Honours Courses
2025
School of Mathematics
University of the Witwatersrand

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

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Chapter 1

Introduction

Warm welcome to Bachelor of Science with Honours in the field of Mathematics.

Please make sure you are familiar with the rules relevant to the Degree of Bachelor of Science with Honours and Honours in the field of Mathematics, including admission criteria, syllabus content and outcomes, as contained in the **Faculty of Science Rules and Syllabus book.**

Inquiries should be addressed to the coordinator of the Honours program.

1.1 Coordinator

- Coordinator: Bertin Zinsou
- Office: MSB350
- Phone: 011 717 6205
- Email address: bertin.zinsou@wits.ac.za

1.2 Admission

To be admitted to the BSc with Honours program in the School of Mathematics, a candidate must pass MATH III with an average mark of at least 60%. In addition, the applicant must pass all the three compulsory courses of MATH III major. They are

- MATH3048A Real Analysis III (RA),
- MATH3006A Group Theory III (GT),
- MATH3004A Complex Analysis III (CA).

1.3 Honours in the field of Mathematics (120 credits)

A candidate must successfully complete the following compulsory courses as well as three elective courses to obtain a Bachelor of Science Honours in the field of Mathematics.

1.3.1 Compulsory courses

The compulsory courses are given below

Compulsory courses

Course Code	Description	NQF Credits	NQF Level
MATH4026	Research Project	36	8
MATH4025	Measure Theory	12	8
MATH4027	Topology	12	8
MATH4016	Algebra	12	8
MATH4021	Functional Analysis	12	8

1.3.2 Elective courses

The elective courses are given below

Elective courses

Course Code	Description	NQF Credits	NQF Level
MATH4020	Complex Analysis	12	8
MATH4024	Number Theory	12	8
MATH4019	Combinatorics	12	8
MATH4018	Calculus of Variations	12	8
MATH4017	Asymptotics	12	8
MATH4023	Graph Theory	12	8
MATH4022	GA Topology	12	8
MATH4028	Mathematical Logic	12	8

Note.

GA Topology = Geometry and Algebraic Topology

Chapter 2

Course contents

2.1 Compulsory courses

2.1.1 MATH4016 Algebra

The course consists of a selection from the following topics.

PART I: RINGS AND MODULES

This course is an introduction to the theory of associative rings and their modules. Review the fundamental concepts of algebras.

Topics covered include the complete ring of quotients of commutative rings, prime ideals and prime ideal spaces, primitive rings and radicals and completely reducible rings and modules. Artinian and Noetherian rings and idempotents. Injective and projective modules. Introduction to homological algebra.

PART II: AUTOMORPHISMS GALOIS THEORY

This course introduces the study of field extensions. The main idea of Galois Theory is to consider the relation of the group of permutations of the roots of a polynomial to the algebraic structure of its splitting field. The course includes the Fundamental Theorem of Galois Theory, composite extensions and simple extensions, the Galois group of polynomials, solvability and radical extensions leading to the result on the insolvability of the quintic.

PART III: FINITE DIMENSIONAL VECTOR SPACES

The purpose of this course is to treat linear transformations on finite dimensional vector spaces by simple geometric notions common to many parts of mathematics and in a language that is used in the theory of integral equations and Hilbert Theory. The course builds on the elementary notions of vector spaces over fields and introduces dual spaces, quotient spaces and the direct sum of vector spaces. Central to the development is the introduction of bilinear forms and inner products and the Riesz Representation Theorem with the ideas of adjoint and self-adjoint linear transformations. The course includes a survey of orthogonal projections, eigenvalues and the Spectral Decomposition Theorem.

2.1.2 MATH4021 Functional Analysis

This is a foundational course in functional analysis and as such it requires as a prerequisite only a knowledge of classical real analysis. The topics covered in the course are:

1. Normed linear spaces, inner product spaces, Banach spaces & Hilbert spaces.
2. Properties and characterization of bounded linear operators on normed linear spaces.
3. The principle of uniform boundedness, the open mapping theorem, the Hahn-Banach theorem or the Hilbert space analogues thereof in terms of orthogonality, depending on the focus for that year.

