MH1802 Calculus for the Sciences

This course aims to equip students with

- mathematical knowledge and analytical skills so that they are able to apply techniques of calculus (along with their existing mathematical skills) to solve scientific problems whenever applicable;
- mathematical reading skills so that they can read and understand related mathematical content in the basic and popular scientific and engineering literature; and
- mathematical communication skills so that they can effectively and rigorously present their mathematical ideas to mathematicians, scientists and engineers.

Content

Basics (BAS)
Types of numbers; Functions and Graphs; Commonly used functions and their graphs; Important algebraic, trigonometric, logarithmic and exponential identities; Basic Complex numbers.

Differential Calculus (DIF)
Limits; Differentiation; Techniques of Differentiation; Applications of Differentiation; Basic Partial derivatives.

Integral Calculus (INT)
Integration; Techniques of Integration; Calculus of Logarithmic, exponential and Inverse Trigonometric Functions; Applications of Integration;

Differential Equations (DE)
Basics; First Order Ordinary Differential Equations; Second Order Ordinary Differential Equations; Series, Sequences and Differential equations.

MH1812 Discrete Mathematics

Learning Objective

This Course introduces basic notions in discrete mathematics commonly used in mathematics and computer science.

Content
- counting, permutations and combinations, binomial theorem
- recurrence relations
- graphs, paths and circuits, isomorphisms
- trees, spanning trees
- graph algorithms (e.g., shortest path, maximum flow) and their computational complexity, big-O notation

MH2100 Calculus III

Learning Objective
This is the last course in the calculus sequence. In this course, multi-variable calculus is introduced.

Content
Parametric equations, polar coordinates. Vector-valued functions, calculus of vector-valued functions, solid analytic geometry. Functions of more than one variable, limits, continuity, partial derivatives, differentiability and total differential, chain rule, Implicit Function Theorem. Directional derivatives, gradients, Lagrange multipliers. Double integrals, area of a surface, triple integrals. Line integrals, Green's Theorem, surface integrals, Gauss' divergence theorem, Stokes' Theorem.

MH2500 Probability & Introduction to Statistics

Learning Objective
This course focuses on probability theory, with the view of probability distributions as models for phenomena with statistical regularity.

Content
Discrete distributions (binomial, hypergeometric and Poisson). Continuous distributions (normal, exponential) and densities. Random variables, expectation, independence, conditional probability. Introduction to the law of large numbers and the central limit theorem. Sampling distributions. Elementary statistical inference (confidence intervals and hypothesis tests).

MH2802 Linear Algebra for Scientists

This course aims to

1. Acquire a wider range of mathematical concepts related to vector spaces and linear algebra.
2. Develop a strong set of mathematical skills for upper level Science and Engineering courses.
3. Solve large systems of linear equations and related areas.
4. Develop thinking, reasoning, communication and modelling skills through a mathematical approach to problem-solving
5. Connect ideas within mathematics and apply mathematics in the contexts of Science and Engineering.
6. Experience and appreciate the rigour and abstraction in the discipline.

Content
1. Vector Algebra & Analytical Geometry
2. Calculus of Vectors
3. Linear Spaces
4. Matrices & Linear Transformations
5. Determinants
6. Eigenvalues and Eigenvectors
7. Applications of Linear Algebra to problems in Science and Engineering

MH3500 Statistics

Learning Objective
The purpose of this course is to introduce modern statistical concepts and procedures derived from a mathematical framework.

Content
Probability distributions of functions of random variables, the law of large numbers and the central limit theorem. Point and interval estimation, optimal estimation, maximum likelihood methods, more on tests of hypotheses, Neyman-Pearson lemma, likelihood ratio tests, large sample theory, Chi-square tests and contingency tables.

MH3510 Regression Analysis

Learning Objective
The object of study in this course is regression analysis – one of the most widely used statistical techniques.

Content
Simple and multiple linear regression, nonlinear regression, analysis of residuals and model selection. One-way and two-way factorial experiments, random and fixed effects models.

MH3511 Data Analysis with Computer

Learning Objective
This course introduces the use of statistical computer packages for performing data analysis.

