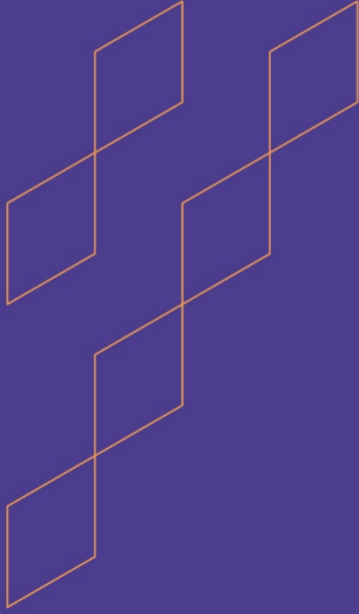# Key Learning Outcomes for Mathematics Programs

2024

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

Introduction

Based on the mandate of the Education and Training Evaluation Commission (ETEC), issued by Royal Decree No. 108, dated 14/2/1440 H, ETEC is mandated to "building systems for evaluation and accreditation - including institutional and programmatic - in education and training, including rules, standards, frameworks and indicators and its terms, procedures, approval, and application." And based on the authority's keenness to build and develop high-quality national academic programs, the authority has worked on preparing specialized academic standards for mathematics programs.

The standards contribute to setting the minimum curriculum requirements of mathematics undergraduate programs to ensure their academic quality, and to assure their ability to produce highly qualified professionals in the field of mathematics with the knowledge and skills required by the market and the national needs, in line with best practices and academic requirements for this field.

Goals

The main goal of this work is to develop specialized Learning Outcomes (SLOs) that should represent the minimum requirements achieved by mathematics students at graduation. It will direct programs, course design and organization, building the curriculum map including the appropriate teaching and learning strategies, assessment tools, evaluation strategy, and link academic and professional aspects.

Methodology

This document describes the minimum knowledge units (KUs) and learning outcomes (LOs) in the field of mathematics, which graduates are expected to obtain upon completion of the program. The KU-specific learning outcomes specify the minimum of what students should know or be able to do after successfully completing the KU.

The methodology follows the following phases:
1. Identifying International Benchmarks.
2. Identifying Program Key Learning Outcomes.
3. Identifying Curriculum General Criteria
4. Identifying the General Knowledge Units.
5. Identifying the Specialized Knowledge Units for each General Knowledge Unit.
6. Identifying the Specialized Learning Outcomes for each Specialized Knowledge Unit.

It is important for educational institutions to take into account the depth and expansion; and to include LOs related to communication skills and values in the curricula. Educational institutions can offer the desired elective KUs that are relevant to their programs and students can choose from them to complete their graduation requirements. It is important to note that a KU is not necessarily a credit course. A KU may be covered by one or more credit courses and a credit course may cover one or more KUs partially or completely. The KUs are derived from analysing nine QS high ranked international programs (see Appendix A).

Scope and Uses

This document covers the bachelor's degree programs in the field of mathematics. The document can be used and applied to mathematics programs offered by higher educational public and private institutions in Saudi Arabia.

Terms

Write the main terms, you can use ETEC glossary:

ETEC: Education and Training Evaluation Commission – Saudi Arabia.

Knowledge Units: Thematic groupings that encompass multiple related topics, where the topics cover the required curricular content for each KU. Each KU contains a set of learning outcomes.

Essential Knowledge Units (EKUs): The required topics in mathematics.

General Knowledge Units (GKUs): Knowledge Units that introduce students to the main topics in mathematics. All students majoring in any field of mathematics should complete these GKU's.

Key Learning Outcomes (KLOs): It describes what students are expected to know and will be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program.

Learning Outcomes (LOs): Phrases describing what a learner should know, understand, and be able to do at the end of the program. They represent the bottom line of the learning process.

NQF: National Qualifications Framework.

Specialized Key Learning Outcomes (SLOs): The specificity needed for interpretation of the general criteria as applicable to a given discipline.

Specialized Knowledge Units (SKUs): Knowledge Units that introduce students to intermediate and advanced topics in a major.

