hrs)

Projective Geometry: Lines
3.1: Perspective- Perspective in Art, Mathematical Perspective, Desargues' Theorem
3.2: The Projective Plane $\mathbb{RP}^2$ -Projective Points, Projective Lines, Embedding Planes, An equivalent definition of Projective Geometry
3.3: Projective Transformations- The Group of Projective Transformations, Some Properties of Projective Transformations, Fundamental Theorem of Projective Geometry,*[The subsection "3.3.4.Geometrical Interpretation of Projective Transformations" omitted]*
3.4: Using the Fundamental Theorem of Projective Geometry- Desargues' Theorem and Pappus' Theorem, *[The subsection "3.4.2. Duality" omitted]*
3.5: Cross-Ratio-Another Projective Property, *properties of cross ratio*, *Unique Fourth Point Theorem, Pappus' Theorem*, Cross-Ratio on Embedding Planes, An Application of Cross-Ratio

References:

1	George A Jennings: Modern Geometry with Applications *Universitext, Springer (1994) ISBN:0-387-94222-X*
2	Walter Meyer: Geometry and its Application(2/e) *Elsever, Academic Press (2006)ISBN:0-12-369427-0*
3	Judith N Cederberg : A Course in Modern Geometries(2/e) *UTM, Springer (2001)ISBN: 978-1-4419-3193-1*
4	Patric J Ryan: Euclidean and Non Euclidean Geometry-An Analytic Approach *Cambridge University Press, International Student Edition (2009) ISBN:978-0-521-12707-3*
5	David C Kay: College Geometry: A Unified Approach *CRC Press Tayloe and Francic Group(2011) ISBN: 978-1-4398-1912-8 (Ebook-PDF)*
6	James R Smart: Modern Geometries(5/e) *Brooks/Cole Publishing Co.,(1998) ISBN:0-534-35188-3*
7	Michele Audin: Geometry *Universitext, Springer(2003)ISBN:3-540-43498-4*

OPEN COURSES

FIFTH SEMESTER (OPEN COURSE)
(For students not having Mathematics as Core Course)

GMAT5D01T: APPLIED CALCULUS

Lecture Hours/ week: 3 **Credits: 3**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

COs	COURSE OUTCOMES
CO1	Identify the independent and dependent variables of a function and compute its domain and range.
CO2	Evaluate functions given by formulas at given points
CO3	Plot the graphs of straight lines and conics
CO4	Compute limits
CO5	Check continuity
CO6	Compute derivatives and write down the equation of the tangent line
CO7	Determine whether the function is increasing or decreasing using derivatives
CO8	Compute velocity and acceleration
CO9	Compute marginal cost/revenue/profit of production
CO10	Compute differential and use it to approximate the error occurred
CO11	Perform implicit differentiation
CO12	Compute convexity, concavity and points of inflection
CO13	Sketch curves
CO14	Determine extreme values
CO15	Determine the level of elasticity and use it for predicting the behaviour of revenue/cost/profit
CO16	Combine the techniques of model building with optimization techniques
CO17	Use exponential/logarithmic function to compute compound interest, radioactive decay etc.
CO18	To compute the area under a curve, average value of a function using integration
CO19	Integrate using substitution
CO20	To estimate the future and present value of an income flow
CO21	To compute the survival and renewal functions
CO22	To compute anti derivative
CO23	To determine population density
CO24	To find the area and volume of surface of revolution

Text	Calculus: For Business, Economics, and the Social and Life Sciences BRIEF (10/e): Laurence D. Hoffmann, Gerald L. Bradley *McGraw-Hill(2010)ISBN: 978–0–07–353231–8*

Module I 16 hrs

Chapter1:- Functions, Graphs, and Limits
1.1: Functions
1.2: The Graph of a Function
1.3: Linear Functions
1.4: Functional Models
1.5: Limits
1.6: One sided limits and continuity

Chapter2:- Differentiation: Basic Concepts
2.1: The Derivative
2.2: Techniques of Differentiation
2.3: Product and quotient rules: Higher order derivatives *[proof of product and quotient rules omitted]*
2.4: The Chain rule *[proof of general power rule omitted]*

