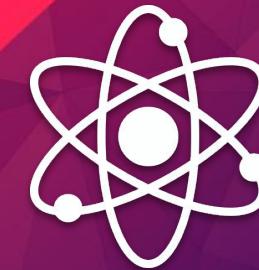




Learning Quantum Computing



Lecture/Lesson 0:

- *Hello Quantum World*

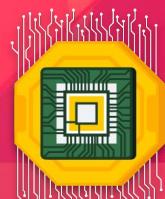
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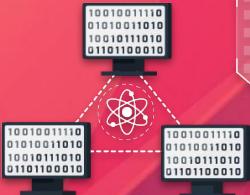
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QUANTUM ALGORITHM



QUANTUM RESEARCH



QUANTUM NETWORK



QUANTUM DATA PROTECTION



QUBIT



QUANTUM LOGIC



QUASIPARTICLE



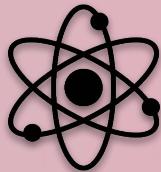
QUANTUM COMPUTER



QUANTUM TELEPORTATION

Introduction

Hello Quantum World



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Hello Quantum World



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Table of contents

1 Brief description of this course

2 Course overview

i *Introduction to Quantum*

ii *Discovering the Quantum Computing*

iii *Applying the Quantum Computing*

iv *Practicing the Quantum Computing*

Total: 4 cores [xx Weeks | yy Lectures/Lessons]

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Brief description of this course

- This course is suited for beginners in ***Quantum Mechanics***, ***Quantum Physics*** and ***Quantum Computing***.
- If you are familiar with the basic concepts of ***Quantum Mechanics*** and ***Quantum Physics***, you are encouraged to move forward in this course, to the ***Week 10 - Lesson/Lecture 12 (Core 2*** of this course).
- This course will be focused on *learning by doing*. So, don't be nervous. A little sense of humor throughout this course will help you relax.

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Brief description of this course

- Initially, it will be addressed the basic fundamentals, and concepts, of ***Quantum Mechanics***, and ***Quantum Theory***, in the basis of the study, and research on ***Quantum Computing***.
- It will be given a detailed, and complete, explanation of the ***Quantum Computing***, and its advantages, and specifications.
- It will be shown some existing prototypes of ***Quantum Computers***. It will be shown also, their specifications, and capabilities.

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<https://github.com/rubenandrebarreiro/learning-quantum-computing/>



Brief description of this course

- It will be explained, the architecture and components of a **Quantum Computer**, like per examples, **QPUs**, among others, and, how they work.
- It will be addressed how a **Quantum Computer** process the information, and data, making also, a reference to its processing unit, the **Quantum Bit (or, Qubit)**, and its computation power, and capabilities.
- It will be made a comparison between **Classical Computing** and **Quantum Computing**, as also, showing the differences between them.

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Brief description of this course

- It will be also addressed the history, and timeline, of the ***Quantum Computing***, as also, its current state of art, and research, in Portugal, and worldwide.
- It will be explored the many paradigm breaks that ***Quantum Computing*** promises to meet, in ***Artificial Intelligence***, ***Cryptography***, ***Networks***, and ***Communications***, per example, and some of its applications, like ***NMRs***, among many others.

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Week 0 - July, 2019 | Lecture/Lesson 1

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<https://github.com/rubenandrebarreiro/learning-quantum-computing/>

Brief description of this course

- It will be explained some of the existing ***Quantum Algorithms***, proposed by many authors, like per example, ***David Deutsch, Peter Shor, Lov Grover***, among others. And it will be solved some practical exercises about them.
- It will addressed other ***Quantum Algorithms*** related to the ***QKDs***, with direct application to the ***Post-Quantum Cryptography***, proposed by ***Charles Bennett, Gilles Brassard, Artur Ekert, and Subhash Kak***.