4. The Riesz-Fischer Theorem, duality and reflexivity.

5. Spectral theory of compact operators.

6. Bounded selfadjoint operators.

2.1.3 MATH4025 Measure Theory

This is a foundational course in measure theory and as such it requires as a prerequisite only a knowledge of classical real analysis. The topics covered in the course are:

1. Algebras and sigma algebras of sets.

2. Definition and properties of measures.

3. Completions of measures.

4. The monotone class theorem and the Caratheodory construction of measures.

5. Properties of measurable functions.

6. Construction of the Lebesgue integral.

7. Fatou's Lemma, the Lebesgue monotone convergence and dominated convergence theorem.

8. The space of Lebesgue integrable functions.

2.1.4 MATH4026 Research Project

The course consists of a research project on a pure mathematics topic which is carried out under standard exploratory, investigative and analytical principles. The stages consist of Topic selection, Proposal Construction, Approval of Proposal, Project Work, Project Report Writing and Report Submission. The report should not exceed 35 printed pages on A4 sized paper. The following items are recommended for the proposal:

1. Title,

2. Aim,

3. Problem Statement,

4. Research Questions,

5. Methodology,

6. Contents,

7. Literature review,

8. Further Work,

9. References.

2.1.5 MATH4027 Topology

Topology is the branch of mathematics concerned with the properties of space that are preserved under continuous deformations. It may be considered as a modern geometry. This course introduces the student with the fundamental concepts of a topological space and a continuous mapping, with basic constructions and results. The list of presented topics includes cardinal invariants of spaces, separation axioms, compact spaces, Urysohn's lemma which says that any two disjoint closed subsets of a normal space can be separated by a continuous function, and Tychonoff theorem which says that the product of compact spaces is compact.

References

1. R. Engelking, General topology, Springer-Verlag, 1989;

2. K. Kunen and J. Vaughan (eds.), Handbook of set-theoretic topology, Elsevier, Amsterdam, 1984.

2.2 Elective courses

2.2.1 MATH4017 Asymptotics

This is a continuation of the Honours Topic Combinatorics. It includes a selection from

1. General principles of enumeration;
2. Symbolic computer algebra with Mathematica;
3. Methods of asymptotic enumeration including asymptotics of sums, asymptotics of recurrence relations, Mellin transforms, Rice's method, singularity analysis, saddle point method, limiting distributions.

2.2.2 MATH4018 Calculus of Variations

The course deals with the Invariance approach to the analysis of variational differential equations as introduced by Sophus Lie.

The course content is as follows.

1. Differential Geometric Preliminaries (Manifolds, Groups, Lie Groups, Lie group transformations).
2. Lie point symmetries of ordinary differential equations (methods and applications).
3. Calculus of Variations (Introduction and definitions, Euler-Lagrange equations, Inverse problems, conservation laws).
4. Noether symmetries
5. Noether's theorem (conservation laws).
6. Association between symmetries and first integrals.
7. Symmetries of PDEs.
8. Conservation laws of variational PDEs

2.2.3 MATH4019 Combinatorics

Starting at an elementary level, the course introduces students to a selection from the following topics:

1. Permutations and combinations.
2. Binomial coefficients, Stirling numbers and combinatorial identities.
3. The principle of inclusion and exclusion.
4. Recurrence relations.
5. Ordinary and exponential generating functions.
6. The exponential formula and trees.
7. Lagrange inversion.
8. The symbolic method of enumeration.
9. Discrete probability.
10. Bivariate generating functions and combinatorial parameters.
11. Pólya's Theory of Counting.

2.2.4 MATH4020 Complex Analysis

This is structured as a second course in complex analysis, where students already know the Cauchy theorems. The topics covered in this course are: counting of zeros; the argument principle; counting of zeros and poles and the argument principle for meromorphic functions; the open mapping theorem; Rouché's theorem; Hurwitz's theorem; maximum modulus principle and theorem; Schwarz's lemma; the Schwarz-Pick theorem; geometry of holomorphic and biholomorphic mappings on $\mathbb{C}$ and the unit disc; fractional transformations; infinite products.

2.2.5 MATH4022 Geometry and Algebraic Topology

The course is an introduction to algebraic topology with geometric applications. It is aimed at honours students who have some knowledge of basic topology and differential geometry, such as what is provided by the third-year courses MATH 3010 and MATH 3031 offered at Wits. The main content follows.

Introduction to the basic concepts and tools of algebraic topology, such as fundamental group, covering spaces, homology and cohomology. Introduction to certain applications of algebraic topology to geometry, such as de Rham cohomology, the classification of closed surfaces, and the Jordan Curve Theorem.

2.2.6 MATH4023 Graph Theory

The course will introduce the fundamental concepts of Graph theory. Elements of topological graph theory, graph polynomials, connectivity, and embedding will be introduced. The Major part of the course will be devoted to some or all of the following parts:

PART I

Basic Graph Theory. Basic concepts and results in graph theory and introduction to open problems. Traversals (Eulerian graphs, Hamiltonian graphs), connectivity and planarity. Research in graph theory on these topics.

References

1. R. Diestel, Graph Theory, 4th edition, Springer-Verlag 2010 (corrected edition in 2012);
2. G.F. Royle and C. Godsil, Algebraic Graph Theory, Springer-Verlag 2001.

