Subject: Pure Mathematics (PMAT)				
B.Sc.				
	Course Units	**Status**	**Pre-requisite**	**Co-requisite**
Year 1 Sem 1	PMAT 11513: Discrete Mathematics I	C	A/L Combined Mathematics	
	PMAT 11522: Matrix Algebra	C	A/L Combined Mathematics	
	PMAT 11212: Discrete Mathematics for Computing I[a]	C	-	
	PMAT 11703: Topics in Basic Mathematics [1]	A	-	
Year 1 Sem 2	PMAT 12532: Discrete Mathematics II	C	PMAT 11513	
	PMAT 12543: Theory of Calculus	C	PMAT 11513	
	PMAT 12212: Discrete Mathematics for Computing II[b]	C	PMAT 11212	
	PMAT 12713: Introduction to Calculus[1]	A		
Year 2 Sem 1	PMAT 21553: Linear Algebra	C	PMAT 11522	
	PMAT 21562: Infinite Series	C	PMAT 12543	
Year 2 Sem 2	PMAT 22572: Ordinary Differential Equations	C	PMAT 12543	
	PMAT 22583: Functions of Several Variables	C	PMAT 21553	
	PMAT 22213: Mathematical Methods for Computing [c]	O	-	
Year 3 Sem 1	PMAT 31593: Complex Variables	C	PMAT 22583	
	PMAT 31602: Abstract Algebra	O	PMAT 21553	
Year 3 Sem 2	PMAT 32612: Theory of Riemann Integration	O	PMAT 12543	
	PMAT 32622: Mathematical Methods	O	PMAT 22583	
	PMAT 32632: Geometry	O	PMAT 22583	

[1] Available only for students who have not offered combined Mathematics for GCE (A/L) Examination.
[a] For BSc (MIT) and (SENG) programmes
[b] For BSc (MIT) and (SENG) programmes
[c] For BSc (SENG) programmes

B.Sc. (Hons)				
	Course Units		**Pre-requisite**	**Co-requisite**
Year 3 Sem 1	PMAT 41763: Complex Analysis	C	PMAT 22583	
	PMAT 41783: Differential Geometry	O	PMAT 22583	
Year 3 Sem 2	PMAT 42793: Advanced Theory of Riemann Integration	C	PMAT 12543	
	PMAT 42803: Advanced Mathematical Methods	O	PMAT 22583 PMAT 22572	
Year 4 Sem 1	PMAT 41813: Functional Analysis[1]	C/O	PMAT 21553	
	PMAT 41823: Topology[2]	C	PMAT 21553	
	PMAT 41962: Research Methodology	C		
	PMAT 43976: Research Project[3]	C		
Year 4 Sem 2	PMAT 42833: Measure Theory	C	PMAT 42793	
	PMAT 42843: Group Theory	C	PMAT 21553	

[1] Optional for students BSc Hons (Statistics)
[2] Students in the Mathematical Physics program are strongly advised to attend these lectures
[3] Compulsory for the students who have not offered AMAT 43976

Pure Mathematics

Level – 1

Course code : PMAT 11513
Title : Discrete Mathematics I
Pre-requisites: A/L Combined Mathematics

Learning Outcomes:
On successful completion of the course, the student should be able to;

1. apply rules of propositional, predicate logic and methods of proof
2. demonstrate working knowledge of sets
3. define equivalence relations and equivalence classes
4. explain the conditions for the existence of the inverse function

Course Contents:
Mathematical Logic: Propositional logic; Predicates and quantifiers; Arguments; Methods of proof; Mathematical induction; Strong induction; Well ordering principle.
Sets: Set notations; Sets of numbers and intervals; Subsets and equal sets; Power set; Cartesian product of sets; Set operations; Algebra of sets.
Boolean Algebra
Relations: Equivalence relations.
Functions: Function notation; One-to-one and onto functions; Inverse function; Composition of functions; Graph of a function.

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:

1. Johnsonbaugh, R., (8th edition , 2017), *Discrete Mathematics*, Pearson.
2. Rosen, K.H., Krithivasan, K., (7th edition, 2013), *Discrete Mathematics and Its Applications*, McGraw-Hill.

