



**ROCHESTON<sup>®</sup> CERTIFIED**  
**QUANTUM COMPUTING ENGINEER**

*Certified by Rochester<sup>®</sup>*

**RCQE<sup>®</sup>** Certification Program Guide





## About Rocheston

Rocheston, a young New York based internet technology start-up, despite being in its nascent stage, is a company that is raring to go. Rocheston has a worldwide presence, with its headquarters in New York. The company's technology development center is based out of Chennai, with reach offices in Singapore and Dubai.



The team at Rocheston consists of young, liberal, innovative and forward-thinking individuals **who want to make a difference and change the world. At its core, Rocheston is a next-generation innovation company,** with cutting-edge research and development in emerging technologies such as Cybersecurity, Internet of Things, Big Data and automation.





**RCQE** With the emergence of smart technologies, the future looks exciting, but are we adequately equipped to handle those technologies? Rocheston is a pioneer in offering the latest, innovative and cutting-edge technology courses to train and create awareness to deal with evils of the cyber world. **Be it Artificial Intelligence, IoT, cyberthreat analysis, incident handling, penetration testing, prevent phishing fraudulent activities, cyber investigation of data theft and so on,** Rocheston courses are much sought.







The **Rocheston Certified Quantum Computing Engineer (RCQE)** course is a gamechanger in the revolutionary field of computing. As an RCQE, enter the world of 'wonder computing' where molecules storing huge amounts of information can be harnessed to unleash their quantum power! The power is not from a single molecule but innumerable molecules harnessed at a time. The applications of quantum mechanics in computing is phenomenal.

**Quantum computing is not just a technology that seamlessly combines quantum physics, computer science and information theory.** It is an excitingly new domain of computing that promises to expand and scale up our tech world exponentially. Quantum computing opens up the matrix of atomic and sub-atomic particles; the uncertainty and wonder that lies within is bewitching, empowering us with the magical states of not just one but many parallel computing states. Learn about all this and more in the RCQE course!

# RCQE

Rocheston Certified Quantum Computing Engineer

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## RCQE BENEFITS

- The certified **RCQE can help in solving certain complex mathematical equations much faster than classical computers as well as replace supercomputers** in large scale simulations and other such applications.
- The **RCQE can assist in simulation of electrons in atoms and molecules, resulting** in faster processing than classical computers.
- The super-fast processing can revolutionize the designing of new materials or drugs.
- The mysterious ever-changing quantum states of atoms looks quite impossible to be realized by conventional computers; D-Wave quantum computers is faster than the fastest computers today – born to overcome the limitations of classical computers.
- **Quantum computing offers capabilities that are far ahead of those of classical computers.** While the classical computing arena used electronic bits to represent ‘1’ and ‘0’ (ON/OFF), quantum computers operate with “qubits” that can represent ‘1’ and ‘0’ simultaneously.
- **With the qubits representing atoms, ions, photons/electrons and control devices huge volumes of numerical calculations can be processed, resulting in super efficiency and increased computing speed.** This is a big paradigm shift in the world of computing!





## SKILLS YOU WILL LEARN

**As an RCQE, you will be equipped to take up multiple job roles and tasks including:**

- Collaborating with world-class team of quantum physicists, quantum chemists, computer scientists, HPC software developers, and operations researchers.
- Ensure systems-level improvements
- Recasting problems to harness the power of quantum computing
- Efficiently translate fundamental physics into engineering specifications
- Design quantum circuits for deploying them as quantum computers
- Building and maintaining the database solution required for operating a quantum computer
- Documenting the control software that will allow successful operation of our quantum computers



- Improve the performance of the system that runs quantum programs
- Developing novel hybrid quantum-classical algorithms for solving computationally challenging problems
- Focuses on prototyping, developing, testing and validating new ideas using object-oriented languages such as C++ and python and following good practices in continuous delivery, documentation, and testing
- Supporting the development of a quantum computing software infrastructure project which involves the interfaces to a diverse set of gate-model quantum emulators







## JOB OPPORTUNITIES

“By the year 2023, as per Gartner’s estimation, 20% of the organizations will have quantum computing technology budgeting when compared to the current investments.”