Key Learning Outcomes

Upon successful completion of a bachelor's degree in mathematics, graduates should be able to:

KLO 1	Demonstrate an understanding of common mathematical concepts, formulas, results, and their interrelationships.
KLO 2	Analyze mathematical problems and apply problem-solving strategies and logical reasoning to solve them.
KLO 3	Utilize technology and software in presenting, understanding, modelling, and solving mathematical and real-world problems.
KLO 4	Apply logical reasoning to analyze and understand proofs, recognize logical fallacies, and construct logically sound proofs.
KLO 5	Demonstrate sufficient mathematical maturity ranging from the direct execution of calculations and procedures to the more mature levels of comprehension, abstraction, and generalization, including the ability to interpret mathematical results and/or communicate them graphically and in words.
KLO 6	Adhere to professional levels of self-management, self-learning, critical thinking, punctuality, independence, collaboration, leadership, ethics, and responsibility.

Curriculum General Criteria

Based on benchmarking study of leading universities (Appendix A), and analyzing all knowledge units (KUs) and skills of mathematics programs, it is found that these KUs are grouped into the following categories:

1. Essential knowledge units: 6 credit hours
2. Specialized knowledge units: 73 credit hours
3. General knowledge and skills units: remaining credit hours

Each group consists of different subgroups that is essential in any typical mathematics program. To show the importance of each of the subgroups, a range of allocated credit hours in a typical mathematics program is shown in the next section.

knowledge Units

The following table provides an overall view of the curriculum distribution of Knowledge Units: essential, general, specialized and others. The tables also provide general recommendation on the acceptable range of credit hours for each knowledge unit.

Essential Knowledge Units (EKU)

Calculated based on a minimum of credits for precalculus. This part of the knowledge units should not be used in standardized tests.

Table 1: Essential Knowledge Unit of Mathematics program

#	EKU	Description	Minimum Requirements
1	Precalculus	This EKU concerns the practical review of properties of real and complex numbers, algebraic operations on polynomials and rational expressions, equations and inequalities, basic properties of real functions in a single variable, exponential functions, logarithmic functions, and trigonometric functions.	6 credit hours*

*One credit hour is equivalent to a 50-minute period conducted weekly throughout a 15-week semester (according to NQF).

Program core Knowledge Units

Percentages are calculated based on a minimum of credits for the mathematics program.

Table 2: Generalized and Specialized Knowledge Units of Mathematics

#	GKU	Weight (%)	SKU	Weight (%)
1	Foundations and Discrete Mathematics	22	1.1 Foundations of Mathematics	5.5
			1.2 Combinatorics and Graphs	6.9
			1.3 Analytic Geometry	4.1
			1.4 Number Theory	5.5
2	Differentiation and Integration	26	2.1 Differential Calculus	6.9
			2.2 Integral Calculus	6.9
			2.3 Multivariable Calculus	6.9
			2.4 Differential Equations	5.3
3	Mathematical Analysis	12	3.1 Real Analysis	6.9
			3.2 Complex Analysis	5.1
4	Algebra	18	4.1 Linear Algebra	9.6
			4.2 Abstract Algebra	8.4
5	Numerical Mathematics	11	5.1 Numerical Methods	6.9
			5.2 Programming and Software	4.1
6	Statistics and Probability	11	6.1 Statistics	5.5
			6.2 Probability	5.5

*One credit hour is equivalent to a 50-minute period conducted weekly throughout a 15-week semester (according to NQF).

Appendix (A): International Practices analysis

The KUs are derived from the following sources:
1. Cambridge University (UK)
2. Imperial College London (UK)
3. University of Manchester (UK)
4. McGill University (Canada)
5. Georgia Institute of Technology (USA)
6. University of Illinois at Urbana-Champaign (USA)
7. University of Washington (USA)
8. Pennsylvania State University (USA)
9. Michigan State University (USA)

Table A1: International and local universities considered in the analysis of mathematics programs requirements.

#	University	Department name	QS University Ranking 2023
1	Cambridge University	Faculty of Mathematics	2
2	Imperial College London	Mathematics	10
3	Georgia Institute of Technology	School of Mathematics	25
4	McGill University	Mathematics and Statistics	55
5	University of Illinois at Urbana-Champaign	Mathematics	56
6	University of Manchester	Mathematics	58
7	University of Washington	Mathematics	60
8	Pennsylvania State University	Mathematics	81
9	Michigan State University	Mathematics	82

Required Subjects/Topics in Top International and Local Universities

You should explain in brief how did you identify the Knowledge Units. Those topics and their corresponding sub-topics were used as a reference for the comparison with the university's courses.

Table A2: Mathematics program required Subjects/Topics in elite International and local Universities.