Course code : PMAT 11522
Title : Matrix Algebra
Pre-requisites: A/L Combined Mathematics

Learning Outcomes:
On successful completion of the course, the student should be able to;

1. demonstrate knowledge in the fundamentals of matrix algebra
2. apply matrix methods to solve simultaneous equations
3. compute eigenvectors and eigenvalues

Course Contents:

Matrices: Algebra of matrices; Special types of square matrices; Transpose of a matrix, Inverse of a matrix; Elementary row and column operations, Elementary matrices and their properties, Properties of Inverse matrices
System of Linear Equations: Gaussian Elimination, Row echelon form of a matrix, Solutions of System of Equations, Applications of System of Linear Equations.
Determinant of a matrix: Expansion by co-factors, Triangular matrices, Evaluation by elementary row operations.
Eigenvalues and Eigenvectors: Eigenvalues and eigenvectors of a matrix.

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:

1. Larson, R. and Falvo, D. (6th edition , 2009), *Elementary Linear Algebra*, Houghton Mifflin Harcout Publishing Company.
2. DeFranza, J and Gagliardi, D. (1st edition , 2008), *Introduction to linear algebra*, McGraw-Hill.
3. Anton, H. and Rorers C. (11th edition , 2014), *Elementary Linear Algebra Applications*, Wiley.

Course code : PMAT 11212
Title : Discrete Mathematics for Computing I

Learning outcomes:

On completion of this course, the student should be able to:

1. Explain logic, sets, relations and functions
2. Apply Boolean algebra in simplifying combinatorial circuits

Course Content:

Propositional Logic: Propositions, Truth values, Logical connectives, Truth table, Tautology and Contradiction, Logical equivalence, Algebra of propositions, Validity of an argument
Predicate Logic: Quantifies, Nested quantifiers, Negation of quantified statements, Validity of an argument with quantifiers
Methods of Proof: Informal idea of a thermo and a proof, Converse, inverse and the contrapositive of statement, Direct proof, Proof by contradiction, contrapositive, exhaustion and cases, Disproving by counter-examples, Principles of Mathematical induction (weak and strong from)

Sets: Set notations, sets of numbers, Subsets of the real numbers and interval notation, operations on sets, Algebra of sets, set identities, power sets, Cartesian product of sets
Relations : Equivalence relations and equivalence classes, properties of equivalence classes. Partitioning o sets.
Functions: Function notations, image and pre-image, One-to-one and onto functions, Composition of functions, Inverse function, image and inverse image of subsets under functions
Boolean Algebra: Axioms of Boolean algebra and its properties, Correspondence between Boolean algebra and combinatorial logic circuits, Simplifications of combinatorial logic circuits using Boolean algebra.

Method of Teaching and Learning: Lectures, interactive classroom sessions, and case discussions

Assessment: End of course unit examination, group assignment, mid-term examination, class attendance

Recommended Reading:

1. Johnsonbaugh, R., (8th edition , 2017), *Discrete Mathematics*, Pearson.
2. Rosen, K.H., Krithivasan, K., (7th edition, 2013), *Discrete Mathematics and Its Applications*, McGraw-Hill.

Course code : PMAT 11703
Title : Topics in Basic Mathematics

Learning Outcomes:

At the end of this course, the student should be able to

1. demonstrate knowledge in basic discrete mathematical concepts stated in the content
2. apply these concepts in appropriate manner in given problems

Course Contents:

Set theory, Product sets, Relations, Functions and graphs, Determinants of order two and three, Matrices, Linear Equations. Finite series, Binomial theorem, Exponential, Trigonometric and logarithmic functions.

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on the tutorials, tests, and end of course examination.

Recommended Reading:

1. Johnsonbaugh, R., (8th edition , 2017), *Discrete Mathematics*, Pearson.
2. Rosen, K.H., Krithivasan, K., (7th edition, 2013), *Discrete Mathematics and Its Applications*, McGraw-Hill.

Course code : PMAT 12532
Title : Discrete Mathematics II
Pre-requisites: PMAT 11513

Learning Outcomes:
On successful completion of the course, the student should be able to;

1. demonstrate knowledge in applications of the fundamental theorem of arithmetic
2. demonstrate knowledge in fundamental notions of graph theory

Course Contents:
Counting: Basic principles of counting; pigeonhole principle; Permutations and combinations.
Number Theory: Divisibility; Modular arithmetic; The fundamental theorem of arithmetic.
Graph Theory: Graph terminology; Special types of simple graphs; Subgraphs; Euler cycles; Hamiltonian cycles; Representations of graphs; Isomorphic graphs; Planar graphs; Kuratowski's theorem; Graph colouring.

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:

1. Johnsonbaugh, R., (8^{th} edition , 2017), *Discrete Mathematics*, Pearson.
2. Rosen, K.H., Krithivasan, K., (7^{th} edition, 2013), *Discrete Mathematics and Its Applications*, McGraw-Hill.