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Brief description of this course

- In this course, throughout its lectures/lessons, it will be used some useful programming languages like **Rigetti's Pyquil** (based on **Python**), **Microsoft's Q#**, and **Haskell's** host based **Quipper**. It will be also used, the very known IBM's frameworks **Qiskit** and **IBM Q Experience** (both, also based on **Python** and **Jupyter Notebook's** environment).
- It will be resolved some exercises based on **Quantum Computing**, using the previously mentioned tools.

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Course overview

- **Course composed by 4 main cores:**
 - **Core 1 - Introduction to Quantum [10 weeks], with 11 Lectures/Lessons:**
 - **Week 0:**
 - 1 - Hello Quantum World (Introduction)
 - 2 - What is Quantum? (From Classical Physics to Quantum Physics)
 - **Week 1:**
 - 3 - Fundamentals of the Quantum Physics (Discovering the Quantum)

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Course overview

- **Course composed by 4 main cores:**
 - **Core 1 - Introduction to Quantum [10 weeks], with 11 Lectures/Lessons:**
 - **Week 2:**
 - *4 - Quantum Properties, Definitions and Theories (Exploring the Quantum)*
 - **Week 3:**
 - *5 - Quantum Effects (Causing the Quantum)*
 - **Week 4:**
 - *6 - Quantum Experiments (Experimenting the Quantum)*

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Week 0 - July, 2019 | Lecture/Lesson 1

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Course overview

- **Course composed by 4 main cores:**
 - **Core 1 - Introduction to Quantum [10 weeks], with 11 Lectures/Lessons:**
 - **Week 5:**
 - *7 - Quantum Formulations (Formulating the Quantum)*
 - **Week 6:**
 - *8 - Quantum Equations (Understanding the Quantum)*
 - **Week 7:**
 - *9 - Quantum Interpretations (Interpreting the Quantum)*

Hello Quantum World



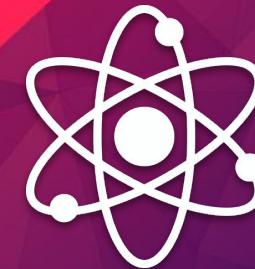
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Course overview

- **Course composed by 4 main cores:**
 - **Core 1 - Introduction to Quantum [10 weeks], with 11 Lectures/Lessons:**
 - **Week 8:**
 - **10 - Quantum Advanced Topics (Mastering the Quantum)**
 - **Week 9:**
 - **11 - Reviewing Quantum Physics/Mechanics (Ending the Quantum)**



Learning Quantum Computing



Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

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Week 0 - July, 2019 | Lecture/Lesson 1

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 0 (Lectures/Lessons 1 and 2):**
 - **Lecture/Lesson 1 - Hello Quantum World (Introduction):**
 - Brief description of this course
 - Course overview
 - **Lecture/Lesson 2 - What is Quantum? (From Classical Physics to Quantum Physics):**
 - Definition
 - What is *Quantum Physics/Mechanics*?
 - What is an *atom*?
 - *Classical Physics/Mechanics vs. Quantum Physics/Mechanics*

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 1 (Lecture/Lesson 3):**
 - **Lecture/Lesson 3 - Fundamentals of the Quantum Physics (Discovering the Quantum) [1/5]:**
 - Coherence
 - Decoherence
 - Complementarity
 - Energy level
 - Entanglement
 - Uncertainty principle
 - Ground state

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 1 (Lecture/Lesson 3):**
 - **Lecture/Lesson 3 - Fundamentals of the Quantum Physics (Discovering the Quantum) [2/5]:**
 - *Quantum interference*
 - *Quantum measurement*
 - *Quantum nonlocality*
 - *Quantum observable*
 - *Quantum fluctuation*
 - *Quantum foam*
 - *Quantum levitation*

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 1 (Lecture/Lesson 3):**
 - **Lecture/Lesson 3 - Fundamentals of the Quantum Physics (Discovering the Quantum) [3/5]:**
 - *Quantum number*
 - *Quantum noise*
 - *Quantum realm*
 - *Quantum state*
 - *Quantum system*
 - *Quantum teleportation*
 - *Spin*