GKUs	SKUs	1	2	3	4	5	6	7	8	9	Count Total	Note
Foundations and Discrete Mathematics	Foundations of Mathematics	Y		Y	Y	Y	Y	Y	Y	Y	**8**	A
	Combinatorics and Graphs			Y	Y	Y	Y		Y	Y	**6**	A
	Analytic Geometry	Y			Y	Y	Y	Y	Y		**6**	A
	Number Theory	Y		Y	Y			Y	Y	Y	**6**	A
Differentiation and Integration	Differential Calculus	Y	Y	Y	Y	Y	Y	Y	Y	y	**9**	A
	Integral Calculus	Y	Y	Y	Y	Y	Y	Y	y	Y	**9**	A
	Multivariable Calculus	Y	Y	Y	Y	Y	Y	Y	Y	Y	**9**	A
	Differential Equations	Y	Y	y	Y	Y	y	Y	Y	Y	**9**	A
Mathematical Analysis	Real Analysis	Y	Y	Y	Y	Y	Y	Y	Y	Y	**9**	A
	Complex Analysis	Y	Y	Y	Y		Y		Y	Y	**7**	A
Algebra	Linear Algebra	Y	Y	Y	Y	Y	Y	Y	Y	Y	**9**	A
	Abstract Algebra	Y	Y	Y	Y	Y	Y		Y	Y	**8**	A
Numerical Mathematics	Numerical Methods		Y	Y	Y		Y	Y	Y	Y	**7**	A
	Programming and Software	Y	Y	Y	Y	Y	Y	Y		Y	**8**	A
Statistics and Probability	Statistics		Y	Y	Y	Y	Y		Y		**6**	A
	Probability	Y	Y	Y	Y	Y	Y		Y		**7**	A

● Any specialized knowledge unit that was taught by 65 % or more of the universities should be considered an important SKU and should be recommended and Labeled "A."
● If the comparison showed that a particular SKU scored below 65% and was believed to be important, they should be further screened by applying another acceptance condition as defined in the FE exam by QIYAS and SCE. The SKUs that satisfy this condition are recommended and labeled by "B."
● SKUs not meeting the above conditions should not be recommended, labeled by "C," and eliminated from Specialized Learning Outcomes.

Appendix (B): Alignment of Key Learning Outcomes of Mathematics with NQF.

Alignment of the Key Learning Outcomes for Mathematics with the NQF.

Mathematics Key Learning Outcomes	NQF Learning Areas		
	Knowledge and Understanding	Skills	Values, Autonomy, and Responsibility
KLO 1	✓		
KLO 2		✓	
KLO 3		✓	
KLO 4		✓	
KLO 5		✓	
KLO 6			✓

Appendix (C): Learning Outcomes and Topics for Knowledge Units

Essential Knowledge Unit (EKU): Precalculus

Description	This EKU in concerned with the practical review of properties of real and complex numbers, algebraic operations on polynomials and rational expressions, equations and inequalities, basic properties of real functions in a single variable, exponential functions, logarithmic functions, and trigonometric functions.
Topics	**The following topics must be included in this EKU:** 1. Basic properties of real and complex numbers. 2. Algebraic operations on polynomials and rational expressions. 3. Equations and inequalities. 4. Basic properties of real functions of a single variable. 5. Exponential functions, logarithmic functions, and trigonometric functions.
Specialized Learning Outcome	**By completing this EKU, students should be able to:** 1. Explain basic properties of sets of numbers (order property, intervals, absolute value, exponents, radicals) and perform algebraic operations by hand dealing accurately with signs and simplifications. 2. Perform and simplify algebraic operations on polynomials and rational expressions. 3. Find sets of solutions (and plot them if possible) for equations and inequalities in one variable. 4. Illustrate basic properties of functions in one variable (domain, range, monotonicity, evenness, oddness, injectivity, surjectivity, and inverses), perform algebraic operations on them, graph the common ones, and describe the effect of vertical and horizontal shifting. 5. Define transcendental functions (trigonometric functions, exponential functions, and logarithmic functions), and discuss their properties. **The table below shows maps the essential learning Outcomes for the EKU to the KLOs**

ELOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓					
2		✓			✓	
3		✓			✓	
4	✓	✓			✓	
5	✓	✓				

General Knowledge Unit (GKU 1): Foundations and Discrete Mathematics

Description	This GKU covers the areas of foundations of mathematics, graphs, combinatorics, analytic geometry, and elementary number theory.