Course code : PMAT 12543
Title : Theory of Calculus
Pre-requisites: PMAT 11513

Learning Outcomes:
On successful completion of the course, the student should be able to;

1. demonstrate knowledge of the axiomatic description of the field of real numbers and prove theorems from the given set of axioms
2. explain the concepts of limits continuity and differentiation of real-valued functions
3. use the concepts of limits, continuity and the derivatives to describe the qualitative behavior of a graph of a single variable function
4. use derivatives to solve applied problems.

Course Contents:
Real Numbers: Supremum and infimum of a set, completeness axioms, symbols $+\infty$ and $-\infty$
Real Valued Functions of a Real Variable: Review of Polynomial, Rational, Algebraic, Trigonometric, exponential and Logarithmic Functions, Composite Functions, Piece-wise Functions

Functions and Limits: Limits of Functions, Continuous Functions, Asymptotes and limits involving infinity Derivative and Applications: Derivative of a function, Chain rule, Implicit functions and Implicit differentiation, Higher order derivatives, Rolle's Theorem, Mean Value Theorem, Monotonicity and first derivative test, Concavity and second derivative test, Absolute extrema, Curve sketching
Indeterminate Forms: L'hospital Rule.
Integrals: Areas between Curves, Volumes, Volumes by Cylindrical Shells, Arc Length, Area of a Surface of Revolution

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:

1. Ross, K.S., (2^{nd} edition, 2015 *) Elementary Analysis: The Theory of Calculus*, Springer.
2. Stewart, J., (8^{th} edition, 2015) *Calculus Early Transcendentals*, Thomson Learning, Inc.

Course code : PMAT 12212
Title : Discrete Mathematics for Computing II
Pre-requisites: PMAT 11212

Learning Outcomes:
Upon successful completion of the course unit, the student should be able to:

1. apply matrices in analyzing systems of linear equations
2. apply counting techniques in modelling real world problem
3. explain basic graph theory

Course Contents:
Matrices: Matrix notations, Algebra of matrices, Inverse of a matrix, Elementary row operations and calculation of inverse matrix, Determinant of a matrix, Minor and cofactor, properties of determinants, Adjoint of a matrix and calculation of inverse matrix
Systems of linear equations: Matrix form of a system of equations and conditions for unique solutions, augmented matrix and echelon form, Conditions for existence of a unique solution, infinitely many solutions and no solution
Counting techniques: Factorial notation, Sum rule and product rule, Permutations and combinations, Binomial expansion
Graphs: Graph notation and basic definitions, Complete and bipartite graphs, Euler and Hamiltonian circuits, directed and undirected graphs, Trees and their basic properties

Method of Teaching and Learning: Lectures, interactive classroom sessions, and case discussions

Assessment: End of course unit examination, group assignment, mid-term examination, class attendance

Recommended Reading:

1. Epp. S.E, (4th edition, 2011), *Discrete mathematics with Applications*, Cengage learning.
2. Rosen, K.H., Krithivasan, K., (7th edition, 2013), *Discrete Mathematics and Its Applications*, McGraw-Hill.

Course code : PMAT 12713
Title : Introduction to Calculus

Learning Outcomes:

At the end of this course, the student should be able to

1. demonstrate knowledge in basic mathematical concepts of calculus required for the undergraduate studies
2. use basic mathematical concepts of calculus for further studies

Course Contents:

Limits, Continuity, Differential Calculus, Maxima and Minima, indeterminate Forms, Methods of Integration, Improper Integrals, Taylor's formula, Newton's methods, Ordinary Differential Equations.

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on the tutorials, tests, and end of course examination.

Recommended reading:

1. Ayres, Jr .F. & Mendelson, E., (6th edition, 2012). *Schaum's Outline of Calculus*, McGraw-Hill.
2. Arora, S. & Malik, S.C., (5th edition, 2017). *Mathematical Analysis*, New Age International.