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 1 (Lecture/Lesson 3):**
 - **Lecture/Lesson 3 - Fundamentals of the Quantum Physics (Discovering the Quantum) [4/5]:**
 - *Quantum superposition*
 - *Quantum symmetry*
 - *Quantum symmetry (spontaneous) breaking*
 - *Quantum vacuum state*

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 1 (Lecture/Lesson 3):**
 - **Lecture/Lesson 3 - Fundamentals of the Quantum Physics (Discovering the Quantum) [5/5]:**
 - Wave propagation
 - Quantum wave function
 - Quantum wave function collapse
 - Quantum wave-particle duality
 - Quantum matter wave

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Week 0 - July, 2019 | Lecture/Lesson 1

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 2 (Lecture/Lesson 4):**
 - **Lecture/Lesson 4 - Quantum Properties, Definitions and Theories (Exploring the Quantum) [1/2]:**
 - Mathematical formulation
 - *Bra-ket notation*
 - Operators in *Quantum Physics/Mechanics*
 - *Hamiltonian*
 - Vectors and vectors' spaces
 - The problem of auto-vector, and auto-value
 - The physical meaning of the *Quantum* operators, as also, their auto-vectors, and auto-values



Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 2 (Lecture/Lesson 4):**
 - **Lecture/Lesson 4 - Quantum Properties, Definitions and Theories (Exploring the Quantum) [2/2]:**
 - *Quantum information*
 - *Bloch sphere*
 - *Pauli's exclusion principle*
 - *Rutherford-Bohr's model*
 - *Quantum observer effect*
 - *Ehrenfest theorem*
 - *Time Travel*



Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 3 (Lecture/Lesson 5):**
 - **Lecture/Lesson 5 - Quantum Effects (Causing the Quantum):**
 - Zeeman effect
 - Stark effect
 - Aharonov-Bohm effect
 - Landau quantization
 - Quantum Hall effect
 - Quantum Zeno effect
 - Quantum tunnelling
 - Photoelectric effect
 - Casimir effect

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 4 (Lecture/Lesson 6):**
 - **Lecture/Lesson 6 - Quantum Experiments (Experimenting the Quantum) [1/2]:**
 - Afshar
 - Bell's inequality
 - Davisson-Germer
 - Double-slit
 - Elitzur-Vaidman
 - Franck-Hertz
 - Leggett-Garg inequality

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 4 (Lecture/Lesson 6):**
 - **Lecture/Lesson 6 - Quantum Experiments (Experimenting the Quantum) [2/2]:**
 - Mach-Zehnder
 - Popper
 - Quantum eraser (delayed-choice)
 - Schrödinger's cat
 - Quantum suicide and immortality
 - Stern-Gerlach
 - Wheeler's delayed-choice



Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 5 (Lecture/Lesson 7):**
 - **Lecture/Lesson 7 - Quantum Formulations (Formulating the Quantum):**
 - Heisenberg's picture
 - Interactions picture
 - Matrix mechanics
 - Phase-space's formulation
 - Schrödinger's picture
 - Sum-over-histories (path-integral formulation)
 - Hellmann-Feynman theorem

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 6 (Lecture/Lesson 8):**

- **Lecture/Lesson 8 - Quantum Equations (Understanding the Quantum):**
 - Dirac's equation
 - Klein-Gordon's equation
 - Pauli's equation
 - Rydberg's equation
 - Schrödinger's equation

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 7 (Lecture/Lesson 9):**
 - **Lecture/Lesson 9 - Quantum Interpretations (Interpreting the Quantum) [1/2]:**
 - Consistent histories
 - Copenhagen interpretation
 - de Broglie-Bohm (pilot wave theory)
 - Ensemble interpretation
 - Hidden-variable theories
 - Many-worlds interpretation
 - Objective-collapse theories