Content
Data analysis process and collecting data, graphical and numerical methods for describing data, summarizing bivariate data, probability and population distribution, estimation and hypothesis testing using a single sample, comparing two population or treatments, analysis of categorical data and goodness-of-fit tests.

MH3701 Basic Optimization

Learning Objective
This is the first course in optimization and operations research. Basic methods and concepts are introduced.

Content
Introduction of optimization models: objective and constraints, convex sets and functions, polyhedron and extreme points. Introduction to LP: solving 2-variable LP via graphical methods; simplex method; dual LP and sensitivity analysis.
Karush-Kuhn-Tucker optimality conditions, optimal solution via optimality conditions. Duality theory. Network optimization: Shortest path, maximum flow, minimum cost flow, assignment problem, transportation problem, network simplex method.

MH4500 Time Series Analysis

Learning Objective
This course introduces time series models used in economics, engineering and finance.

Content
Trend fitting, autoregressive and moving average models, spectral analysis. Seasonality, forecasting and estimation. Use of computer package to analyze real data sets.

MH4501 Multivariate Analysis

Learning Objective
This course focuses on the standard methods of multivariate statistical analysis.

Content
Distribution theory: multivariate normal distribution, Hotelling's T2 and Wishart distributions, inference on the mean and covariance, principal components and canonical correlation, factor analysis, discrimination and classification.

MH4511 Sampling & Survey

Learning Objective
This course gives an introduction to sampling and the design of sample surveys.

Content
Ratio and regression estimators under simple random sampling, separate and combined estimators for stratified random sampling. Systematic sampling and its relationship with stratified and cluster sampling. Further aspects of stratified sampling, cluster sampling with clusters of unequal sizes. Subsampling; multi-stage sampling. Complex sample designs.

MH4513 Survival Analysis

Learning Objective
This course focuses on the standard methods of survival data analysis.

Content
Examples of survival data analysis, types of censoring, parametric survival distributions (exponential, Weibull, lognormal), nonparametric methods, Kaplan-Meier estimator, tests of hypotheses, graphical methods of survival distribution fitting, goodness of fit tests, parametric accellerated failure time model, Cox's proportional hazards model.

MH4515 Applied Bayesian Statistics

This course focuses on introducing conceptual, computational, and practical Bayesian approaches, with applications to various areas, such as social sciences, econometrics and health sciences.

Content
Bayesian statistics offer flexible techniques for analyzing data in which classical statistical methods may not be properly applied. This course provides a sound basis in Bayesian statistics by introducing conceptual, computational, and practical Bayesian approaches. It covers Bayes' theorem, common prior distributions, summarizing posterior distributions, comparison between Bayesian approaches and frequentist methods, Gibbs sampling, the Metropolis-Hastings algorithm, the evaluation of informative hypotheses, as well as Bayesian modelling using R.

MH4516 Applied Categorical Data Analysis

This course focuses on the statistical tools for analyzing categorical data with applications in medical and biological sciences.

Content
The course provides statistical methods and models for analysis of categorical data including proportions, count and binary/binomial type of data. The topics covered in this course include contingency tables, logistic, probit, Poisson regression and log-linear models, as well as analysis of ordered response categories. The implementation of methods using R or SAS and interpretation of results will also be emphasized.

MH4517 Data Applications in Natural Sciences

This course introduces topological data analysis (TDA) and discusses its applications in natural sciences.

Content
Review of algebraic concepts like: Simplicial complex, Vietoris-Rips complex, nerves, homology, Smith normal form, cohomology, etc. Recent new topological tools including: discrete Morse theory, Reeb graphs, Conley index, persistent homology, etc and their applications in natural sciences.

MH4518 Simulation Techniques in Finance

This course introduces a broad range of standard and specified simulation methods in finance with a focus on option pricing and risk management.

Content
Simulating sample paths. Pricing financial products and computing risk measures with the simulation techniques. Use of computer software to implement the Monte-Carlo simulation and its applications.