LEVEL II

Course code : PMAT 21553
Title : Linear Algebra
Pre-requisites: PMAT 11522

Learning outcomes:
Upon successful completion of the course students should be able to

1. recognize vector spaces and subspaces, linear transformations and eigenspaces of matrices
2. recognize the concepts of the terms span, linear independence, basis, and dimension, and apply these concepts to various vector spaces and subspaces
3. use the definition and properties of linear transformations and matrices of linear transformations and change of basis, including kernel, range and isomorphism
4. compute with the characteristic polynomial, eigenvectors, eigenvalues and eigenspaces, as well as the geometric and the algebraic multiplicities of an eigenvalue and apply the basic diagonalization result
5. compute inner products and determine orthogonality on vector spaces, including Gram-Schmidt orthogonalization
6. apply orthogonal decomposition of inner product spaces

Course Contents:
Vector Spaces: Vector Spaces, Subspaces, Spanning sets and Linear Independence, Basis and dimension, Coordinates, Change of Basis and Transition matrix, Similarity, Dimensional Theorem.
Linear transformations: Kernel and Range of Linear Transformation, Rank and Nullity Theorem. Isomorphisms, Standard Matrix, Applications of Linear Transformation
Eigenvalues and Eigenvectors: Eigenvalues and eigenvectors, Eigen spaces, Diagonalization, Inner product, Gram-Schmidt orthogonalization process, Orthogonal complement, Orthogonal projections, Characteristic polynomial, Cayley-Hamilton,Minimum polynomial.

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended readings:

1. Larson, R. and Falvo, D.C., (8^{th} edition, 2016) *Elementary Linear Algebra*, Brooks Cole.
2. Andrilli, S. and Hecker, D., (3^{rd} edition, 2016) *Elementary Linear Algebra*, Elsevier Science.
3. DeFranza, J. and Gagliardi, D., (2015) *Introduction to Linear Algebra with Applications*, Waveland Press.

Course Code **:** PMAT 21562
Title **:** Infinite Series
Pre-requisites **:** PMAT 12543

Learning Outcomes:
At the end of this course, the student should be able to

1. define the meaning of convergence of a real sequence of real numbers
2. use definition to discuss the behavior of a given sequence
3. describe the nature of the convergence of infinite series and conditions under what differentiation and integration can be performed.

Course Contents:
Sequences: Limits and limit theorems for sequences, Monotone sequences.
Series: Convergence of Infinite Series, the Integral Test and Estimates of Sums, The Comparison Tests, Alternating Series, Absolute Convergence and the Ratio and Root Tests
Power Series: Representations of Functions as Power Series, Taylor and Maclaurin Series, Binomial Series, Applications of Taylor Polynomials

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:

1. Stewart. J., (8^{th} edition, 2015) *Calculus Early Transcendentals*, Cengage Learning.

Course Code **:** PMAT 22572
Title **:** Ordinary Differential Equations
Pre-requisites **:** PMAT 12543

Learning Outcomes:
At the end of this course, the student should be able to

1. distinguish linear and non-linear ordinary differential equations
2. to solve linear ordinary differential equations using appropriate methods

Course Contents:
First-Order Ordinary Differential Equations (ODEs): Separable ODEs. Exact ODEs. Integrating Factors, Linear ODEs. Bernoulli Equation. Orthogonal Trajectories. Existence and Uniqueness of Solutions for Initial Value Problems
Second-Order Linear ODEs: Homogeneous Linear ODEs of Second Order, Homogeneous Linear ODEs with Constant Coefficients, Differential Operators, Euler–Cauchy Equations, Existence and Uniqueness of Solutions. Nonhomogeneous ODEs, Solution by Variation of Parameters
Higher Order Linear ODEs: Homogeneous Linear ODEs, Homogeneous Linear ODEs with Constant Coefficients, Nonhomogeneous Linear ODEs

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:

1. Kreyszig, E., (10th edition, 2011) *Advanced Engineering Mathematics*, Wiley.

Course Code **:** PMAT 22583
Title **:** Functions of Several Variables
Pre-requisites **:** PMAT 21553

Learning Outcomes:
At the end of this course, the student should be able

1. demonstrate analytical and geometrical properties of functions of several variables

Course Contents:
Geometrical Aspects: Level curves, Parametric surfaces; Some special surfaces such as planes, spheres, cylinders and cones; Surface area.
Analytical Aspects: Domain of a function of two variables; Limits and continuity; Partial derivatives; Differentiability; Tangent planes and linear approximations; Chain rules; Maxima and minima; Lagrange multipliers.
Coordinate Systems: Cartesian, polar, spherical and cylindrical. coordinates
Multiple Integrals: Double integrals; Iterated integrals; Double integrals over general regions.

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:

1. Malik, S. C. and Arora, S., (5th edition, 2017) *Mathematical Analysis*, New Age International

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Course Code **:** PMAT 22213
Title **:** Mathematical Methods for Computing

Learning Outcomes:
At the end of this course, the student should be able

1. solve linear ordinary differential equations
2. acquaint with the basic mathematical tools Laplace transform, Fourier series, and Fourier Transforms

Course Contents:

Ordinary differential equations: Second & higher order linear differential equations with constant coefficient, General solution of homogenous and non-homogeneous equations, method of variation of parameters, Euler-Cauchy equation, simultaneous liner equations.