Module II 18 hrs

2.5: Marginal Analysis and Applications using increments
2.6: Implicit Differentiation and Related Rates

Chapter3:- Additional Applications of Derivative
3.1: Increasing and Decreasing Functions; Relative Extrema,
3.2: Concavity and Points of Inflection
3.4: Optimization; Elasticity of Demand
3.5: Additional Applied Optimization
Chapter4: Exponential and Logarithmic Functions
4.1: Exponential functions; continuous compounding
4.2: Logarithmic functions

Module II 14 hrs

Chapter5:- Integration
5.1: Anti differentiation: The Indefinite Integral
5.2: Integration by Substitution
5.3: The Definite Integral and the Fundamental Theorem of Calculus *[only statement of FTC required; Justification given at the end of the section omitted]*

5.5: Additional Applications to Business and Economics
5.6: Additional Applications to the Life and Social Sciences *[The derivation of volume formula omitted; only the formula and its applications required]*

References:

1. Soo T Tan: Applied Calculus for the Managerial, Life, and social sciences(8/e) *Cengage Learning(2011) ISBN: 978-0-495-55969-6*
2. Ron Larson : Brief Calculus *An Applied Approach(8/e)Houghton Mifflin Company(2009)ISBN: 978-0-618-95847-4*
3. Stefan Waner, Steven R. Costenoble: Finite Mathematics and Applied Calculus (5/e) *Brooks/Cole Cengage Learning (2011) ISBN: 978-1-4390-4925-9*
4. Frank C. Wilson, Scott Adamson: Applied Calculus *Houghton Mifflin Harcourt Publishing Company (2009)*
5. Geoffrey C. Berresford, Andrew M. Rockett: Applied Calculus(7/e) *Cengage Learning (2016)ISBN: 978-1-305-08531-2*

FIFTH SEMESTER (OPEN COURSE)
(For students not having Mathematics as Core Course)

GMAT5D02T: DISCRETE MATHEMATICS FOR BASIC AND APPLIEDSCIENCES

3

Lecture Hours/ week: 3 **Credits: 3**

Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

COs	COURSE OUTCOMES
CO1	Identify correct and incorrect arguments
CO2	Understand the criteria for the evaluation of arguments
CO3	Understand the scientific way of decision making using the laws of logic
CO4	Understand the concept of algebraic structures in Mathematics
CO5	Identify a given algebraic structure as belonging to a particular family of structures and to state the characteristic properties of the members of the family
CO6	Understand the concept of groups and derive basic theorems on groups
CO7	Define the concept of Boolean algebra as an algebraic structure and list its properties
CO8	Understand the applications of Boolean algebra in switching circuits
CO9	Define a Graph and identify different classes of graphs
C10	Understand various applications of Graph theory

Text	Discrete Mathematics; Proofs, Structures and Applications (3/e): *Rowan Garnier & John Taylor CRC Press, Taylor & Francis Group (2009) ISBN: 978-1-4398-1280-8(hardback)/ 978-1-4398-1281-5 (eBook - PDF)*

Module I **14 hrs**

Chaper-1 Logic

1.1: Propositions and Truth Values

1.2: Logical Connectives and Truth Tables- *Disjunction, Conditional Propositions, Bi conditional Propositions*

1.3: Tautologies and Contradictions

1.4: Logical Equivalence and Logical Implication- *More about conditionals*

1.5: The Algebra of Propositions- *The Duality Principle, Substitution Rule*

1.6: Arguments

1.7: Formal Proof of the Validity of Arguments
1.8: Predicate Logic- *The Universal Quantifier, The Existential Quantifier, Two-Place Predicates, Negation of Quantified Propositional Functions*
1.9: Arguments in Predicate Logic- *Universal Specification* (*US*), *Universal Generalization* (*UG*), *Existential Specification* (*ES*), *Existential Generalization* (*EG*)