PH4410 Econophysics

Content
This course introduces statistical physics-inspired approaches to economics and finance. Review basic concepts in probability and statistics. Low- and high-frequency data in economics and finance. Gaussian and fat-tailed return distributions. Autocorrelation, memory, and nonstationarity in time series data. Cross correlations in financial markets. Random matrix theory. Correlation filtering and minimal spanning trees. Time series clustering. Agent-based models of financial markets. Stylized facts from simulation results.

CZ3* Data Visualization**

This course is designed to provide students with the foundations necessary for understanding and extending the current state of the art in data visualization.

Content
The value of visualization, data and image models, visualization design, exploratory data analysis, multidimensional data, interaction techniques, visualization software, graphical perception, color, animation, using space effectively, mapping and cartography, design critiques, graph layout and network analysis, text visualization, narrative visualization, collaborative visual analysis, and visualization evaluation.

CZ4* Distributed Computing for Data Science and AI**

The course covers the landscape of distributed systems relevant to large-scale data science, the principles on which they rely, their tradeoffs, and how to evaluate their utility against applications' requirements.

Content
MapReduce and Parallel Dataflow Programming, NoSQL: Systems and Concepts, and Graph Analytics.

CZ1* Introduction to Data Science**

This course focuses on the foundational topics in data science and the expected ability of data scientists.

Content
The course will focus on breadth by presenting the topics briefly instead of focusing on a single topic in depth. The topics covered in this course include data preparation and manipulation, data cleaning and integration, data analysis with statistics and machine learning, data visualization and communication, as well as working with big data. The implementation of methods will use Python or R.

CZ4* Developing Data Products**

This course focuses on the statistical fundamentals of creating data products as well as the basic developing tools.

Content
The course introduces the process of creating data-intensive products as well as basic developing tools in R. A data product utilizes data as it's input, and processes such data to obtain algorithmically generated results. The topics covered in this course include interactive visualization with Shiny and rCharts, presenting data analysis with slidify and Rstudio presenter, useful R Packages and R Classes, as well as reproducible presentations and interactive graphics. This course will focus on the way of creating a data product from a statistical analysis.

CZ1003 – Introduction to Computational Thinking

The objective of this course is to take students with no prior experience of thinking in a computational manner to a point where they can derive algorithms and write programs in Python to solve various problems. Upon completion of the course, students should be able to:

a. Understand how algorithmic solutions may be used to solve numerical and textual problems.
b. Capture requirements in a methodical fashion and derive an appropriate algorithm.
c. Implement algorithms using a high-level programming language.
d. Be able to understand and use appropriate file management techniques.
e. Plan for testing of programs.
f. Acquire and adopt good programming practice

CZ1007 - Data Structures

The objective of the course is to teach the concepts, implementations and applications associated of data structures such as arrays, stacks, queues linked lists and trees and to use such data structures to solve real world problems. This also includes abstract data types, dynamic memory allocation, recursion and testing. Upon completion of the course, students should be able to:

a. Understand the abstract design and practical implementation of data structures.
b. Select and apply appropriate data structures for a given requirement.
c. Visualize the data structures created.
d. Capable of proposing new data structures.
e. Implement software to solve real world problems using data structures.

CZ2001 Algorithms – Syllabus

Learning Objectives

a. Learn basic mathematical techniques for complexity analysis of algorithms

b. Apply, design and analyse algorithms for efficient sorting and searching, graphs and certain types of optimization problems.

CZ2002 - Object Oriented Design and Programming

Students should know essential object-oriented concepts such as encapsulation, the separation of design from implementation; the use of inheritance and polymorphism. These concepts will be described using appropriate UML diagrams. Students will also learn about good design principles for reuse, with opportunities to realise these principles using object-oriented programming languages such as C++ and/or Java.

CZ2004 – Human-Computer Interaction

Learning Objectives

This is an introductory course to HCI. The objectives are to have students:

a. Appreciate and understand the significance of considering usability issues in interface development, including user requirements, measurements and various usability tests.
b. Acquire vocabulary to frame and articulate HCI issues and considerations for different computing applications.
c. Learn first principles in user interface design and develop basic ability to apply design considerations to both current and future interface modalities.
d. Obtain a perspective of how HCI needs to be aligned with human thought processes and physical abilities.
e. Be aware of the large range of user interfaces in society today, and appreciate how HCI design is applied in various sectors of the computing industry.