Special functions: Power series method, Forbenious method, Legendre equation, Legendre polynomials, Bessel equations, Bessel function of first kind, Orthogonal property, Rodrigues' formula.

Laplace Transforms: Basic properties, Laplace transform of derivatives and integrals, Inverse Laplace transform, differentiation and integration of Laplace transforms, convolution theorem, unit of step function, Periodic function, Laplace transform to IVP and boundary value problem application, system of linear simultaneous differential equations.

Fourier series: Fourier series, Dirichlet conditions, Even and odd functions, half range series, harmonic analysis.

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:

1. Kreyszig, E. (10th edition, 2011) *Advanced Engineering Mathematics*, Wiley
2. Greenberg, E. (2nd edition, 1998) *Advanced Engineering Mathematics*, Pearson

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LEVEL III

Course Code **:** PMAT 31593
Title **:** Complex Variables
Pre-requisites **:** PMAT 22583

Learning Outcomes:

At the end of this course, the student should be able to

1. demonstrate knowledge of complex numbers and complex valued functions
2. apply knowledge of complex numbers and complex valued functions in applications

Course Contents:

Complex Numbers: Basic Algebraic Properties, Exponential Form, Roots of Complex Numbers, Regions in the Complex Plane

Analytic Functions: Limits, Theorems on Limits, Continuity, Derivatives, Differentiation Formulas, Cauchy–Riemann Equations, Sufficient Conditions for Differentiability, Analytic Functions, Harmonic Functions

Integrals: Definite Integrals of Complex-Valued Function of a Real Variable, Contour Integrals, Anti-derivatives, Cauchy–Goursat Theorem, Cauchy Integral Formula, Liouville's Theorem and the Fundamental Theorem of Algebra, Maximum Modulus Principle

Series: Taylor Series, Laurent Series

Residues and Poles: Isolated Singular Points, Residues, Cauchy's Residue Theorem, Residue at Infinity, Isolated Singular Points, Residues at Poles
Applications of Residues: Evaluation of Improper Integrals

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:

1. Brown, J.W., Churchill, R.V., (9^{th} edition, 2014) *Complex variables and applications*, McGraw-Hill

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Course Code **:** PMAT 31602
Title **:** Abstract Algebra
Pre-requisites **:** PMAT 21553

Learning Outcomes:
At the end of this course, the student should be able to

1. define and identify groups & rings
2. prove properties of groups & rings

Course Contents:
Groups: Basic properties of groups; Examples of groups; Subgroups; Normal subgroups; Quotient groups; Group isomorphism.
Rings: Basic properties of rings; Examples of rings; Subrings; Characteristic of a ring; Ideals; Quotient ring; Integral domains; Euclidean domains.

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:

1. Dummit, D.S. and Foote, R.M., (3^{rd} edition, 2011) *Abstract Algebra*, Wiley

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Course Code **:** PMAT 32612
Title **:** Theory of Riemann Integration
Pre-requisites **:** PMAT 12543

Learning Outcomes:
At the end of the course the student should be able to

1. demonstrate knowledge of the basic concepts of Riemann Integration improper integrals
2. apply knowledge in solving problems

Course Contents:
Riemann Integration: The Riemann integral, Properties of the Riemann integral, Intermediate Value Theorem for Integrals, Dominated Convergence Theorem, Monotone Convergence Theorem, Fundamental theorem of calculus.
Improper integrals: Properties of Improper Integrals, Leibnitz's rule.

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:
1. Ross, K.A., (2^{nd} edition, 2015) *Elementary Analysis*. *The Theory of Calculus*, Springer.
2. Widder, D.V. (2^{nd} edition, 2012) *Advanced Calculus*. Courier Corporation.

Course Code **:** PMAT 32622
Title **:** Mathematical Methods
Pre-requisites **:** PMAT 22583

Learning Outcomes:
At the end of this course, the student should be able to solve different types ordinary and partial differential equations using various techniques learned.