**There are several job opportunities for the qualified quantum computing engineer; some of the popular designations are:**

- Data Engineer Advanced Analytics Quantum Computing
- Front End Developer with Quantum Computing
- Quantum Full Stack Developer
- Research Scientist: Quantum Error Correction
- Data Engineer: Advanced Analytics (Quantum Computing)
- Systems Support Analyst
- Quantum analyst
- Quantum Data Scientist









## Who Can Take **The RCQE Program**

Rocheston is the leader in the certification industry to help and train you to be the best Quantum Computing Engineer! Professionals working with multinationals and other companies that have heavily invested in quantum computing are best suited to take up the RCQE course.

**Individuals who wish to build a career across the following industries, can also contribute in a big way as skilled quantum engineer:**

- Computing
- Technology
- Hardware
- Communications
- Metrology



Apart from the above-mentioned **professionals, students and graduates who are interested in working towards the development of a qualitative analysis of quantum computing would also benefit from the RCQE course.**





## Eligibility

**Quantum computing being a highly technical and complex integrated field of study,** the RCQE candidate should possess at least a Bachelor's degree in any of the following disciplines in addition to a minimum of 1-year experience:

- Computer Science
- Physics
- Mathematics & Statistics
- Electrical & electronic engineering
- Systems Engineering
- IT and other computer-related fields



Potential candidates having basic knowledge and exposure to computational biology, quantum cryptography machine learning algorithms and programming languages would have an advantage.



## WHY **RCQE** IS DIFFERENT FROM OTHER **QUANTUM** COMPUTING COURSES?

**RCQE** is one of the most sought after courses from the Rochester stable. The course is designed to give the learner a great opportunity to get a firm grip of the fundamentals of the quantum computing technology and the updates in its applications.

Unlike other quantum computing courses, the **RCQE emphasizes a great deal on the understanding of qubits, entanglement, teleportation, No-cloning theorem**, with exhaustive explanation of state variable and algorithms suitable for Quantum computation.

The **RCQE course stresses on practical understanding and application of the knowledge gained. With interactive discussions, carefully designed demos and practical DIY sessions, the RCQE course promises a fantastic learning experience.**

The well-qualified RCQE trainers walk the students through the highly complex topics of quantum computing while explaining all the aspects in a very simple manner. Even those students with no mathematics subject background can grasp the concepts of quantum computing.



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## Course Materials

### On registration you will be provided with:

- Course Materials - Soft copy
- Exam Voucher
- Exam (computer-based) will be conducted either on the last day or based on instructor's discretion on a later date.
- Cyberclass/e-learning access for 6 months
- Certificate of Attendance and Course Completion from Soebit and Rochester.





## COURSE FEE & STRUCTURE

### What the course will consist of:

- A 5-day Training Program
- Time: 9:30 AM – 6 PM
- The provision of an active web portal
- Seminars conducted by qualified engineers
- Best in-class environment
- Exam can be taken on Rochester Cyberclass or Pearson VUE testing platform



### Cost

For pricing in your region, please contact the local coordinator/distributor.



## RCQE Exam

- Exam can be taken on Rochester Cyberclass testing platform.
- The exam consists of 50 multiple choice questions.
- The passing score is 70%
- Retake Policy - You may retake the exam any time on an additional fee. For further details contact the exam coordinator.







## The Cyberclass **Web Portal**

The access to an online e-learning platform will be given to attendants on registration. It will contain a series of study videos, pre-recorded lectures, white papers, educational animations and power point presentations. The Web Portal can be used to catch-up on a missed session or to view an attended session again.

<http://cyberclass.rocheston.com>









## Course Completion

- On completing the course and successfully passing the exam, the candidate will be provided with a RCQE certification.
- Candidates are free to use the logo as per the Terms & Conditions as a Rocheston Certified Professional.
- The candidate will also receive a Welcome Kit and login information to access the Members' Portal.
- The Members' Portal is an online forum for Certified RCQEs to interact.
- The certification is valid for two years and it can be renewed online.
- Contact the course coordinator for any enquiries about the renewal fee or downloading of the updated course material.



