Title	Quantum Information Security
Long Title	Quantum Information Security
Credits	**5**
NFQ Level	**Expert**
Module Author	**Hazel Murray**

Module Description:

Quantum computing is an emerging technology with the potential to revolutionise industries and reshape scientific research. As it advances, professionals across diverse disciplines and industry sectors will need a fundamental understanding of its principles and applications. This module offers an accessible introduction to quantum computing, requiring no prior knowledge of mathematics, physics, or computer science. Students will explore core quantum concepts and key algorithms, with a strong focus on real-world industry applications. The module also examines quantum cryptography, including Quantum Key Distribution (QKD), and the broader security and computational implications of quantum technologies. Through interactive labs, students will gain hands-on experience with quantum programming tools, bridging theoretical knowledge with practical implementation.

Learning Outcomes

On successful completion of this module the learner will be able to:

LO1	Describe and analyze the fundamental principles of quantum computing, including qubits, superposition, entanglement, and quantum gates.
LO2	Implement and evaluate key quantum algorithms such as Grover's search, Shor's factorization, and quantum teleportation.
LO3	Design and develop quantum programs using a quantum language of choice to model quantum fundamentals and execute complex algorithms.
LO4	Critically assess the current and emerging impact of quantum technologies on cybersecurity.
LO5	Conduct a comparative analysis of quantum cryptography and post-quantum cryptography approaches, evaluating their relative strengths and weaknesses.
LO6	Assess and critique industry applications of quantum computing, including its role in communications, finance, optimization, and material sciences, through a research informed approach.

Indicative Content

Quantum Fundamentals:

Introduction to quantum Fundamentals: Qubits, Superposition, Entanglement, Measurement. The no-cloning theorem and its consequences for security and communication.

Quantum Programming:

Quantum Gates and Circuits: Implementing Hadamard, Pauli, CNOT, Toffoli gates, and simple circuits. Quantum Programming: Hands-on experience with Qiskit, Silq, Q#, or other quantum languages.

Quantum Algorithms:

Grover's algorithm: quadratic speed-up for unstructured search. Shor's algorithm: prime factorisation and implications for RSA security. Quantum Fourier Transform (QFT) and its use in quantum phase estimation. Quantum teleportation: theoretical basis and circuit implementation. Introduction to quantum error correction: bit-flip, phase-flip, and Shor code and the BQP (Bounded-Error Quantum Polynomial Time) class.

Quantum Cybersecurity:

Explore the impact quantum will have on cybersecurity. The future threat of quantum computers to classical cryptography. Quantum cryptographic protocols. Post-quantum cryptography (PQC). Quantum key distribution (QKD): protocols, real-world implementations, limitations. Hybrid approaches, standards and transitional strategies for organisations. Ethical, legal, and societal considerations of quantum-secured systems.

Industry Use Cases and Applications:

Critically evaluate real-world use cases of quantum technologies across sectors such as finance, healthcare, logistics, and communications. Discuss the challenges and opportunities of integrating quantum technologies into existing systems and workflows. Applications for FinTech, material science, drug discovery, optimisation, simulation, and communication.

Course Work

Assessment Type	*Assessment Description*	*Outcome Addressed*	*% of Total*	*Assessment Date*
Presentation	Students prepare a presentation demonstrating their understanding of a quantum principle. Where possible this should include the benefits and disadvantages of this principle, an implementation in quantum programming and an example of a use-case.	1,2,3	40	Week 6
Project	Students will write a report on quantum computing, investigating a particular problem or application case. It should include a critical evaluation of quantum technologies, assessing	4,5,6	60	Sem End

both the strengths and weaknesses of current quantum technology in relation to this problem.

No End of Module
Formal Exam

Assessment Breakdown

Assessment Breakdown	%
Coursework	100

Re-Assessment Requirement

Coursework Only
This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.

Workload – Full Time

Workload Type	*Workload Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lectures covering the theoretical concepts underpinning the learning outcomes	2	Every Week	2.00
Lab	Lab to support the learning outcomes.	2	Every Week	2.00
Independent & Directed Learning (Non-contact)	Independent learning by the student	3	Every Week	3.00
		Total Hours		7.00
		Total Weekly Learner Workload		7.00
		Total Weekly Contact Hours		4.00

Workload – Part Time

Workload Type	*Workload Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lectures covering the theoretical concepts underpinning the learning outcomes	2	Every Week	2.00
Lab	Lab to support learning outcomes.	2	Every Week	2.00
Independent & Directed Learning (Non-contact)	Independent learning by the student	3	Every Week	3.00
		Total Hours		7.00
		Total Weekly Learner Workload		7.00
		Total Weekly Contact Hours		4.00

Recommended Book Resources

Ray LaPierre. (2022), Introduction to Quantum Computing, Springer, p.366, [ISBN: 9783030693206].

Scott Aaronson. (2013), Quantum Computing Since Democritus, Cambridge University Press, https://www.scottaaronson.com/, p.403, [ISBN: 978-0521199568].

Supplementary Article/Paper Resources:
Anila Mjeda and Hazel Murray. (2024), Quantum Computing Education for Computer Science Students: Bridging the Gap with Layered Learning and Intuitive Analogies., IEEE International Conference on Quantum Computing and Engineering, 3, p.9, https://arxiv.org/abs/2405.09265

Ukpabi D, Karjaluoto H, Bötticher A, Nikiforova A, Petrescu D, Schindler P, Valtenbergs V, Lehmann L.. (2023), Framework for understanding quantum computing use cases from a multidisciplinary perspective and future research directions., Futures, https://www.academia.edu/download/106135 609/2212.pdf

Purohit, A., Kaur, M., Seskir, Z. C., Posner, M. T., & VenegasGomez, A.. Building a quantumready ecosystem, IET Quantum Communication, https://scholar.google.com/scholar?outpu t=instlink&q=info:M782m4IBcZgJ:schol ar.google.com/&hl=en&as_sdt=0,5& amp;as_ylo=2024&scillfp=109383625044 38887087&oi=lle

Other Resources:

IBM Quantum Experience, https://quantum-computing.ibm.com/

Microsoft Azure Quantum, https://azure.microsoft.com/en-us/soluti ons/quantum-computing/

Qiskit Tutorials, https://qiskit.org/documentation/tutoria ls/

PennyLane Quantum Programming Software, https://pennylane.ai/

Andy Matuschak and Michael Nielsen. Quantum computing for the very curious,