Course Contents:
Special Functions: Legendre Polynomials, Bessel Functions
Laplace Transforms: Laplace Transform. Linearity, Shifting Theorems, Transforms of Derivatives and Integrals, Unit Step Function (Heaviside Function), Differentiation and Integration of Transforms.
Fourier Series: Fourier Series, Even and Odd Functions, Half-Range Expansions, Fourier Integral, Fourier Cosine and Sine Transforms
Partial Differential Equations (PDEs): Basic Concepts of PDEs, Wave Equation
Solution by Separating Variables, Use of Fourier Series, D'Alembert's Solution of the Wave Equation. Characteristics

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:
1. Kreyszig, E., (10^{th} edition, 2011) *Advanced Engineering Mathematics*, Wiley.

Course code : PMAT 32632
Title : Geometry
Pre-requisites: PMAT 22583

Learning outcomes:
Upon successful completion of the course students should be able to

1. develop an intuitive understanding of the nature of general equation of second degree
2. define conic sections and their properties
3. explain and use various techniques for calculating tangents, normals pair of tangents, pole and polar of conic sections
4. compute lines, plane, cone, sphere, ellipsoid and hyperboloid in three dimension
5. choose appropriate mathematical functions to model physical phenomena

Course contents:
Analytical Geometry in Two Dimensions: Pairs of straight lines, General equation of second degree, Translations and rotations of axes,
Conic sections: Parabolas, Ellipses, Hyperbolas, Classifying conic sections by eccentricity. Equations of tangents, Pairs of tangents and chords of contact, Harmonic conjugates, Pole and Polar, Invariance, Reduction to standard forms of conic, Parametric treatment, Degenerate conic, Properties of conic, Matrix methods.
Polar equations of straight lines, circles and conics.
Analytical Geometry in Three Dimension: Vector Equations of a line, plane and sphere, Cone ellipsoid and hyperboloid. Tangent plane, Normal, Pole and Polar, Ruled surfaces, General Equation of the second degree.

Method of Teaching and Learning: A combination of lectures and tutorial discussions.

Assessment: Based on tutorials, tests and end of course examination.

Recommended Reading:

1. Chatterjee, D., (2008) *Analytical Geometry*, Alpha Science International.
2. Thomas, G.B. and Finney, R.L., (2008) *Calculus and Analytic Geometry*.
3. Maxwell, E.A., (1962) *Elementary Coordinate Geometry*, Oxford University press.
4. Jain, P.K. & Ahmad, K. (1994) *Analytical Geometry of Two Dimensions*, Wiley.
5. Kishan, H. (2006) *Coordinate Geometry of Two Dimensions*. Atlantic Publishers & Dist.
6. Jain, P.K. (2005) *A Textbook of Analytical Geometry Of Three Dimensions*. New Age International.

B.Sc. Hons
LEVEL IV

Course Code : PMAT 41763
Title : Complex Analysis
Pre-requisites : PMAT 22583

Learning Outcomes:
At the end of this course, the student should be able to

1. demonstrate knowledge of the role of complex numbers in Mathematics and similarities and the differences of the results in both real and complex number systems.
2. use complex numbers, complex functions and advanced theoretical aspects involving complex functions.

Course Contents:
Complex Numbers, Complex Valued Functions, Limits, Continuity, Differentiability, Cauchy-Riemann Equations, Elementary Functions, Line Integrals, Cauchy's Integral Theorem, Taylor and Laurent Series, Singularities, Residue Theorem, Analytic functions, Maximum modulus theorem, Conformal mappings, Schwarz Christoeffel Transformation, Rouche's theorem.

Method of Teaching and Learning: A combination of lectures, tutorial discussions and presentations.

Assessment: Based on tutorials, tests, presentations and end of course examination.

Recommended Reading:

1. Brown, J.W., Churchill, R.V., (9^{th} edition, 2014) *Complex variables and applications*, McGraw-Hill

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Course Code : PMAT 41783
Title : Differential Geometry
Pre-requisites : PMAT 22583

Learning Outcomes:
At the end of this course the student should be able to

1. demonstrate the fundamental knowledge of curves and surfaces in space
2. identify the importance of the two factors curvature and torsion, and their intrinsic properties.

Course Contents:
Theory of Curves: Concept of a curve, Arc length, Curvature and torsion, Frenet-serret formulae, General helix, intrinsic equations, Fundamental existence and uniqueness theorems for space curves, Canonical representation of a curve. Involutes and Evolutes, Theory of contact.

Theory of Surfaces: Concept of a surface, Topological properties of a surface, Surface of revolution, Ruled surfaces, Length of arc on a surface, Vector element of an area, First and second fundamental forms, Curves on a surface, Direction coefficients, Direction ratios, Family of curves on a surface, Double family of curves. Umbilical point, Intrinsic properties of a surface, Geodesies.
Curvature: Principle curvature and directions, Gaussian and mean curvatures, Lines of curvature Rodrigues formula.
Introduction to Riemannian geometry

Method of Teaching and Learning: A combination of lectures, tutorials and presentations.
Assessment: Based on tutorials, tests, presentations and end of course examination.