Module II 16 hrs

Chapter-8 Algebraic Structures
8.1: Binary Operations and Their Properties
8.2: Algebraic Structures- *Semigroups*
8.3: More about Groups
8.4: Some Families of Groups- *Cyclic Groups, Dihedral Groups, Groups of Permutations*
8.5: Substructures
8.6: Morphisms

Chapter 10 Boolean Algebra
10.1: Introduction
10.2: Properties of Boolean Algebras
10.3: Boolean Functions
10.4: Switching Circuits
10.5: Logic Networks
10.6: Minimization of Boolean Expressions

Module II 18 hrs

Chapter 11 Graph Theory
11.1: Definitions and Examples
11.2: Paths and Cycles
11.3: Isomorphism of Graphs
11.4: Trees
11.5: Planar Graphs *[proof of Euler formula omitted]*
11.6: Directed Graphs

Chapter 12 Applications of Graph Theory
12.2: Rooted Trees
12.3:Sorting
12.4:Searching Strategies

References:

1 Edward R. Scheinerman: Mathematics *A Discrete Introduction(3/e) Brooks/Cole, Cengage Learning(2013)ISBN: 978-0-8400-4942-1*

2 Gary Haggard, John Schlipf, Sue Whitesides: Discrete Mathematics for Computer Science *Thomson Brooks/Cole(2006)ISBN:0-534-49601-x*

3 D P Acharjya, Sreekumar: Fundamental Approach to Discrete Mathematics *New Age International Publishers (2005) ISBN:**978-81-224-2304-4***

4 Gary Chartrand ,Ping Zhang: Discrete Mathematics *Waveland Press, Inc (2011)ISBN: 978-1-57766-730-8*

5 Tom Jenkyns, Ben Stephenson: Fundamentals of Discrete Math for Computer Science *A Problem-Solving Primer Springer-Verlag London (2013)ISBN: 978-1-4471-4068-9*

6 Faron Moller, Georg Struth: Modelling Computing *Systems Mathematics for Computer Science Springer-Verlag London (2013) ISBN 978-1-84800-321-7*

FIFTH SEMESTER (OPEN COURSE)
(For students not having Mathematics as Core Course)

GMAT5D03T: LINEAR MATHEMATICAL MODELS

Lecture Hours/ week: 3 **Credits: 3**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

COs	COURSE OUTCOMES
CO1	the students will be able to Understand the idea of slope of the lines, understand to find solution of Linear Systems by the Echelon Method and Gauss Jordan method
CO2	Gets an idea of matrices, understand how to add, subtract and multiplication of matrices and understand how find the inverse of a matrix
CO3	Understand the methods of solving linear programming problems geometrically and understands the drawbacks of geometric methods and to solve LP problems more effectively using Simplex method
CO4	Understand duality theory, a theory that establishes relationships between linear programming problems of maximization and minimization

Text	Finite Mathematics and Calculus with Applications (9/e) *Margaret L. Lial, Raymond N. Greenwell & Nathan P. Ritchey* Pearson Education, Inc(2012) ISBN: 0-321-74908-1

Module I 18 hrs

Chapter-1 Linear Functions
1.1: Slopes and Equations of Lines
1.2: Linear Functions and Applications
1.3: The Least Squares Line

Chapter-2 Systems of Linear Equations and Matrices
2.1: Solution of Linear Systems by the Echelon Method
2.2: Solution of Linear Systems by the Gauss-Jordan Method
2.3: Addition and Subtraction of Matrices
2.4: Multiplication of Matrices
2.5: Matrix Inverses
2.6: Input-Output Models

Module II 12 hrs

Chapter-3 Linear Programming: The Graphical Method

3.1: Graphing Linear Inequalities

3.2 : Solving Linear Programming Problems Graphically

3.3 : Applications of Linear Programming

Module III 18 hrs

Chapter-4 Linear Programming: The Simplex Method

4.1: Slack Variables and the Pivot

4.2: Maximization Problems

4.3: Minimization Problems; Duality

4.4:Nonstandard Problems

References:

1 Soo T Tan: Finite Mathematics For the Managerial, Life, and social sciences (11/e) *Cengage Learning(2015) ISBN: 1-285-46465-6*

