Module Title	**Foundations of calculus, statistics, and optimisation**
Course Title	MSc Applied AI
School	☐ ASC ☐ ACI ☐ BEA ☐ BUS ☒ ENG ☐ HSC ☐ LSS
Division	Computer Science and Informatics
Parent Course (if applicable)	
Level	7
Semester	The module will be offered in both semester
Module Code *(showing level)*	CSI_7_FCS
JACS Code (completed by the AQE)	
Credit Value	20 credit points
Student Study Hours	Total: 200 Contact hours: 52 Student managed learning hours: 148 Requirements for Self-Managed Learning Hours: Undertake research work, complete and write up lab exercises and assessments.
Pre-requisite Learning	None
Co-requisites	None
Excluded combinations	None
Module co-ordinator	TBC
Short Description (max. 100 words)	This module will cover the fundamentals concepts and techniques from linear algebra, differential calculus and probability. The acquired tools will help the student to understand how AI is built and enable them to tailor standard methods to specific problems they will be facing and to interpret the results obtained through data analysis.
Aims	The module aims at providing the students with the fundamentals mathematical knowledge and skills to successfully understand and develop AI techniques and architectures.
Learning Outcomes (4 to 6 outcomes)	**A. Knowledge and Understanding:** On successful completion of this module you will have knowledge and understanding of: • the basic mathematical principles and methods needed to underlying AI with main focus on differential calculus and linear algebra. (covers BCS requirements: 6.1.1, 6.1.2, 6.1.3, 7.1.1 - 7.1.4; 8.1.1 - 8.1.2; 8.2.1; 9.1.1, 9.1.2, 9.2.2; 10.1.1, 10.1.2, 10.2.1) • the basic and more advanced concepts in probability theory and statistics relevant to machine learning and AI (covers BCS requirements: 6.1.1, 6.1.2, 6.1.3, 7.1.1 - 7.1.4; 8.1.1 - 8.1.2; 8.2.1; 9.1.1, 9.1.2, 9.2.2; 10.1.1, 10.1.2, 10.2.1) **B. Intellectual Skills:**

	• Conduct a critically evaluative analysis of a case-based domain using appropriate statistical and quantitative methods; also developing the in-depth knowledge necessary to identify and apply suitable techniques in order to synthesize advanced theory/practical concepts. (covers BCS requirements: 8.1.1 - 8.1.3; 9.1.1 - 9.1.3; 10.1.1 - 10.1.3) • Ability to abstract a practical problem and define it in probability terms (BCS requirements: 6.1.1, 6.1.2, 6.1.3, 8.1.1 - 8.1.3; 9.1.1 - 9.1.3; 10.1.1 - 10.1.3) • Ability to apply rigorous techniques and ideas for the formalization and solution of practical problems (BCS requirements: 8.1.1 - 8.1.3; 9.1.1 - 9.1.3; 10.1.1 - 10.1.3) **C. Practical Skills:** • Develop the in-depth knowledge necessary to identify statistical and mathematical modelling and quantitative project domains and apply suitable techniques in order to synthesize advanced concepts to derive innovative mathematical and statistical modelling solutions using suitable tools as well as being able to specify, manage, critically evaluate a project applying appropriate concepts, technology, techniques, life-cycle/methodology (covers BCS requirements: 8.2.1, 8.2.1; 9.2.1 - 9.2.3; 10.2.1 - 10.2.3) • Be able to make concise, engaging and well-structured oral presentations, arguments, and explanations; Communication /presentation of advanced mathematical and statistical modelling projects and concepts to a wide range of audiences. (BCS requirements: 8.2.1, 8.2.1; 9.1.1 - 9.2.3; 10.2.1 - 10.2.2) **D. Transferable Skills:** • Critically evaluate existing/emerging mathematical and statistical modelling technology and techniques, carrying out independent research, recognize and contribute to opportunities for innovation, deal with uncertainty, evaluate and manage risks, synthesise ideas/theories/solutions and report back appropriately to your peers, also conducting effective peer reviews. (covers course outcomes: d2, d3; BCS requirements: 7.1.1 - 7.1.5) • Self-manage your study time and work effectively to meet deadlines, select and evaluate appropriate knowledge, skills, etc...; also select and evaluate supporting resources/tools for a particular purpose, as well as being able to make effective contributions as team member/leader when required. (covers course outcomes: d1, d4; BCS requirements: 7.1.5 - 7.1.9)
Employability	There is current and rapidly increasing commercial need/demand for graduates/postgraduates with skills in the areas of Data Science, Business Intelligence and Analytics. The module delivers skills in these areas that are directly relevant in both commercial and research environments.
Teaching and learning pattern	Contact hours includes the following: (please click on the checkboxes as appropriate) √ Lectures ☐ Group Work: ☐ Seminars ☐ Tutorial: ☒ Laboratory ☐ Workshops ☐ Practical ☐ VLE Activities
Indicative content	The following list of topics is indicative (not exhaustive) of typical module content: • Calculus – Functions, scalar derivatives (definition, meaning, local approximation, basic rules of differentiation, chain rule, partial derivatives), integrals and summations.

	Gradient, derivatives of vector valued functions. Gradient algorithms. • Linear algebra – Definition and use of vectors, vector operations, distance and norm, orthogonality. Definition and use of matrices, matrix operations, determinant, inverse, eigenvalues. • Probability – Basic definitions (sample space, events, dependent and independent events, conditional probabilities), random variables (continuous and discrete, probability distribution and density, expectation, mean and variance). Bayes' rule, chain rule, maximum a posteriori, maximum likelihood. Useful probability distributions. Distances: entropy, cross entropy, divergence, mutual information Optimization theory - calculus of variations, convex optimization theory, decision theory, game theory, linear programming, Markov chains, optimization theory, queuing systems
Assessment method (Please give details – of components, weightings, sequence of components, final component)	Formative assessment: The students will usually be given a range of weekly tutorial-based tasks (both individual/group work) comprised of formative exercises imparting the knowledge and skills required to satisfy the learning outcomes Summative assessment: Coursework 50% Examination 50%
Mode of resit assessment (if applicable)	Formative assessment: Summative assessment: Coursework 50% Examination 50%
Indicative Sources ***(Reading lists)***	**Core Materials:** • Courant R, John F. Introduction to calculus and analysis I[M]. Springer Science & Business Media, 2012 **Optional Materials:** • Boyd S, Boyd S P, Vandenberghe L. Convex optimization[M]. Cambridge university press, 2004 • M. Spivak, Calculus, Cambridge university press, 2006 • S. Lang, Undergraduate Analysis, Springer (2010) • P. Deisenroth, A. Faisal, C. Soon Ong, Mathematics for Machine Learning, Cambridge University Press (2020) • J. Dawany, Hands-On Mathematics for Deep Learning, Packt Publishing, 2020
Other Learning Resources	TBD Supplementary materials for all of the software used in the module will be available on the module VLE site.