Specialized Knowledge Unit (SKU 1.1): Foundations of Mathematics

Description	This SKU is concerned with the study of mathematical logic, methods of proof, sets, relations, functions, and binary operations.
Topics	**The following topics must be included in this SKU:** 1. Introductory mathematical logic. 2. Methods of proof. 3. Sets. 4. Relations and functions. 5. Binary operations and properties.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Explain concepts from elementary mathematical logic and compose truth tables of various propositional forms highlighting connectives, equivalence of propositions, contradictions, and tautologies. 2. Distinguish between universal and existential quantified statements as well as their negations both in meaning and in use. 3. Identify and use a suitable method of proof (direct proof, proof by contradiction, proof by contraposition, proof by cases, proofs involving quantifiers or their negations, and mathematical induction) in order to show the truth or falsehood of a given mathematical statement. 4. Explain basic set-theoretic concepts (belonging, containment, equality, power set, indexed families of sets, and famous sets of numbers), and perform operations on sets (intersection, union, complement, difference, and symmetric difference). 5. Discuss properties of relations and resulting notions (equivalence classes, partitioning, and ordering). 6. Explain properties of functions and related concepts such as injectivity, surjectivity, bijectivity, images and preimages of sets, inverse function, equivalent sets, cardinality, finite and infinite sets. 7. Illustrate properties of binary operations (associativity, commutativity, the identity, and invertibility), and give examples and counterexamples of relevant algebraic structures.

The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓	✓				
2	✓	✓				
3		✓		✓	✓	
4	✓	✓		✓	✓	
5	✓	✓			✓	
6	✓	✓		✓	✓	
7	✓	✓		✓	✓	

Specialized Knowledge Unit (SKU 1.2): Combinatorics and Graphs

Description	This SKU is concerned with the study of counting principles, permutations, combinations, recurrence relations, generating functions, graphs, and trees.
Topics	**The following topics must be included in this SKU:** 1. Basics of counting principles. 2. Binomial coefficients, permutations, and combinations. 3. Recurrence relations and generating functions. 4. Graphs, paths, planar graphs, graph coloring, and properties. 5. Trees, spanning trees, and rooted trees.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Apply combinatorial techniques (the pigeonhole principle, the inclusion-exclusion principle, the binomial coefficients, permutations and combinations) to solve counting problems. 2. Identify different types of recurrence relations, compute generating functions, and use relevant results to enumerate structures and solve combinatorial problems. 3. Outline definitions and properties of graphs, digraphs, subgraphs, graph isomorphism, connected paths, Euler's paths, Hamilton paths, planar graphs, graph coloring, and trees. 4. Express suitable problems in terms of graphs and trees and apply relevant results to solve them.

The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓	✓				
2	✓	✓				
3	✓					
4		✓		✓	✓	

Specialized Knowledge Unit (SKU 1.3): Analytic Geometry

Description	This SKU is concerned with the study of Cartesian coordinates in 2- and 3-dimensional spaces, lines, planes, circles, conic sections, polar coordinates, cylindrical coordinates, and spherical coordinates.
Topics	**The following topics must be included in this SKU:** 1. Cartesian coordinates in the 2- and 3-dimensional spaces, distance, and vectors. 2. Line segments and straight lines in the 2- and 3-dimensional spaces, and convex sets. 3. Planes in the 3-dimensional space and their properties. 4. Circles, conic sections, and their properties. 5. Coordinate systems and relation to rectangular coordinates: polar coordinates, cylindrical coordinates, and spherical coordinates.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Describe the Cartesian coordinate system, plot points and vectors, draw line segments, and find lengths, distances, and division points, and perform operations on vectors (addition, scalar multiplications, and inner product). 2. Discuss the equations and parametric equations of lines, parallel lines, perpendicular lines, planes, parallel planes, and draw them. 3. Describe solution regions for inequalities in two variables and describe convex sets. 4. Determine the equation and the characteristics of a circle (center, radius, tangent lines, and intersection of circles), and sketch it. 5. Develop the equations of conic sections, extract their characterizing properties, and sketch them. 6. Describe the polar, cylindrical, and spherical coordinate systems, and use them to express the afore-mentioned algebraic and geometric notions. **The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓	✓				
2	✓	✓				
3	✓	✓		✓		
4	✓	✓		✓		
5	✓	✓		✓		
6	✓	✓				