2 Ronald J. Harshbarger, James J. Reynolds: Mathematical Applications for the Management, Life, and Social Sciences (9/e) *Brooks/Cole CengageLearning(2009) ISBN: 978-0-547-14509-9*

3 Stefan Waner, Steven R. Costenoble: Finite Mathematics and Applied Calculus (5/e) *Brooks/Cole Cengage Learning(2011) ISBN: 978-1-4390-4925-9*

4 Seymour Lipschutz, John J. Schiller, R. Alu Srinivasan: Beginning Finite Mathematics *Schaum's Outline Series, McGraw-Hill(2005)*

5 Howard L. Rolf: Finite Mathematics *Enhanced Edition*(7/e) *Brooks/Cole, Cengage Learning (2011) ISBN:978-0-538-49732-9*

6 Michael Sullivan: Finite Mathematics An Applied Approach(11/e*) John Wiley & Sons, Inc (2011) ISBN: 978-0470-45827-3*

FIFTH SEMESTER (OPEN COURSE)
(For students not having Mathematics as Core Course)

GMAT5D04T: MATHEMATICS FOR DECISION MAKING

Lecture Hours/ week: 3 **Credits: 3**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

COs	COURSE OUTCOMES
CO1	The student could understand the classifications of data. Student is also introduced to various data collection techniques
CO2	Student will learn to visualize various types of data with the use of frequency charts and appropriate graphs
CO3	Student understands concepts like measures of central tendency, measures of variation and measures of position
CO4	Student gets a clear understanding of basic probability concepts. Student learns conditional probability, addition rule and other basic theories in probability
CO5	Student will learn various probability distributions of discrete and continuous variables
CO6	Student learns about the normal distribution, which is an important continuous probability distribution in inferential statistics
CO7	Student understands the standard normal distribution and learns the conversion of normal variable to standard normal variable

Text	Elementary Statistics: Picturing the World (6/e) *Ron Larson &* *Betsy Farber Pearson Education, Inc(2015) ISBN: 978-0-321-91121-6*

Module I (16 hrs)

Chapter1 Introduction to Statistics

1.1: An Overview of Statistics
1.2: Data Classification
1.3: Data Collection and Experimental Design

Chapter2 Descriptive Statistics

2.1: Frequency Distributions and their Graphs
2.2: More Graphs and Displays

2.3: Measures of Central Tendency
2.4: Measures of Variation
2.5: Measures of Position

Module II (16 hrs)
Chapter3 Probability
3.1: Basic Concepts of Probability and Counting
3.2: Conditional Probability and the Multiplication Rule
3.3: The Addition Rule
3.4: Additional topics in probability and counting

Module III (16 hrs)
Chapter4 Discrete Probability Distribution
4.1: Probability Distributions
4.2: Binomial Distributions
4.3: More Discrete Probability Distributions

References:

1	Mario F. Triola: Elementary Statistics(13/e) : *Pearson Education, Inc(2018) ISBN: 9780134462455*
2	Neil A. Weiss: Elementary Statistics(8/e) *Pearson Education, Inc(2012) ISBN: 978-0-321-69123-1*
3	Nancy Pfenning: Elementary Statistics: Looking at Big Picture *Brooks/Cole Cengage Learning(2011) ISBN: 978-0-495-01652-6*
4	Frederick J Gravetter, Larry B. Wallnau: Statistics for the Behavioral Sciences (10/e) *Cengage Learning(2017) ISBN: 978-1-305-50491-2*
5	Seymour Lipschutz, John J. Schiller, R. Alu Srinivasan: Beginning Finite Mathematics *Schaum's Outline Series, McGraw-Hill(2005)*
6	Michael Sullivan: Finite Mathematics An Applied Approach(11/e*) John Wiley & Sons, Inc(2011)ISBN: 978-0470-45827-3*

MATHEMATICS
(COMPLEMENTARY COURSES)

FIRST SEMESTER
GMAT1C01T: MATHEMATICS-1

Lecture Hours/ week: 4 **Credits: 3**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