Recommended Reading:

1. Lipschutz, L., (1969) *Differential Geometry*, McGraw-Hill.
2. Willmore, T.J., (2013) *An Introduction to Differential Geometry*, Oxford University Press.
3. Do Carmo, M.P., (2016) *Differential Geometry of Curves and Surfaces*, Prentice-Hall, New Jersey.

Course Code : PMAT 42793
Title : Advanced Theory of Riemann Integration
Pre-requisites : PMAT 12543

Learning Outcomes:
At the end of the course the student should be able to demonstrate knowledge of the concepts and theorems of Riemann Integration and to apply them in solving advanced integration problems.

Course Content:
Riemann Integration: The Riemann integral, Properties of the Riemann integral, Fundamental theorem of calculus**.**
Improper Integrals: Properties of Improper Integrals, Leibnitz's rule.

Method of Teaching and Learning: A combination of lectures, tutorials and presentations.
Assessment: Based on tutorials, tests, presentations and end of course examination.

Recommended Reading:

1. Ross, K.A., (2nd edition, 2015) *Elementary Analysis*. *The Theory of Calculus*, Springer.
2. Widder, D.V. (2nd edition, 2012) *Advanced Calculus*. Courier Corporation.

Course Code : PMAT 42803
Title : Advanced Mathematical Methods
Pre-requisites : PMAT 22583

Learning Outcomes:
At the end of this course, the student should be able to demonstrate knowledge of solving problems involving partial differential equations**.**

Course Content:
Special Functions: Legendre Polynomials, Bessel Functions
Laplace Transforms: Laplace Transform. Linearity, Shifting Theorems, Transforms of Derivatives and Integrals, Unit Step Function (Heaviside Function), Differentiation and Integration of Transforms.
Fourier Series: Fourier Series, Even and Odd Functions, Half-Range Expansions, Fourier Integral, Fourier Cosine and Sine Transforms
Partial Differential Equations: Introduction to first order and second order partial differential equations. Parabolic, elliptic and hyperbolic partial differential equations
Integral Transforms: Laplace Transforms, Fourier Transforms, Hankel Transforms, Fourier method for partial differential equations.
Applications of Boundary Value Problems

Method of Teaching and Learning: A combination of lectures, tutorial discussions and presentations.

Assessment: Based on tutorials, tests, presentations and end of course examination.

Recommended Reading:

1. Kreyszig, E., (10th edition, 2011) *Advanced Engineering Mathematics*, Wiley.
2. Pinsky, M.A., (2011) *Partial Differential Equations and Boundary Value Problems with Application*, American Mathematical Soc.
3. Raisinghania, M.D., (1995). Advanced Differential Equations, S.Chands, India.

Course Code : PMAT 41813
Title : Functional Analysis
Pre-requisites : PMAT 21553

Learning Outcomes:
At the end of this course, the student should be able to

1. demonstrate knowledge of the functionals and its analysis under a topological background comprehending
2. understand how algebra and analysis combine to form a separate part of Pure Mathematics.

Course Contents:
Metric spaces, Completion of metric spaces, Normed spaces, Banach spaces, Linear operators and functionals, Inner product spaces, Hilbert spaces, Fundamental theorems for normed and Banach spaces.

Method of Teaching and Learning: A combination of lectures, tutorial discussions and presentations.

Assessment: Based on tutorials, tests, presentations and end of course examination.

Recommended Reading:

1. Madox, I.J., (1992) *Elements of Functional Analysis*, Cambridge University Press.
2. Jain, P.K., Ahuja, O.P. & Ahmad, K., (2^{nd} edition, 2010) *Functional Analysis*, New Age Science Limited
3. Kreyszig, E., (2007) *Introductory Functional Analysis with Applications*, John Wiley, New York.
4. Pannasamy, S., (2^{nd} edition, 2005) *Foundations of Complex Analysis*, Alpha Science International.

Course Code : PMAT 41823
Title : Topology
Pre-requisites : PMAT 21553

Learning Outcomes:
By the end of this course, the student should be able to,

1. demonstrate knowledge of definitions of topological and metric spaces and should be able to demonstrate knowledge of the difference between standard topological and non-topological properties
2. explain the roles of open sets and their interconnections in topological spaces
3. describe the topological notion of connectedness and its relation to path-connectedness
4. describe the topological notion of compactness, and its significance in basic analysis.