CZ2006 - Software Engineering

Learning Objectives

To equip SCSE graduates with foundation knowledge on issues and techniques required for the design and implementation of quality software.

Computer Science students will have the necessary knowledge and skills to delve deeper into systems analysis (CZ3003) and advanced topics in Advanced Software Engineering (CZ3002).

CZ2007 – Introduction to Databases

Learning Objectives

- Discuss the importance of, and uses for, databases within organizations
- Be able to design a basic relational database management system (DBMS) for storing and analyzing datasets of medium complexity
- Formulate basic relational database queries and execute these in order to analyze business opportunities and risks
- Ensure data integrity through enacting the process of database normalization
- Understand the significance of XML in today's world
- Be able to formulate basic XML queries on XML documents
- Acquire the language necessary for speaking knowledgeably about data management

CZ3005 – Artificial Intelligence

This course is a core subject of computer science and the Intelligent Systems Thread. Its emphasis is placed on mimicking human like and cognitive structures, particularly, the engineering of procedural and symbolic representations in intelligent systems. Practical exposures to relevant case studies and tools are provided. The techniques covered are focused on those generally accepted established traditional practices recommended by intelligent knowledge engineering practitioners.

Content

This course introduces topics in human cognition and various well established paradigms pertaining to the formal representations of artificial intelligence and knowledge engineering for computational problem solving.

1. Human brain and Cognitive structure: thinking and acting. The foundation of AI.
2. Structure of intelligent agents
3. Procedural Representation (Algorithmic)
4. Symbolic Representation (Knowledge Engineering)

CZ4024 – Cryptography and Network Security

This course provides an introduction to cryptographic algorithms, and how these algorithms are used to implement cryptographic protocols which are then used to achieve network security in the real world. This course will complement all courses in the Networking and Mobility specialisation by enabling students to be aware of the risks and security related to networking.

This course covers the following fundamental areas: 1. Threats, defences, and concepts of security. 2. Foundation mathematics such as Number Theory, Finite Fields, etc. 3. Cryptographic algorithms such as AES, RSA, SHA, MD5, etc. 4. Cryptographic protocols such as Needham-Schroeder protocol, Diffie-Hellman key exchange, SRP, etc.

CZ4031 - Database System Principles

This subject covers the basic concepts and methods of implementing a data management system. The coverage is introductory and hence emphasis should be on general awareness.

Learning Objectives

- Learn basic database implementation principles.
- Apply these principles to create a database management system.

CZ4032 –Data Analytics and Mining

This subject covers a comprehensive introduction to data analytics and mining. The coverage is introductory and hence emphasis should be on general awareness. In addition to the lectures and tutorials, there will be a set of laboratories.

Learning Objectives

- Discuss basic concepts and general knowledge of data analytics, data mining and the KDD process
- Be able to pre-process the data so that it can be analyzed further using sophisticated data analytics and mining algorithms
- Be able to perform core data analytics & mining tasks with large amount of data.
- Discuss several major data mining tasks (including classification, clustering, and association rule mining, etc) and related algorithms to solve them
- Be able to apply data mining techniques to tackle real-world big data applications
- Acquire the language necessary for speaking knowledgeably about data analytics and data mining

CZ4034 – Information Retrieval

This course covers both the basics of information retrieval (e.g., basics of search engines), advanced topics in information retrieval (e.g., relevance feedback, query expansion, language models) and web search basics.

Learning Objectives

The course covers the basic concepts of information retrieval and the associated techniques. These concepts and techniques are required for one to understand the different information retrieval tasks and systems. In particular, the major topics related to text and Web search will be included. The course also provides a systematic coverage of information retrieval system, ranging from small intranet search engines to Internet search engines.

CZ4041– Machine Learning

The aim of this course is to introduce the principles of various fundamental machine learning techniques and their applications in data mining, computer vision and other fields. This course covers various areas ranging from unsupervised learning to supervised learning as well as the various applications of machine learning that may be encountered in industry.