COs	COURSE OUTCOMES
CO1	The fundamental ideas of limit, continuity, and differentiability
CO2	Increasing and decreasing functions, local maxima, minima, concavity, and inflection points
CO3	How to apply these ideas in drawing the graphs of functions
CO4	To find the solution of maximum-minimum problems using the idea of derivatives
CO5	The Mean Value Theorem and L'Hospital rule
CO6	Riemann sums
CO7	Fundamental Theorem of Calculus and proof
CO8	To solve the area problem, the problem of finding the arc length of a plane curve, and volume of solids
CO9	Average values and the Mean Value Theorem for integrals

Text:

1. George B. Thomas Jr. and Ross L. Finney : Calculus, LPE, Ninth edition, Pearson Education.
2. Frank Ayres JR : Matrices, Schaum's Outline Series, TMH Edition.

Module I:Matrices (18 hrs)

Rank of a Matrix, Non-Singular and Singular matrices, Elementary Transformations, Inverse of an elementary Transformations, Row Canonical form, Normal form.

Systems of Linear equations: Homogeneous and Non Homogeneous Equations, Characteristic equation of a matrix; Characteristic roots and characteristic vectors. Cayley-Hamilton Theorem (statement only) and simple applications (relevant sections of Text 2).

Module II:Application of Derivatives and L'Hopital's Rule (24 hrs)

Application of derivatives: Extreme values of a function. The mean value theorem, First derivative test, Graphing with y' and y''. Limits as $x \to \pm\infty$. Asymptotes and Dominant Terms.

L'Hopital's Rule. (Section 3.1, 3.2, 3.3, 3.4, 3.5 and see section 6.6 of the Text 1).

Module III: Integration and its Applications (22 hrs)

Integration: Properties of definite integrals, areas and the Mean value theorem. The Fundamental theorem. (Section 4.6, 4.7 of the Text 1).

Application of Integrals: Areas between curves, Finding Volumes by slicing, Volumes of Solids of Revolution (Disk method only), Lengths of plane curves. Areas of surfaces of revolution.

(Section 5.1, 5.2, 5.3, 5.5, 5.6 of the Text 1.)

References:

1. S.S. Sastry, Engineering Mathematics, Volume 1, 4th Edition PHI.
2. Muray R Spiegel, Advanced Calculus, Schaum's Outline series.
3. Shanthi Narayanan & P.K. Mittal, A Text Book of Matrices, S. Chand.
4. Harry F. Davis & Arthur David Snider, Introduction to Vector Analysis, 6th ed., Universal Book Stall, New Delhi.
5. Murray R. Spiegel, Vector Analysis, Schaum's Outline Series, Asian Student edition.
6. S.S. Sastry, Engineering Mathematics, Vol. II, 4th ed., PHI.
7. Murray R. Spiegel, Laplace Transforms, Schaum's Outline Series.
8. Jerrold Marsden & Alan Weinstein: Calculus I (2/e) Springer-Verlag New York Inc(1985) ISBN 0-387-90974-5
9. Jerrold Marsden & Alan Weinstein: Calculus II (2/e) Springer-Verlag New York Inc(1985) ISBN 0-387-90975-3
10. Dennis G Zill: Advanced Engineering Mathematics(6/e) Jones & Bartlett Learning, LLC(2018)ISBN: 978-1-284-10590-2
11. Soo T Tan: Calculus Brooks/Cole, Cengage Learning(2010)ISBN 0-534-46579-X
12. Gilbert Strang: Calculus Wellesley Cambridge Press(1991)ISBN:0-9614088-2-0
13. Ron Larson. Bruce Edwards: Calculus(11/e) Cengage Learning(2018) ISBN: 978-1-337-27534-7
14. Peter V O’Neil: Advanced Engineering Mathematics(7/e) Cengage Learning(2012)ISBN: 978-1-111-42741-2
15. Glyn James: Advanced Modern Engineering Mathematics(4/e) Pearson Education Limited(2011) ISBN: 978-0-273-71923-6