Course Contents:
Topological spaces, Basis for a topology, the subspace topology, Closed sets, Limit points, Continuous functions, the product topology, the metric topology, Connected spaces, Compact spaces.

Method of Teaching and Learning: A combination of lectures, tutorial discussions and presentations.

Assessment: Based on tutorials, tests, presentations and end of course examination.

Recommended Reading:

1. Munkres, J.R., (2015). *Topology, a first course*, Prentice-Hall, India.

Course Code : PMAT 41962
Title : Research Methodology

Learning Outcomes:
At the end of this course, the student should be able to understand the methods in research and independent-study in areas in Mathematics/Statistics.

Course Contents:
This course unit is meant to provide honors students with some of the background skills needed to successfully engage in mathematical research, familiarizes students with some of the famous problems which mathematicians are involved in. This will also guides students through the processes of selecting an area of mathematical inquiry, developing research questions, choosing and implementing appropriate methodologies, building outlines, developing bibliographies, writing literature reviews, and preparing drafts.

Method of Teaching and Learning: A series of seminars by senior academic members in the department.

Assessment: Submission of a research/study proposal.

Recommended Reading:
Required reading material will be distributed during each seminar.

Course Code : PMAT 43976
Title : Research/Study Project

Learning Outcomes:
At the end of this course, the student should be able to demonstrate competence in research/independent-study in an area in Mathematics/Statistics.

Course Contents:
Undergraduate research project is an inquiry, investigation, or creation produced by a final year honours degree undergraduate that makes a contribution to the discipline and reaches beyond the traditional curriculum. Undergraduate research project is designed to provide students with the opportunity to develop and practice advanced discipline-specific projects in collaboration with senior academics in the department.

Method of Teaching and Learning: A research/study project under the supervision of a senior staff member of the Department.

Assessment: Submission of a research/study project report and an oral presentation.

Recommended Reading:
Required reading material will be recommended by the supervisor depending on the relevant project

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Course Code : PMAT 42833
Title : Measure Theory
Pre-requisites : PMAT 42793

Learning Outcomes:
At the end of the course the student should be able to demonstrate knowledge of the concepts and theorems of abstract Measure Theory and to apply them in Lebesgue integrals.

Course Contents:
Measure Theory: Algebra, σ-algebra, additivity properties of a set function, Measure, Borel sets, Lebesgue measure, outer Measure, measurable subsets, measurable functions, Integral, Properties that hold almost everywhere, integrable functions, Additivity Theorem, Monotone convergence theorem, Dominated convergence theorem, Fatou's lemma, Relation of Riemann and Lebesgue integrals, Modes of convergence.

Method of Teaching and Learning: A combination of lectures, tutorial discussions and presentations.
Assessment: Based on tutorials, tests, presentations and end of course examination.

Recommended Reading:
1. Cohn, D.L., (2nd edition, 2015) M*easure Theory*, Springer New York.
2. Barra, G., (2nd edition, 2003) *Measure Theory and Integration*, Elsevier.

Course Code : PMAT 42843
Title : Group Theory
Pre-requisites : PMAT 21553

Learning Outcomes:
At the end of the course the student should be able to demonstrate knowledge of the structure of Groups and to apply the knowledge in solving problems in different areas in Algebra.

Course Contents:
Groups, Subgroups, Normal subgroups, Quotient groups, Permutation groups, Derived group, Homomorphisms, Automorphisms, Isomorphism theorems, Sylow's theorems, Internal direct product, Structure theory of finite Abelian Groups, Groups of small order.

Method of Teaching and Learning: A combination of lectures, tutorial discussions and presentations.

Assessment: Based on tutorials, tests, presentations and end of course examination.

Recommended Reading:

1. Khanna, V.K. & Bhambri, S.K., (2016) *A Course in Abstract Algebra*, Vikas Publishing House.
2. Frakeigh, J.B., (2003) *A first course in Abstract Algebra*, Pearson Education India.
3. Baumslag, B. & Chandler, B., (1968) *Group theory*, McGraw-Hill, New York.
4. Narayan, S. & Pal, S., (1992) *A Text Book of Modern Abstract Algebra*, S.Chands, India. (1992).
5. Rotman, J.J., (4th edition, 2014) *An Introduction to the Theory of Groups*, Springer-Verlag.
6. Linda Gilbert, (8th edition, 2014) *Elements of Modern Algebra* (8e) Cengage Learning.

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