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 7 (Lecture/Lesson 9):**
 - **Lecture/Lesson 9 - Quantum Interpretations (Interpreting the Quantum) [2/2]:**
 - *Quantum Bayesianism*
 - *Quantum logic*
 - *Relational Quantum Physics/Mechanics*
 - *Stochastic Quantum Physics/Mechanics*
 - *Scale relativity*
 - *Transactional interpretation of Quantum Physics/Mechanics*

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 8 (Lecture/Lesson 10):**
 - **Lecture/Lesson 10 - Quantum Advanced Topics (Mastering the Quantum) [1/2]:**
 - *Quantum annealing*
 - *Chaos theory*
 - *Quantum chaos*
 - *Quantum computing*
 - *Density matrix*
 - *Quantum field theory*
 - *Fractional Quantum Physics/Mechanics*
 - *Quantum gravity*

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Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 8 (Lecture/Lesson 10):**

- **Lecture/Lesson 10 - Quantum Advanced Topics (Mastering the Quantum) [2/2]:**

- *Quantum information science*
 - *Quantum machine learning*
 - Perturbation theory in *Quantum Physics/Mechanics*)
 - Relativistic *Quantum Physics/Mechanics*
 - Scattering theory
 - Spontaneous parametric down-conversion
 - *Quantum statistical Physics/Mechanics*

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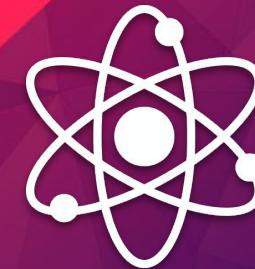


Course overview | Core 1 - Introduction to Quantum [10 Weeks | 11 Lectures/Lessons]

- **Week 9 (Lecture/Lesson 11):**
 - **Lecture/Lesson 11 - Reviewing Quantum Physics/Mechanics (Mastering the Quantum):**
 - Relevant contributors for the studies about *Quantum Physics/Mechanics*
 - Review about the Introduction to *Quantum Physics/Mechanics*
 - Some interesting curiosities



Learning Quantum Computing



Course overview | Core 2 - Discovering Quantum Computing [4 Weeks | 7 Lectures/Lessons]

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Week 0 - July, 2019 | Lecture/Lesson 1

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Course overview | Core 2 - Discovering Quantum Computing [4 Weeks | 7 Lectures/Lessons]

- **Week 10 (Lecture/Lesson 12):**
 - **Lecture/Lesson 12 - Basis of Quantum Computing (Beyond the Computing Theory):**
 - *Quantum Superposition*
 - *Schrödinger's Cat Experience*
 - *Quantum Entanglement*
 - *Quantum Teleportation*
 - *Rutherford Scattering*
 - *Existence of Multiverse*
 - Key aspects and considerations
 - Some interesting curiosities

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Course overview | Core 2 - Discovering Quantum Computing [4 Weeks | 7 Lectures/Lessons]

- **Week 11 (Lectures/Lessons 13 and 14):**
 - **Lecture/Lesson 13 - What is Quantum Computing? (Beyond the Computing Power):**
 - Moore Law
 - Motivation
 - Definition
 - How it works?
 - *Classic Computing vs. Quantum Computing*
 - Scientific applications of *Quantum Computing*
 - Breaking paradigms

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Week 0 - July, 2019 | Lecture/Lesson 1

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Course overview | Core 2 - Discovering Quantum Computing [4 Weeks | 7 Lectures/Lessons]

- **Week 11 (Lectures/Lessons 13 and 14):**
 - **Lecture/Lesson 14 - What is a Quantum Bit? (Beyond the Computing Units):**
 - Definition
 - How it works?
 - Relationship between *Quantum Bit* and *Quantum Physics/Mechanics*
 - *Quantum Bit* viewed as an atom/particle
 - *Bit vs. Qubit*
 - Bell Pairs