PART II

Topological Graph Theory. Fundamental concepts of the relationship between graph theory and Knot theory. Some knot invariants calculated via the corresponding graphs: pathwidth, component number, the Kauffman polynomial, the Jones polynomial and the Alexander polynomial.

Reference: C. Adams, The Knot Book;

PART III

Graph Polynomials. Fundamental concepts of graph colouring and graph operations. Graph polynomials namely chromatic polynomial, the Tutte polynomial, the Martin polynomial and Penrose polynomial.

Reference: F. M. Dong, K.M. Koh and K.L. Teo, Chromatic polynomials and Chromatic graphs.

2.2.7 MATH4024 Number Theory

This module deals with mainstream and advanced concepts and trends in Elementary, Analytic and Algebraic theory of Numbers. These will include a selection from the following topics:
I. Infinitude of primes, prime numbers of different kinds, solution of Diophantine equations and congruences, arithmetic functions, Euler function, quadratic residues, irrational numbers and continued fractions, decimal expansions of real numbers;

II. Algebraic properties of arithmetical functions, pseudoconvergence, average values, densities, the zeta function, the nth prime, Prime Number Theorem, Dirichlet characters, Ramanujan expansions, orders of magnitude;. III. Ring localizations, integral elements, prime and maximal ideals, Dedekind domains, unique factorization of ideals, algebraic number fields, integral bases, discriminants, norms, class number.

2.2.8 MATH4028 Mathematical Logic

Mathematical logic is a fundamental mathematical field. In the early twentieth century, the discovery of Russell's and other foundational paradoxes shook the mathematical community to its core and it became a matter of urgency to re-establish mathematics on firm foundations. In the ensuing quest, mathematical logic began to emerge in its modern form and to produce some of the most sensational and shocking results of the last hundred years, including Gödel's incompleteness theorems, and the independence of the continuum hypothesis from the axioms of Zermelo-Fraenkel set theory. Besides its central role in mathematics, mathematical logic has wide-ranging applications, especially in theoretical computer science, artificial intelligence and linguistics.

This course introduces the field of Mathematical Logic. It consists of propositional logic, first-order logic and non-classical logic. The course explores the syntax, semantics and proof systems for each logic considered, pursuing these themes up to and including soundness and completeness theorems and the characterisation of expressivity in terms of model-theoretic invariance results.

Chapter 3

Semester courses

The Honours are divided in two blocks of compulsory and elective courses. Three of the compulsory courses with a selection of three elective courses will be taught in the first semester. The remaining compulsory and elective courses will be taught during the second semester.

3.1 First semester courses

The first semester courses with the details of the different lecturers are given below.

3.1.1 Compulsory courses

MATH4016: Algebra

Lecturer's details

- Lecturer: Dr Rugare Kwashira,
- Office: MSB337,
- Email address: rugare.kwashira@wits.ac.za,
- Phone: 0117176228

Assessments

- Assignment 1 15%,
- Assignment 2 15%,
- Class Test 30%,
- Exam 40%.

MATH4025: Measure Theory

Lecturer's details

- Lecturer: Dr Wen-Chi Kuo,
- Office: MSB357,
- Email address: Wen.Kuo@wits.ac.za,
- Phone: 0117176215.

Assessments

- 10 weekly quizzes on Fridays,
- No class test,
- Exam 40%.

MATH4026: Research Project

Lecturer's details

- Lecturer: Dr Bertin Zinsou,
- Office: MSB350,
- Email address: bertin.zinsou@wits.ac.za,
- Phone: 0117176205.

Assessments

- Research project presentation,
- Research project report.

MATH4027: Topology

Lecturer's details

- Lecturer: Prof Yevhen Zelenyuk,
- Office: MSB317,
- Email address: yevhen.zelenyuk@wits.ac.za,
- Phone: 0117176247.

Assessments

- Test – 40% (First Block),
- Exam 60% (End of the term).

3.1.2 Elective courses

MATH4018: Calculus of Variations

Lecturer's details

- Lecturer: Prof Abdul Kara,
- Office: MSB346,
- Email address: abdul.kara@wits.ac.za,
- Phone: 0117176242.

Assessments

- Eight tests of 10 marks each,
- A bigger test of 40 marks.

MATH4019: Combinatorics

Lecturer's details

- Lecturer: Prof Arnold Knopfmacher,
- Office: MSB310,
- Email address: arnold.knopfmacher@wits.ac.za,
- Phone: 0117176241.

Assessments

- Regular small tests or assignments.
- Exam

MATH4024: Number Theory

Lecturer's details

- Lecturer: Prof Darlison Nyirenda,
- Office: MSB349,
- Email address: darlison.nyirenda@wits.ac.za,
- Phone: 0117176224.