SECOND SEMESTER
GMAT2C02T: MATHEMATICS-2

Lecture Hours/ week: 4 **Credits: 3**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

COs	COURSE OUTCOMES
CO1	Represent points in polar coordinates and convert from one system to another
CO2	Do the graphing in polar coordinates
CO3	Fid the derivatives and anti-derivatives of hyperbolic and inverse hyperbolic functions
CO4	Find the arc length and surface area of revolution using definite integrals
CO5	Find the improper integrals
CO6	Find the limit of sequences
CO7	Find the integral using the trapezoidal rule and Simpson's rule
CO8	Find the convergence and divergence of series
CO9	Solve a system of linear equations using matrix theory
C10	To Find the rank and inverse of a matrix using elementary row transformations
C11	Find the eigen values and the corresponding eigen vectors of a matrix
C12	To check whether a matrix is diagonalizable or not

Text:

1. George B Thomas, Jr and Ross L Finney: CALCULUS, LPE, Ninth edition, Pearson Education.
2. Erwin Kreyszig: Advanced Engineering Mathematics, Eighth Edition, Wiley, India.

Module I: Hyperbolic functions , Polar Coordinates (20 hrs)

Hyperbolic Functions- Definitions and Identities, Derivatives and Integrals, Inverse Hyperbolic
Functions, Derivatives and Integrals.

Polar coordinates, Graphing in Polar Coordinates, Polar equations for conic sections, Integration in Polar coordinates.

(Section 6.10, 9.6, 9.7, 9.8, 9.9 of the Text 1)

Module II: Complex Analysis (30 hrs)

A Quick Review: Complex Numbers, Complex Plane, Polar Form of Complex Numbers, Powers and Roots.

Derivatives, Analytic functions, Cauchy-Riemann Equations, Laplace's Equation, Line Integral in the Complex Plane, Cauchy's Integral Theorem, Cauchy's Integral Formula, Derivatives of Analytic Functions. (**All proofs omitted)**

(Section 12.1, 12.2, 12.3, 12.4, 13.1, 13.2, 13.3, 13.4(statements only) of the Text 2).

Module III: Multivariable Functions and Partial Derivatives (14 hrs)

Functions of Several Variables, Limits and Continuity, Partial Derivatives, differentiability, Chain rule (Sections 12.1, 12.2, 12.3, 12.4, 12.5 of the Text 1)

References:

1. S.S. Sastry, Engineering Mathematics, Volume 1, 4th Edition PHI.
2. Murray R. Spiegel: Complex Variables, Schaum's Outline series.
3. James Ward Brown and Ruel V. Churchill : Complex Variables and Applications (8th Edn.), McGraw Hill.
4. Harry F. Davis & Arthur David Snider, Introduction to Vector Analysis, 6th ed., Universal Book Stall, New Delhi.
5. Murray R. Spiegel, Vector Analysis, Schaum's Outline Series, Asian Student edition.
6. S.S. Sastry, Engineering Mathematics, Vol. II, 4th ed., PHI.
7. Murray R. Spiegel, Advanced Calculus, Schaum's Outline Series.
8. Murray R. Spiegel, Laplace Transforms, Schaum's Outline Series.
9. Jerrold Marsden & Alan Weinstein: Calculus I (2/e) Springer-Verlag New York Inc(1985) ISBN 0-387-90974-5
10. Jerrold Marsden & Alan Weinstein: Calculus II (2/e) Springer-Verlag New York Inc(1985) ISBN 0-387-90975-3
11. Dennis G Zill: Advanced Engineering Mathematics(6/e) Jones & Bartlett Learning, LLC(2018)ISBN: 978-1-284-10590-2
12. Soo T Tan: Calculus Brooks/Cole, Cengage Learning(2010)ISBN 0-534-46579-X
13. Gilbert Strang: Calculus Wellesley Cambridge Press(1991)ISBN:0-9614088-2-0
14. Ron Larson. Bruce Edwards: Calculus(11/e) Cengage Learning(2018) ISBN: 978-1-337-27534-7
15. Peter V O'Neil: Advanced Engineering Mathematics(7/e) Cengage Learning(2012)ISBN: 978-1-111-42741-2
16. Glyn James: Advanced Modern Engineering Mathematics(4/e) Pearson Education Limited(2011) ISBN: 978-0-273-71923-6