Specialized Knowledge Unit (SKU 1.4): Number Theory

Description	This SKU is concerned with the study of divisibility of integers, prime numbers, linear Diophantine equations, congruences, Euler's Theorem, Fermat's Little Theorem, Wilson's Theorem, arithmetic functions, and some cryptographic applications.
Topics	**The following topics must be included in this SKU:** 1. Divisibility of integers and properties of prime numbers. 2. Linear Diophantine equations. 3. Integer representations. 4. Congruences, modular arithmetic, and the Chinese Remainder Theorem. 5. Euler's Theorem, Fermat's Little Theorem, and Wilson's Theorem. 6. Arithmetic and multiplicative functions. 7. Mobius inversion formula. 8. Perfect numbers and Mersenne primes. 9. Basic cryptographic applications.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Articulate and use divisibility properties of integers and primes. 2. Solve linear Diophantine equations and systems in one unknown. 3. Represent linear Diophantine equations and systems in one unknown. 4. Perform modular arithmetic and apply the Chinese Remainder Theorem. 5. Prove and apply Euler's Theorem, Fermat's Little Theorem, and Wilson's Theorem. 6. Define arithmetic and multiplicative functions (Euler phi-function, divisor functions, and Mobius function), manipulate them, and use the Mobius inversion formula. 7. Illustrate properties of perfect numbers and Mersenne primes. 8. Discuss basic number-theoretic cryptographical systems and use them to encrypt and decrypt messages. **The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓	✓		✓		
2	✓	✓		✓		
3	✓	✓		✓		
4	✓	✓		✓		
5	✓	✓		✓	✓	
6	✓	✓		✓		
7	✓	✓				
8	✓	✓		✓	✓	

General Knowledge Unit (GKU 2): Differentiation and Integration

Description	This GKU covers the areas of differential calculus, integral calculus, multivariable calculus, and differential equations.

Specialized Knowledge Unit (SKU 2.1): Differential Calculus

Description	This SKU is concerned with the study of limits of real functions of a single variable, continuity, derivatives and their applications.
Topics	**The following topics must be included in this SKU:** 1. The Limit of a function. 2. Continuity. 3. Derivatives. 4. Applications of derivatives.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** **1.** Determine the existence of limits of functions and use the limit properties to evaluate them (with particular attention to indeterminate forms). **2.** Recognize infinite limits, compute limits at infinity, and interpret the behavior of a function in terms of its asymptotic lines. **3.** Investigate the continuity of a function at a point and on intervals, distinguish between types of discontinuities, and apply properties of continuous functions. **4.** Evaluate the derivatives of a function using the limit definition and the differentiation rules, find the equation of the tangent line of the curve of a function at a point, and apply relevant results to solve optimization and word problems. **5.** Compute the derivative of inverse functions and implicit derivative of the equation of a curve. **6.** Analyze and sketch the graph of a function by determining the asymptotic lines, extrema, intervals of monotonicity, inflection points, and concavity.

The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓			✓		
2	✓			✓		
3	✓			✓		
4	✓	✓	✓			
5	✓					
6	✓		✓		✓	

Specialized Knowledge Unit (SKU 2.2): Integral Calculus

Description	This SKU is concerned with the study of definite and indefinite integrals, transcendental functions, techniques of integration, geometric applications of definite integrals, improper integrals, sequences, and series.
Topics	**The following topics must be included in this SKU:** 1. The definite integral, Riemann sum, and the Fundamental Theorem of Calculus. 2. Indefinite integrals. 3. Transcendental functions. 4. Techniques of integration. 5. Applications of the definite integral in areas, surfaces, volumes, and arc length. 6. Improper integrals. 7. Infinite sequences and series.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Approximate the value of a definite integral using Riemann sums and apply the Fundamental Theorem of Calculus. 2. Evaluate integrals involving the trigonometric functions, logarithmic functions, hyperbolic functions, exponential functions and their inverse functions. 3. Compute an integral using an appropriate integration technique (substitution, integration by parts, trigonometric substitution, partial fractions, and quadratic expressions), and recognize the equivalence of antiderivatives resulting from evaluating an integral using different techniques. 4. Characterize the types of improper integrals and determine their convergence or divergence. 5. Find the areas between graphs of functions, arc length, volumes, and surface areas of solids of revolutions. 6. Find the limits of sequences and apply various convergence tests to determine the convergence or divergence of series. 7. Find the radius and interval of convergence of a power series and represent a function as a power series using Taylor expansion directly or existing expansions of other functions.