Assessments

- Test – 40%,
- Assignment - 20%,
- Exam 40%.

3.1.3 Timetable

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
SCHOOL OF MATHEMATICS

TIMETABLE- MATH HONOURS SEMESTER ONE – 2025

Lecturers: **MATH4025: Measure Theory – Dr W Kuo**
MATH4027: Topology – Prof Y Zelenyuk
MATH4018: Calculus of Variations – Prof A Kara
MATH4026: Project – Dr B Zinsou
MATH4024: Number Theory – Prof D Nyirenda
MATH4019: Combinatorics – Prof A Knopfmacher
MATH4016: Algebra – Dr R Kwashira

Time	8:00 -8:45	9:00 - 9:45		10:15 -11:00	11:15 -12:00		12:30 - 13:15	14:15 - 15:00	15:15 - 16:00
MON	MATH4024	MATH4025		MATH4018	MATH4018		MATH4019		
TUE	MATH4025	MATH4016A		MATH4016A	MATH4018		MATH4019	MATH4026	MATH4026
WED	MATH4024	MATH4024		MATH4026	MATH4026		MATH4019		
THUR	MATH4027	MATH4027		SEMINAR					
FRI		MATH4025		MATH4027	MATH4016A				

VENUE FOR ALL LECTURES: MSB326

3.2 Second semester courses

The second semester courses with the details of the different lecturers are given below.

3.2.1 Compulsory course

MATH4021: Functional Analysis

Lecturer's details

- Lecturer: Prof Sonja Currie,
- Office: MSB315,
- Email address: sonja.currie@wits.ac.za,
- Phone: 0117176233

Assessments

- Test 1 - 25%
- Test 2 - 25%
- Exam - 50%

3.2.2 Elective courses

MATH4017: Asymptotics

Lecturer's details

- Lecturer: Prof Darlison Nyirenda,
- Office: MSB349,
- Email address: darlison.nyirenda@wits.ac.za,
- Phone: 0117176224

Assessments

- Assignment 20%,
- Class test 40%,
- Exam 40%.

MATH4020 Complex Analysis

Lecturer's details

- Lecturer: Prof Bruce Watson,
- Office: MSB345,
- Email address: bruce.watson@wits.ac.za,
- Phone: 0117176209

Assessments

- Assignments and Quizzes 40%,
- Exam 60 %.

MATH4022 Geometry and Algebraic Topology

Lecturer's details

- Lecturer: Dr Jesse Alt,
- Office: MSB353,
- Email address: jesse.alt@wits.ac.za,
- Phone: 0117176201

Assessments

- Assignment 60%,
- Exam 40%.

MATH4023 Graph Theory

Lecturer's details

- Lecturer: Prof Simon Mukwembi,
- Office: MSB324,
- Email address: simon.mukwembi@wits.ac.za,
- Phone: 0117176210

Assessments

- **Test 1** Thursday 21 August 20%,
- **Test 2** Thursday 25 September 20%,
- **Test 3** Thursday 16 October 20%.
- **Exam** 40%

MATH4028 Mathematical Logic

Lecturer's details

- Lecturer: Prof Willem Conradie,
- Office: MSB339,
- Email address:willem.conradie@wits.ac.za,
- Phone: 0117176204

Assessments

- Homework assignments 20 %,
- Class work 10 %,
- Test 1 15%,
- Test 2 15 %,
- Exam 40%.

3.2.3 Timetable

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF MATHEMATICS

TIMETABLE- MATH HONOURS SEMESTER TWO – 2025

Lecturers: MATH4017: Asymptotics – Prof D Nyirenda
MATH4020: Complex Analysis – Prof B Watson
MATH4021: Functional Analysis – Prof S Currie
MATH4022: Algebraic Topology – Dr J Alt
MATH4023: Graph Theory – Prof S Mukwembi
MATH4028: Mathematical Logic – Prof W Conradie

Time	8:00 -8:45	9:00 - 9:45		10:15 -11:00	11:15 -12:00		12:30 - 13:15	13:15 – 14:00	14:15 - 15:00
MON		MATH4020 Complex Analysis		MATH4021 Functional Analysis	MATH4023 Graph Theory		MATH4023 Graph Theory		
TUE	MATH4020 Complex Analysis	MATH4017 Asymptotics		MATH4028A Logic	MATH4028A Logic		MATH4022A GAT		
WED	MATH4017 Asymptotics	MATH4017 Asymptotics			MATH4022A GAT		MATH4022A GAT		
THUR		MATH4023 Graph Theory		SEMINAR	MATH4021 Functional Analysis		MATH4021 Functional Analysis		
FRI	MATH4020 Complex Analysis				MATH4028A Logic				

VENUE FOR ALL LECTURES = MSB326