## Course Objectives

### In the RCQE program you will learn to:

- Learn about the key applications of quantum computing
- Explain the futuristic role of an RCQE
- Recognize the role of Moore's Law in the future of computing
- Understand the fundamental quantum information concepts
- Explore the value proposition in available and forthcoming quantum information technology products
- Identify the importance of quantum superposition, entanglement and interference in quantum algorithms
- Learn about quantum computing hardware and architecture
- Analyse the scope of the quantum information technology industry









## Course Outline

### Module 1: Introduction to Quantum Computing

- What is Quantum Computing?
- Computability
- Programming Languages
- Quantum Bits

### Module 2: Quantum Computing Basics

- Mystery of Probabilistic  $\sqrt{I}$  Gate
- Qbits and Qregisters
- Elementary Quantum Gates
- General Description of the Interferometer
- How to Prepare an Arbitrary Superposition

### Module 3: Turing Machines

- Classical Turing Machine
- Nondeterministic and Probabilistic Computation
- Quantum Turing





- Modifications of the Base Model
- Generalized Quantum Turing Machine
- Classically Controlled Quantum Turing Machine
- Quantum Complexity
- Fantasy Quantum Computing

#### **Module 4:** Quantum Finite State Automata

- Finite Automata
- Deterministic Finite Automata
- Nondeterministic Finite Automata
- Probabilistic Automata
- Quantum Finite Automaton
- Measure-once Quantum Finite Automaton
- Measure-many Quantum Finite Automaton

#### **Module 5:** Q# (Q-sharp)

- The Type Model
- Expressions
- Statements
- File Structure



## **Module 6:** A Brief Introduction To Information Theory

- Classical Information
- Information Content in a Signal
- Entropy and Shannon's Information Theory
- Probability Basics

## **Module 7:** Qubits and Quantum States

- The Qubit
- Vector Spaces
- Linear Combinations of Vectors
- Uniqueness of a Spanning Set
- Basis and Dimension
- Inner Products
- Orthonormality
- Gram-Schmidt Orthogonalization
- Bra-Ket Formalism
- The Cauchy-Schwartz and Triangle Inequalities



## **Module 8:** Random Access Machines

- Classical RAM models
- Elements of RAM Model
- RAM-ALGOL
- Quantum RAM Model
- Quantum Pseudocode
- Elements of Quantum Pseudocode
- Quantum Conditions
- Measurement

## **Module 9:** Computational Circuits

- Computational Circuits
- Boolean Circuits
- Reversible Circuits
- Universal Reversible Gates
- Quantum Circuits



## Module 10: Matrices and Operators

- The Pauli Operators
- Outer Products
- The Closure Relation
- Representations of Operators Using Matrices
- Outer Products and Matrix Representations
- Matrix Representation of Operators in Two-Dimensional Spaces
- Definition: The Pauli Matrices
- Hermitian, Unitary, and Normal Operators
- Definition: Hermitian Operator
- Definition: Unitary Operator
- Definition: Normal Operator
- Eigenvalues and Eigenvectors
- The Characteristic Equation
- Spectral Decomposition
- The Trace of an Operator
- Important Properties of the Trace
- Functions of Operators
- Unitary Transformations
- Projection Operators
- Positive Operators



- Commutator Algebra
- The Heisenberg Uncertainty Principle
- Polar Decomposition and Singular Values
- The Postulates of Quantum Mechanics

### Module 11: Tensor Products

- Representing Composite States in Quantum Mechanics
- Computing Inner Products
- Tensor Products of Column Vectors
- Operators and Tensor Products
- Tensor Products of Matrices

### Module 12: The Density Operator

- The Density Operator for a Pure State
- Definition: Density Operator for a Pure State
- Definition: Using the Density Operator to Find the Expectation Value
- Time Evolution of the Density Operator
- Definition: Time Evolution of the Density Operator
- The Density Operator for a Mixed State
- Key Properties of a Density Operator



- Expectation Values
- Probability of Obtaining a Given Measurement Result
- Characterizing Mixed States
- Probability of Finding an Element of the Ensemble in a Given State
- Completely Mixed States
- The Partial Trace and the Reduced Density Operator
- The Density Operator and the Bloch Vector

### **Module 13:** Quantum Programming Environment

- Architecture Components
- Quantum Intermediate Representation
- Quantum Assembly Language
- Quantum Physical Operations Language
- XML-based Representation of Quantum Circuits
- Basic Elements
- External Circuits