The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓					
2	✓	✓				
3	✓	✓				
4	✓		✓	✓		
5	✓				✓	
6	✓					
7	✓			✓		

Specialized Knowledge Unit (SKU 2.3): Multivariable Calculus

Description	This SKU is concerned with the study of vector-valued functions, functions of several variables and their properties, multiple integrals with applications, and introduction to vector calculus.
Topics	**The following topics must be included in this SKU:** 1. Vectors and vector-valued functions. 2. Functions of several variables. 3. Multiple integrals and their applications. 4. Vector calculus.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Find unit tangents, normal vectors, and curvature of curves determined by vector-valued functions. 2. Determine domains and ranges of functions of several variables and sketch their graphs and level curves. 3. Investigate the limits and continuity of a function of several variables. 4. Find partial derivatives and use them to obtain directional derivatives, gradients, equations of tangent planes, normal lines, critical points, and extrema. 5. Evaluate multiple integrals in rectangular, polar, cylindrical, and spherical coordinate systems and use the Jacobian to make a change of variables. 6. Apply multiple integrals to compute areas, surface areas, and volumes. 7. Evaluate the line integrals of functions of several variables along curves, characterize the independence of path, and apply Green's Theorem.

By completing this SKU, students should be able to:

The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓					
2	✓		✓		✓	
3	✓	✓		✓	✓	
4	✓					
5	✓	✓	✓		✓	
6	✓					
7	✓	✓			✓	

Specialized Knowledge Unit (SKU 2.4): Differential Equations

Description	This SKU is concerned with the study of elements of ordinary differential equations (ODEs), existence and uniqueness of solution, first-order and higher order linear ODEs, modeling with ODEs.
Topics	**The following topics must be included in this SKU:** 1. Definitions, classifications, existence and uniqueness of solution. 2. First-order ODEs. 3. Higher-order linear ODEs with constant coefficients. 4. Second-order linear homogeneous ODEs with variable coefficients. 5. Modelling with ODEs.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Classify ODEs in terms of order and linearity and assess the existence and uniqueness of their solutions. 2. Find analytical solutions of linear, separable, and exact first-order ODEs. 3. Solve higher-order homogeneous and nonhomogeneous linear ODEs with constant coefficients. 4. Slove second-order homogeneous linear ODEs with variable coefficients at ordinary points. 5. Formulate, solve, and interpret simple models described by linear ODEs. **The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓					
2	✓	✓	✓			
3	✓	✓	✓			
4	✓	✓	✓			
5	✓	✓	✓		✓	

General Knowledge Unit (GKU 3): Mathematical Analysis

Description	This GKU covers the areas of real analysis and complex analysis.

Specialized Knowledge Unit (SKU 3.1): Real Analysis

Description	This SKU is concerned with the study of real numbers' properties, sequences, topology of R, limits, continuity, and differentiation.
Topics	**The following topics must be included in this SKU:** 1. Properties of the real numbers. 2. Sequences of real numbers. 3. Topology of R. 4. Limits and continuity of functions. 5. Differentiation.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Recognize the order, completeness, and uncountability properties of the real numbers and use the Archimedean property to establish the density of Q in R. 2. Prove and apply results on convergent sequences, Cauchy sequences, monotonic sequences, and subsequences. 3. Demonstrate understanding of the topological properties of R (open sets, closed sets, bounded sets, and compactness) and prove the Heine-Borel Theorem. 4. Prove and apply various theorems of limits, continuity, and uniform continuity. 5. Develop rigorous proofs of differentiation rules, L'Hopital rule, and Taylor Theorem. 6. Establish the relations between the continuity and differentiability; prove and apply the relevant theorems (the Extreme Value Theorem, the Intermediate Value Theorem, and the Mean Value Theorem). **The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓			✓	✓	
2	✓			✓	✓	
3	✓			✓	✓	
4	✓			✓	✓	
5	✓			✓	✓	
6	✓			✓	✓	