Course overview | Core 2 - Discovering Quantum Computing [4 Weeks | 7 Lectures/Lessons]

- **Week 12 (Lectures/Lessons 15 and 16):**
 - **Lecture/Lesson 15 - Timeline of Quantum Computing (Beyond the Computing History):**
 - Quantum Computing over the years worldwide
 - Quantum Computing over the years in Portugal
 - Relevant contributors for the studies about Quantum Computing
 - Current state of art and research
 - **Lecture/Lesson 16 - Quantum Computers (Beyond the Computing Power):**
 - Quantum machines
 - Current prototypes of Quantum Computers
 - Concerns and cautions about the behaviour of Quantum Computers

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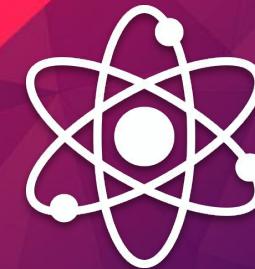
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Course overview | Core 2 - Discovering Quantum Computing [4 Weeks | 7 Lectures/Lessons]

- **Week 13 (Lectures/Lessons 17 and 18):**
 - **Lecture/Lesson 17 - Quantum Hardware (Beyond the Computing Hardware):**
 - Components of a *Quantum Computer*
 - *Quantum Processors*
 - *Quantum Buses*
 - *CPUs vs. GPUs vs. QPUs*
 - **Lecture/Lesson 18 - Quantum Ethics (Beyond the Computing Ethics):**
 - Battle for the *Quantum supremacy*
 - *Quantum Computing* in society
 - Some ethics and social aspects in *Quantum Computing*



Learning Quantum Computing



Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

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Week 0 - July, 2019 | Lecture/Lesson 1

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 14 (Lecture/Lesson 19):**
 - **Lecture/Lesson 19 - Quantum Logic, Theory and Computing Models [1/2]:**
 - *Quantum Circuits*
 - *Quantum Logic Gates*
 - *Quantum Turing Machine*
 - *Quantum Cellular Automatons*
 - *Quantum Dot Cellular Automatons*

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Week 0 - July, 2019 | Lecture/Lesson 1

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LABORATORY FOR COMPUTER SCIENCE AND INFORMATICS

Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 14 (Lecture/Lesson 19):**
 - **Lecture/Lesson 19 - Quantum Logic, Theory and Computing Models [2/2]:**
 - Quantum Finite Automatons
 - One-Way Quantum Computer/Measurement Based *Quantum Computer* (M.B.Q.C.)
 - a) *Quantum Cluster State*
 - Adiabatic *Quantum Computation* (A.Q.C.)
 - Topological *Quantum Computer*

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NOVALINCS
LABORATORY FOR COMPUTER SCIENCE AND INFORMATICS

Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 15 (Lectures/Lessons 20 and 21):**
 - **Lecture/Lesson 20 - Quantum Algorithms, Simulation and Complexity (Quantum Algorithms - Part I):**
 - Matching/Transforming Algorithms:
 - *Deutsch-Jozsa Algorithm*
 - *Quantum Fourier Transform*
 - Search Algorithms:
 - *Grover's Algorithm*
 - *Simon's Problem/Simon's Algorithm*
 - *Quantum Annealing (Q.A.)*

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Week 0 - July, 2019 | Lecture/Lesson 1

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 15 (Lectures/Lessons 20 and 21):**
 - **Lecture/Lesson 21 - Quantum Algorithms, Simulation and Complexity (Quantum Algorithms - Part II):**
 - Factorization Algorithms:
 - *Shor's Algorithm*
 - Solving/Estimation Algorithms:
 - *Quantum Phase Estimation Algorithm/Quantum Eigenvalue Estimation Algorithm*
 - *Quantum Algorithm for Linear Systems of Equations*
 - *Quantum Counting Algorithm* (Var. of *Quantum Phase Estimation Algorithm* and *Grover's Algorithm*)
 - *Quantum Amplitude Amplification* (Generalization of *Grover's Algorithm*)