### **Module 14:** Quantum Programming Languages

- Why Study Quantum Programming Languages
- Quantum Programming Basics





- Requirements for a Quantum Programming Language
- Basic Features of Existing Languages
- Imperative Languages
- Functional Languages

### **Module 15:** Imperative Quantum Programming

- Quantum Computation Language (QCL)
- Basic Elements
- Quantum Memory Management
- Classical and Quantum Procedures and Functions
- Quantum Conditions
- LanQ
- Basic Elements
- Process Creation
- Communication
- Types

### **Module 16:** Functional Quantum Programming

- Functional Modeling of Quantum Computation
- cQPL



- Classical Elements
- Quantum Elements
- Quantum Communication
- Qt Modeling Language (QML)
- Program Structure

### **Module 17:** Quantum Measurement Theory

- Distinguishing Quantum States and Measurement
- Projective Measurements
- Measurements on Composite Systems
- Generalized Measurements
- Positive Operator-Valued Measures

### **Module 18:** Entanglement

- Bell's Theorem
- Bipartite Systems and the Bell Basis
- When Is a State Entangled?
- The Pauli Representation
- Entanglement Fidelity
- Using Bell States For Density Operator Representation
- Schmidt Decomposition



## Module 19: Quantum Gates and Circuits

- Classical Logic Gates
- Single-Qubit Gates
- More Single-Qubit Gates
- Exponentiation
- The Z-Y Decomposition
- Basic Quantum Circuit Diagrams
- Controlled Gates
- Gate Decomposition

## Module 20: Quantum Algorithms

- Hadamard Gates
- Matrix Representation of Serial and Parallel Operations
- Quantum Interference
- Quantum Parallelism and Function Evaluation
- Deutsch-Jozsa Algorithm
- Quantum Fourier Transform
- Phase Estimation
- Shor's Algorithm



## **Module 21:** Quantum Computing and Cryptography

- Quantum Cryptography
- A Brief Overview of RSA Encryption
- Basic Quantum Cryptography
- An Example Attack: The Controlled NOT Attack
- The B92 Protocol
- The E91 Protocol (Ekert)

## **Module 22:** Quantum Noise and Error Correction

- Single-Qubit Errors
- Quantum Operations and Krauss Operators
- The Depolarization Channel
- The Bit Flip and Phase Flip Channels
- Amplitude Damping
- Phase Damping
- Quantum Error Correction
- Measurement Error Mitigation
- Calibrating Qubits with OpenPulse
- Randomized Benchmarking
- Measuring Quantum Volume



## **Module 23:** Quantum Information Theory

- Tools of Quantum Information Theory
- The No-Cloning Theorem
- Trace Distance
- Entanglement of Formation and Concurrence
- Information Content and Entropy

## **Module 24:** Adiabatic Quantum Computation

- Adiabatic Theorem
- Adiabatic Processes
- Adiabatic Quantum Computing

## **Module 25:** Cluster State Quantum Computing

- Cluster States
- Cluster State Preparation
- Adjacency Matrices
- Stabilizer States
- Principles of Quantum Entanglement to Secure Communication (Unhackable networks)
- Aside: Entanglement Witness
- Cluster State Processing



## **Module 26:** Microsoft Quantum Development Kit

- Q# language and compiler
- Q# library
- Local quantum machine simulator
- Quantum computer trace simulator
- Resource Estimator
- Visual Studio extension
- Visual Studio Code extension
- Qsharp for Python
- IQ#

## **Module 27:** IBM's Quantum Computing

- Remote Access via the REST API
- Qiskit
- IBM Q Experience
- Run a job
- Export API methods
- Debugging and Testing





## **Module 28:** D-wave Quantum Computers

- Native Instances
- Mapping General Instance to Native Form
- The D-Wave Platform
- QSage Hybrid Optimizer

## **Module 29:** Fujitsu “Quantum Inspired” Computer

- New Computing Perspective
- Digital Annealer
- Quantum-Inspired Architecture
- Logistics
- Radiation Therapy

## **Module 30:** Qubit Signal Frequency Control in Quantum Advancement

- Precision Atom Qubits
- Quantum Computer Chip in Silicon
- CQC2T



## Module 31: Jupyter Notebooks

- C#
- IQ#
- Jupyter
- Visual Studio
- Python





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