Specialized Knowledge Unit (SKU 3.2): Complex Analysis

Description	This SKU is concerned with the study of complex numbers, complex functions, analytic functions, elementary functions, complex integrals, and the residue theorem.
Topics	**The following topics must be included in this SKU:** 1. Complex numbers. 2. Limits, continuity, and differentiability of complex functions. 3. Analytic functions. 4. Elementary functions. 5. Complex integrals. 6. The residue theorem and applications.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Perform algebraic operations on complex numbers and compute their powers and roots. 2. Demonstrate understanding of domains, regions, and contours in the complex plane. 3. Define and determine the domain of definition, range, limits and limits involving infinity, continuity, differentiability, and boundedness of complex functions. 4. Determine the analyticity of a complex function and recognize various properties of analytic functions. 5. Define the exponential, logarithm, trigonometric, hyperbolic, and power functions of complex variables, and contrast their properties with those of their counterparts in the real case. 6. Evaluate contour integrals directly by the antiderivatives and derive bounds for the modulus of contour integrals. 7. Prove and apply Cauchy's integral theorem and Cauchy's integral formulas for the analytic functions and their derivatives. 8. Classify singularities and poles of a complex function and apply the residue theorem to evaluate real and complex integrals. **The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓				✓	
2	✓				✓	
3	✓				✓	
4	✓				✓	
5	✓				✓	
6	✓	✓			✓	
7	✓	✓		✓	✓	
8	✓	✓			✓	

General Knowledge Unit (GKU 4): Algebra

Description	This GKU includes the areas of linear algebra and abstract algebra.

Specialized Knowledge Unit (SKU 4.1): Linear Algebra

Description	This SKU is concerned with the study of algebra of matrices, solving systems of linear equations, vector spaces, eigenvalues and eigenvectors, inner product spaces, and linear transformations.
Topics	**The following topics must be included in this SKU:** 1. Matrix algebra. 2. Systems of linear Equations. 3. Determinants and invertible matrices. 4. Vector spaces. 5. Eigenvalues and eigenvectors. 6. Inner product spaces. 7. Linear transformations.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Perform algebraic operations and elementary row operations on matrices, find traces and transposes of matrices, and recognize different types of matrices. 2. Solve systems of linear equations and characterize them. 3. Compute inverses and determinants of matrices using different methods, apply their properties, and demonstrate equivalent characterizations of invertible matrices. 4. Calculate the characteristic polynomial of a matrix and find its eigenvalues, eigenvectors, and eigenspace. 5. Recognize vector spaces, subspaces, and their properties, give examples and counterexamples of such concepts, and find the row space, column space, rank, and nullity of a given matrix. 6. Characterize linearly independent vectors, linearly dependent vectors, and spanning property of sets of vectors, find a transition matrix between bases, and compute a basis and the dimension of a vector space. 7. Construct an orthonormal basis for an inner product space. 8. Illustrate different properties of linear transformations and their matrices.

The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓		✓			
2	✓	✓	✓			
3	✓	✓	✓	✓		
4	✓		✓			
5	✓			✓		
6	✓			✓	✓	
7	✓	✓	✓		✓	
8	✓					

Specialized Knowledge Unit (SKU 4.2): Abstract Algebra

Description	This SKU is concerned with the study of groups, subgroups, homomorphisms of groups, rings, subrings, ideals, homomorphisms of groups, integral domains, rings of polynomials, algebraic field extensions.
Topics	**The following topics must be included in this SKU:** 1. Algebraic structures, semigroups, and monoids. 2. Groups, subgroups, abelian and non-abelian groups, cyclic groups, and permutation groups. 3. Group homomorphisms, group isomorphisms, normal groups, and quotient groups. 4. Rings, subrings, ideals, ring homomorphism, ring isomorphism, and quotient rings. 5. Integral domains, fields of fractions, rings of polynomials, ideals in rings of polynomials, and irreducible polynomials. 6. Factorization of polynomials over fields and algebraic field extensions.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Contrast the algebraic structures of semigroups, monoids, groups, rings, and fields. 2. Articulate definitions, invoke facts, give examples and counterexamples, and apply properties of groups, subgroups, cyclic groups, normal subgroups, quotient groups, permutation groups, rings, subrings, ideals, quotient rings, integral domains, fields, rings of polynomials, irreducibility, and factorizations of polynomials. 3. Verify and apply properties of homomorphisms and isomorphisms of groups and rings. 4. Prove and apply Lagrange's Theorem, Cauchy's Theorem, and the Isomorphism Theorems. **The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓	✓		✓	✓	
2	✓	✓		✓	✓	
3	✓	✓		✓	✓	
4	✓	✓		✓	✓	

General Knowledge Unit (GKU 5): Numerical Mathematics

Description	This GKU includes the areas of numerical methods, programming, and software.