Learning Objectives

To provide students with essential concepts and skills in machine learning that will enable them to understand how to apply various machine learning techniques to solve real-world problems, such as classification, regression and clustering tasks.

CZ4045 – Natural Language Processing

Natural language processing is becoming a very hot topic in both industrial practices and academic research. It finds many real-world applications such as information extraction, sentiment analysis, machine translation, question answering, and summarization. Hence, it is an important subject to prepare SCSE students to cope with the huge amount of information, for example, in Web pages and business documents.

Learning Objectives

To equip SCSE students with the basic concepts and techniques of natural language processing on the levels of words, syntax, and semantics. To apply the techniques to real-world problems and evaluate the applications.

CZ4071 – Network Science

Network science is a new discipline that investigates the topology and dynamics of such complex networks, aiming to better understand the behavior, function and properties of the underlying systems. In this course, we will study algorithmic, computational, and statistical methods of network science, as well as its applications in solving real-world problems in communications, biology, sociology, and cyber security. Another pervasive goal of this work is to guide students into the future by presenting research that reveals the "next big thing" in network science.

Learning Objectives

CZ4071 is designed to cover a number of topics in network science and its applications. The specific topics include network metrics, properties, and models, network querying and analytics, network dynamics, and distributed graph engines. Students will

- Learn advanced network science principles relevant to drive data science in the 21st century.
- Apply network science principles to implement a real-world complex network application.

CZ4072 – Big Data Management

This advanced level course will serve to bridge the gap from the world of traditional relational data management technology (course CZ2007 and CZ4031) to the modern cutting-edge data management technologies (this course) which deals with tackling the big data management challenges for building data science applications.
The course teaches the major topics and trends in big data management and helps students acquire the skills that will equip them to handle a vast amount of abundant, rich, and complex data in today's world. The course will also guide students into the future by presenting research that reveals the "next big thing" in the big data management field.

Learning Objectives

CZ4072 is designed to cover a number of advanced topics in big data management. The specific topics include distributed and parallel data management framework for big data infrastructure, data management in the cloud, programming models and declarative languages to support big data framework, managing high velocity data streams, distributed data management using specialized processors, big data cleaning, and big data visualization. Students will

- Learn big data management principles to enable data science in the 21st century.
- Apply big data management principles taught in this course to realize a real-world big data application.

In addition to learning about some of the advanced topics in big data management, this course will also give the students an opportunity to practice important research skills. Students will

- Gain experience reading and critically evaluating original research papers.
- Practice communicating complex technical material, both orally and in written form.

CZ4073 – Special Topic: Data Science for Business

There is a huge demand for software developers who can implement business analytics/data science solutions. This course serves to introduce the basic concepts in business analytics/data science solutions.

Learning Objectives

The course will introduce the basic concepts that underlie the data-centered business problems and data-driven decision making. The content will cover wide range of data mining/ machine learning techniques widely used business data analysis and financial predictions. Content presentation will be arranged around the general principles and baseline ideas rather than around specific algorithms.

CS4022 Social Media Mining

Students learn specialised techniques for mining text, including how to prepare textual data for analysis and carry out techniques including sentiment analysis and opinion mining. The emphasis is on using these tools in real world applications to answer research questions, gain insights for journalistic reporting, or generate information for clients. Strengths, weaknesses, and concerns such as privacy are also discussed throughout. Course Content Principles and concepts of text mining. Various text mining techniques: Pre-processing for Text Mining, Text Categorization, Document Clustering, Information Retrieval, Information Extraction, Opinion Mining and Sentiment Analysis, and Question Answering. Practical use of text mining to real world applications, such as Text Message Spam Detection and Sentiment Analysis Systems analyzing public opinion towards various subjects, such as electronic gadgets, movies, stocks, etc., using social media content.