THIRD SEMESTER
GMAT3C03T: MATHEMATICS-3

Lecture Hours/ week: 5 **Credits: 3**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

COs	COURSE OUTCOMES
CO1	Work on the idea of limit, continuity, and derivative of vector-valued functions
CO2	Use partial derivatives to fiNd the tangent plane and normal line to a point on a surface
CO3	Understand the properties and applications of the gradient of a function
CO4	Apply double integral and triple integral to Find the mass of a lamina, center of mass, etc.
CO5	Evaluate curl and divergence of a vector Field
CO6	Understand line integral, surface integral, and triple integral
CO7	Learn the three important theorems: Green's theorem, Gauss's theorem, and Stokes's theorem and their applications
CO8	Learn about harmonic functions and their relation with analytic functions
CO9	Understand the definition and evaluation of complex integral
C10	Learn the fundamental results on contour integration such as Cauchy-Goursat Theorem
C11	Understand Cauchy's integral formula and apply it to derive Liouville's theorem and the Fundamental Theorem of Algebra

Text:
1. Erwin Kreyszig: Advanced Engineering Mathematics, Eighth Edition, Wiley, India.

Module I: Ordinary Differential Equations (14 hrs)

Basic concepts and ideas, Geometrical meaning of y' = f(x,y). Direction Fields, Separable Differential Equations. Exact Differential Equations; Integrating Factors, Linear Differential Equations; Bernoulli Equation, Orthogonal Trajectories of Curves.

(Sections 1.1, 1.2, 1.3, 1.5, 1.6, 1.8).

Module II: Linear Differential equations of Second and Higher order (16hrs)

Linear Differential equations of Second and Higher order: Differential Operators, Euler-Cauchy Equation, Wronskian, Nonhomogeneous Equations, Solutions by Undetermined Coefficients, Solution by variation of Parameters.

(Sections 2.1, 2.2, 2.3, 2.4, 2.6, 2.7, 2.8, 2.9, 2.10).

Module III: Vector Differential Calculus (24 hrs)

A quick Review of vector algebra, Inner product and vector product in R^2 and R^3 .Vector and scalar functions and Fields, Derivatives, Curves, Tangents, Arc Length, Gradient of a scalar field; Directional Derivative, Divergence of a vector field, Curl of a Vector Field.

(Sections 8.1, 8.2, 8.3, 8.4, 8.5, 8.9, 8.10, 8.11).

Module IV: Vector Integral Calculus (26 hrs)

Line Integrals, Independence of path, Green's Theorem in the Plane (without proof), surfaces for Surface Integrals, Surface Integrals, Triple Integrals, Divergence theorem of Gauss and Stoke's theorem (without proofs).

(Sections 9.1, 9.2, 9.4, 9.5, 9.6, 9.7, 9.9, 9.10)

References:

1. Harry F. Davis & Arthur David Snider, Introduction to Vector Analysis, 6th ed., Universal Book Stall, New Delhi.
2. Murray R. Spiegel, Vector Analysis, Schaum's Outline Series, Asian Student edition.
3. George B. Thomas, Jr. and Ross L. Finney, Calculus, LPE, Ninth Edition, Pearson Education.
4. S.S. Sastry, Engineering Mathematics, Vol. II, 4th ed., PHI.
5. Murray R. Spiegel, Advanced Calculus, Schaum's Outline Series.
6. Murray R. Spiegel, Laplace Transforms, Schaum's Outline Series.
7. Jerrold Marsden & Alan Weinstein: Calculus I (2/e) Springer-Verlag New York Inc(1985) ISBN 0-387-90974-5
8. Jerrold Marsden & Alan Weinstein: Calculus II (2/e) Springer-Verlag New York Inc(1985) ISBN 0-387-90975-3
9. Dennis G Zill: Advanced Engineering Mathematics(6/e) Jones & Bartlett Learning, LLC(2018)ISBN: 978-1-284-10590-2
10. Soo T Tan: Calculus Brooks/Cole, Cengage Learning(2010)ISBN 0-534-46579-X
11. Gilbert Strang: Calculus Wellesley Cambridge Press(1991)ISBN:0-9614088-2-0
12. Ron Larson. Bruce Edwards: Calculus(11/e) Cengage Learning(2018) ISBN: 978-1-337-27534-7
13. Peter V O'Neil: Advanced Engineering Mathematics(7/e) Cengage Learning(2012)ISBN: 978-1-111-42741-2
14. Glyn James: Advanced Modern Engineering Mathematics(4/e) Pearson Education Limited(2011) ISBN: 978-0-273-71923-6