Specialized Knowledge Unit (SKU 5.1): Numerical Methods

Description	This SKU is concerned with the study of root finding, Gaussian elimination with partial pivoting, iterative methods for solving linear systems, interpolation, polynomial approximations, numerical differentiation, and numerical integration.
Topics	**The following topics must be included in this SKU:** 1. Round-off errors and computer arithmetic. 2. Zero-finding methods. 3. Gaussian elimination with partial pivoting. 4. Iterative methods for solving linear systems. 5. Interpolation and polynomial approximations. 6. Numerical differentiation and integration.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Recognize the limitations of computer arithmetic and numerical methods. 2. Explain the concept of errors, rate of convergence, direct methods, indirect methods, approximated solutions, and exact solutions. 3. Find a zero of a function in one variable using the bisection, fixed point, Newton, and secant methods, and estimate the errors. 4. Solve linear systems using Gaussian elimination with partial pivoting and iteratively using Jacobi method and Gauss-Seidel method. 5. Construct the interpolating polynomial of a set of points and estimate its error bound. 6. Compute derivatives and integrals numerically. 7. Develop an algorithm and a computer program for a numerical method.

The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓					
2	✓					
3	✓	✓			✓	
4	✓	✓			✓	
5	✓	✓			✓	
6	✓	✓				
7	✓		✓		✓	

Specialized Knowledge Unit (SKU 5.2): Programming and Software

Description	This SKU is concerned with the study of a programming language, software, and algorithms.
Topics	**The following topics must be included in this SKU:** 1. An overview of programming languages and software. 2. Algorithms and programming (using Python or MATLAB). 3. Visualization techniques, and data representation. 4. Symbolic computations.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Demonstrate understanding of a variety of programming languages and some of their features. 2. Employ software to visualize basic 2-D and 3-D objects, data, and graphs. 3. Use built-in functions to execute numeric or symbolic computations. 4. Develop codes for algorithms utilizing flow control operations (for/do/while loops), conditional statements (if/ else), branches, relational operations, and logical operations. **The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1					✓	
2		✓	✓		✓	
3		✓	✓		✓	
4			✓		✓	

General Knowledge Unit (GKU 6): Statistics and Probability

Description	This GKU includes the areas of introductory statistics and probability.

Specialized Knowledge Unit (SKU 6.1): Statistics

Description	This SKU is concerned with a first look study of statistics covering descriptive and inferential statistics with the help of elementary probability.
Topics	**The following topics must be included in this SKU:** 1. Descriptive statistics. 2. Discrete probability distributions. 3. Continuous probability distributions. 4. Sampling distributions. 5. Point and interval estimation. 6. One and two sample tests.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Describe sets of data graphically and numerically and use a statistical software. 2. Compute discrete probabilities from discrete to continuous distributions (including the binomial, geometric, hypergeometric, exponential, and normal distributions). 3. Demonstrate understanding of the concept of a sampling distribution. 4. Construct confidence intervals. 5. Perform one and two sample tests under normality and for large samples. **The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓		✓			
2	✓	✓				
3	✓	✓				
4	✓	✓				
5	✓	✓				

Specialized Knowledge Unit (SKU 6.2): Probability

Description	This SKU is concerned with the study of events, axioms of probability, random variables, mean and variance of random variables, moments, joint probability distributions, conditional and marginal probability distributions, covariance, correlation, and the central limit theorem.
Topics	**The following topics must be included in this SKU:** 1. Events, operations on events, and independence of events. 2. Axioms of probability, conditional probability, and Bayes' Theorem. 3. Discrete and continuous random variables, mean and variance of a random variable. 4. Moment generating functions. 5. Joint probability distributions, conditional and marginal probability distributions, covariance, and correlation. 6. The central limit theorem.
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Describe operations on events and check for independence of events. 2. Compute conditional probabilities directly and using Bayes' Theorem. 3. Perform probability calculations relating to probability distributions for discrete and continuous random variables. 4. Compute mathematical expectation and variance. 5. Demonstrate understanding of the significance of the central limit theorem. **The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO 1	KLO 2	KLO 3	KLO 4	KLO 5	KLO 6
1	✓	✓				
2	✓	✓		✓		
3	✓	✓				
4	✓	✓				
5	✓	✓		✓		