Module Details

Title Short:	Algebraic Foundations of Quantum Computing APPROVED
Language of Instruction:	English

Module Code:	MA4102

ECTS Credits:	5

NFQ Level:		**EQF Level:**		**EHEA Level:**	

Valid From:	2021-22 (01-09-21 – 31-08-22)
Teaching Period:	Semester 1
Module Delivered in	4 programme(s)
Module Owner:	MICHAEL MC GETTRICK
Module Discipline:	MA_ST_AM - School of Mathematics, Statistics and Applied Mathematics
Module Data:	1 - 4 NON LAB
Module Description:	This course introduces the fundamentals of quantum computing. The focus is on the Linear Algebra used in the circuit model, and the understanding of basic algorithms in quantum computation.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Describe representation of information using vectors in a Hilbert Space (qubits and qudits) and associated operators.
LO2	Prove the no-cloning theorem and calculate the entanglement of composite states using Von-Neumann entropy.
LO3	Manipulate density operators, Completely Positive Trace-Preserving Maps and Positive O perator-Valued Measures
LO4	Explain the Deutsch-Josza algorithm and Quantum Teleportation.
LO5	Describe various logic gates (Hadamard, CNOT) in the quantum circuit model.
LO6	Show Shor's (factorization) algorithm, Grover's (search) algorithm and their application.

Module Content & Assessment

Indicative Content

Algebraic Foundations of Quantum Computing
Qubits, qudits as normalized vectors, Unitary operators and measurement operators. Tensor product states and density matrices. The no-cloning theorem, entanglement and entropy. Kraus operators and quantum channels. Completely positive trace preserving maps and positive operator valued measures. The Deutsch-Jozsa algorithm. Quantum circuit model, gates and teleportation. Computational complexity and Grover's algorithm. The quantum Fourier transform and Shor's factoring algorithm.

Written Assessment

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Marks Out of*	*Pass Marks*	*Sitting*	*Assessment Period*	*Assessment Date*	*Duration*	*Mandatory*
Paper 1 - Written	n/a	1,2,3,4,5,6	70	100	40	First Sitting	Semester 1	n/a	2:00	True
Assessment is marked as bondable but has no matching assessments										
Paper 1 - Written	n/a	1,2,3,4,5,6	70	100	40	Second Sitting	Autumn	n/a	2:00	True
Assessment is marked as bondable but has no matching assessments										

Continuous Assessment

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Marks Out of*	*Pass Marks*	*Sitting*	*Assessment Period*	*Assessment Date*	*Duration*	*Mandatory*
Continuous Assessment 1	n/a	1,2,3,4,5,6	30	100	40	First Sitting	Semester 1	n/a	0	True
Continuous Assessment 1	Continuous assessment mark brought forward from 1st sitting	1,2,3,4,5,6	30	100	40	Second Sitting	Autumn	n/a	0	True

No Oral, Audio Visual or Practical Assessment

No Department-based Assessment

No Research

No Study Abroad

No Computer-based Assessment

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time					
Workload Type	*WorkLoad Description*	*Learning Outcomes*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	1 hour duration	1,2,3,4,5,6	24	Per Semester	2.00
Tutorial	1 hour duration	1,2,3,4,5,6	12	Per Semester	1.00
Independent & Directed Learning (Non-contact)	No Description	1,2,3,4,5,6	84	Per Semester	7.00
				Total Hours	120.00
				Total Weekly Learner Workload	10.00
				Total Weekly Contact Hours	3.00

This module has no Part Time workload.

Module Resources

Recommended Book Resources

Richard J. Lipton and Kenneth W. Regan., *Quantum Algorithms via Linear Algebra*, MIT Press

Michael A. Nielsen and Isaac L. Chuang., *Quantum Computation and Quantum Information*, Cambridge University Press

Ranee K. Brylinski and Goong Chen, *Mathematics of Quantum Computation*, CRC Press

Wolfgang Scherer, *Mathematics of Quantum Computing*, Springer

This module does not have any article/paper resources

This module does not have any other resources

Module Full Time Equivalent

Module Full Time Equivalent	
Discipline	*%*
School of Mathematics, Statistics and Applied Mathematics	100

Module Delivered in

Course Stream Code	*Course Stream Title*
BMS2	BMS2 Bachelor of Science (Mathematical Science) Honours (Approved)
BPT2	BPT2 Bachelor of Science (Physics) Applied, Astrophysics, Biomedical, Theoretical (Hons) (Approved)
BS2	BS2 Bachelor of Science (Hons.) (Approved)
PHO1	PHO1: Bachelor of Science (Physics) Applied, Astrophysics, Biomedical, Climate, Theoretical (Approved)

Module Instructors

Module Instructors	
Staff Member	*Staff Email*
MICHAEL MC GETTRICK	michael.mcgettrick@nuigalway.ie