FOURTH SEMESTER
GMAT4C04T: MATHEMATICS-4

Lecture Hours/ week: 5 **Credits: 3**
Marks: 75(Internal: 15, External: 60) **Examination: 2 Hours**

COs	COURSE OUTCOMES
CO1	They learn the major classifications of differential equations
CO2	They learn the conditions for the existence of solution of first and second order Initial Value Problems
CO3	They learn how to formulate a mathematical model of a physical process
CO4	They learn to solve the first order differential equations that are of linear, separable, exact, and Bernoulli's forms
CO5	They learn about the numerical method of solving a differential equation using Euler's method.
CO6	They become familiar with the theory and method of solving second order linear homogeneous and non-homogeneous equations with constant coefficients
CO7	They learn the method of reduction of order to find a second solution of linear second order equation by reducing to linear first order equation
CO8	They learn the method of solution of Cauchy Euler equations
CO9	They learn about linear models and Boundary value problems
CO10	They acquire the knowledge of solving a differential equation using the Laplace method, which is useful to deal with problems in engineering
CO11	They are familiarized with the Fourier series
CO12	They learn the technique of solving partial differential equations using the method of separation of variables

Texts:

1. Erwin Kreyszig, Advanced Engineering Mathematics, Eighth Edition, Wiley, India.
2. George B. Thomas, Jr. and Ross L. Finney, Calculus, LPE, Ninth Edition, Pearson Education.

Module I: Infinite Series (30 hrs)

Limit of Sequences of Numbers, Theorems for calculating limits of sequences (Excluding Picard's Method), Infinite series, The ratio and root test for series of non negative terms, Power Series, Taylor and Maclaurin Series.

(Sections 8.1, 8.2, 8.3, 8.6, 8.8, 8.9 of the Text 2)

Module II: **Laplace Transforms (24 hrs)**

Laplace Transforms: Laplace Transform, Inverse Transform, Linearity, Shifting, Transforms of Derivatives of Integrals, Differential Equations. Unit step Function, Second Shifting Theorem, Dirac Delta Function, Differentiation and integration of Transforms, Convolution, Integral Equations, Partial Fractions, Differential Equations.

(Sections 5.1, 5.2, 5.3, 5.4, 5.5, 5.6 of Text 1 – excluding Proofs).

Module III : Fourier Series ,Partial differential Equations(18 hrs)

Fourier Series: Periodic Functions, Trigonometric Series, Fourier Series, Even and Odd functions, Half-range Expansions.

Partial differential Equations: Basic Concepts

(Sections 10.1, 10.2, 10.4 of Text 1 – Excluding Proofs) and (sections 11.1of Text 1).

Module IV : Numerical Methods (8 hrs)

Numerical Methods: Methods of First-order Differential Equations (Section 19.1 of Text 1).

Picard's iteration for initial Value Problems.(Section 1.9 of Text 1).

Numerical Integration: Trapezoidal Rule, Simpson's Rule. (Section 4.9 of Text 2).

References:

1. S.S. Sastry, Engineering Mathematics, Vol. II, 4th ed., PHI.
2. Murray R. Spiegel, Advanced Calculus, Schaum's Outline Series.
3. Murray R. Spiegel, Laplace Transforms, Schaum's Outline Series.
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