CS4031 Media Planning & Strategies

The course introduces students to the quantitative aspects of media planning. Topics covered will include brand analysis, audience analysis, market segmentation, and media analysis. Case studies and real-life practices will be included in this class. During the first half of the semester, students will conduct a brand audit and develop and administer a survey to determine target audience media usage. The information from the brand audit and market survey will then be used to compile a strategic media plan. Strategies and recommendations will form the basis of the media plan. The course will be taught in an active learning fashion. It strives for a balanced coverage of theoretical and practical issues, industry norms and ideals, and facts and thoughts. The ultimate goal is for students to form their own perspectives, sharpen their strategic thinking, and advance their planning skills. To this end, students should become critical thinkers who move beyond a view of learning as information gathering to a view of learning as knowledge building. All students are expected to be active and proactive in course activities.

ET0001 Enterprise & Innovation

The course will be delivered online, which will include lectures, survey assessment, real-life examples, supplementary materials, and recommended readings. It aims to provide students with a basic appreciation of the key concepts of enterprise and innovation. The course content will empower students to gain practical insights on the relevance of enterprise and innovation in their lives by introducing them to the enterprise and innovation ecosystem of the University, the Singapore society, and beyond.

GC0001 Introduction to Sustainability: Multidisciplinary Approaches and Solutions

This course is an introduction to sustainability presented in six modules by six different disciplines, as represented by NTU's schools and centres. 1. The ecological basis of the natural environment from a regional and planetary perspective. 2. Key requirements and constraints for social development and survival, including energy, water, and the built environment. 3. The intersection of economic markets and financial systems, both from the perspective of driving growth and consumption, as well as playing a role as incentives for positive change. 4. The political economy framework of global and regional sustainability challenges. 5. The interaction and connectedness between the various single disciplines and themes.

HW0128 Scientific Communication I

The aim of the course is to enhance the abilities of science students in recognising and employing the conventions used by scientists in their field for communication in both academic and public settings. In this course, the emphasis is on micro skills in scientific communication such as searching academic databases, critically reading scientific texts, citing from sources, composing scientific arguments and making effective presentations to a non-specialist audience. As this is a foundation course, it will ensure that science students are ready to engage with the more challenging skills of the second and more advanced scientific communication course that follows.

HW0228 Scientific Communication II

This course introduces students to the conventions of academic writing using a project-based approach. It focuses on the structure and rhetorical moves of academic genres such as a critique, a proposal and an academic paper. Time is also set aside for students to discuss their work with their instructors.

HY0001 Ethics & Moral Reasoning

HY0001 will introduce students to three major ethical theories' utilitarianism, Kant's deontology, and virtue ethics. Then, four weeks will be devoted to teaching the ethical principles underlying academic integrity, research ethics, and intellectual property. Finally, students will discuss issues related to the ethics of environmental sustainability and conservation. All the while, students will be challenged apply the ethical theories learned to concrete moral problems, including world poverty, corporate accountability and whistleblowing, and workplace discrimination.

ML0001 Absolute Basic for Career

In today's competitive world, it is essential that students learn the crucial career skills early to ensure a competitive edge sharpened with a heightened sense of workplace values and ethics. This course takes students through a journey of career discovery, understanding and polishing of oneself which will then be translated into job application tools such as resumes and interview skills. All students will have the opportunity to undergo a robust Career Assessment Tool, which assesses their career options and career self and helps them chart a career action plan. They will also learn how to identify and articulate the concept of personal branding and applying that to resumes and interviews and online social media. Students will also be exposed to the basics of grooming to ensure that they are aware of the importance of first impressions in all situations.

ML0002 Career Power Up

In today's competitive world, it is essential that students learn the crucial career skills early to ensure they have a competitive edge sharpened with a heightened sense of workplace values and ethics. This course imparts to students practical skills needed to survive and succeed in the modern workplace while emphasizing on professional ethics. All students will be exposed to effective business communication and workplace skills ranging from building relationship with different personalities, understanding of cross-cultural diversity, inter-cultural communication, conflict management, problem solving and decision making, time management, planning and organization, team work, and more. Following which they will learn how to network and dine with proper etiquette in professional settings. Lastly, to aid them in their transition to the working life, the course will impart the skills behind coping and succeeding in a new workplace, while upholding high standard of work ethics.

PS8001 Defence Science

This course introduces the role of mathematical and physical sciences in Defence Science.