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 16 (Lectures/Lessons 22 and 23):**
 - **Lecture/Lesson 22 - Quantum Algorithms, Simulation and Complexity (Quantum Simulators and Quantum Complexity):**
 - *Quantum Simulators*
 - *Quantum Complexity*
 - Exact *Quantum Polynomial Time* (E.Q.P.)
 - Bounded-Error *Quantum Polynomial Time* (B.Q.P.)
 - *Quantum Merlin Arthur* (Q.M.A.)
 - Bounded-Error *Quantum Polynomial Time with Post-Selection* (PostBQP)
 - *Quantum Interactive Polynomial Time* (Q.I.P.T.)

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 16 (Lectures/Lessons 22 and 23):**
 - **Lecture/Lesson 23 - Quantum Error Correction and Stabilizers:**
 - Entanglement-Assisted Quantum Error Correction
 - Quantum Steane Code
 - Quantum Calderbank-Shor-Steane Code (C.S.S. Code)
 - Quantum Convolutional Codes
 - Toric Code
 - Quantum Shor Code

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 17 (Lecture/Lesson 24):**
 - **Lecture/Lesson 24 - Quantum Artificial Intelligence and Machine Learning (Quantum Machine Learning) [1/2]:**
 - Linear Algebra Simulation with *Quantum Amplitudes*
 - *Quantum Machine Learning Algorithms Based on Grover's Search*
 - *Quantum-Enhanced Reinforcement Learning*
 - *Quantum Sampling Techniques*
 - *Hidden Quantum Markov Models (H.Q.M.M.s)*

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 17 (Lecture/Lesson 24):**
 - **Lecture/Lesson 24 - Quantum Artificial Intelligence and Machine Learning (Quantum Machine Learning) [2/2]:**
 - Fully Quantum Machine Learning
 - Noisy Data
 - Calculated and Noise-Free Data
 - Variational Circuits

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 18 (Lecture/Lesson 25):**
 - **Lecture/Lesson 25 - Quantum Artificial Intelligence and Machine Learning (Quantum Neural Networks [Q.N.N.s] and Quantum Bayesian Networks) [1/2]:**
 - **Quantum Neural Networks (Q.N.N.s):**
 - *Quantum Perceptrons*
 - *Fuzzy Logic*
 - *Applications on Quantum Networks*
 - *Quantum Associative Memory*
 - *Quantum Computing via Sparse Distributed Representations*

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 18 (Lecture/Lesson 25):**
 - **Lecture/Lesson 25 - Quantum Artificial Intelligence and Machine Learning (Quantum Neural Networks [Q.N.N.s] and Quantum Bayesian Networks) [2/2]:**
 - *Quantum Neural Networks (Q.N.N.s):*
 - *Quantum Learning*
 - *Quantum Generalisations of Feedforward Neural Networks*
 - *Biological Quantum Neural Networks*
 - *Quantum Bayesian Networks (Q.B.N.s)*

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 19 (Lecture/Lesson 26):**
 - **Lecture/Lesson 26 - Quantum Networks, Communications, Security and Cryptography (Quantum Networks):**
 - *Quantum Networks:*
 - *Quantum Networks for Computation*
 - *Quantum Networks for Communication*
 - *Elements of a Quantum Network:*
 - End Nodes: *Quantum Processors*
 - Communication Lines: Physical Layer (Fiber Optic Networks and Free Space Networks)
 - Repeaters (Trusted Repeaters, *Quantum Repeaters*, Error Correction and Entanglement Purification)

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 19 (Lecture/Lesson 26):**
 - **Lecture/Lesson 26 - Quantum Networks, Communications, Security and Cryptography (Quantum Networks):**
 - Applications of *Quantum Networks*:
 - Secure Communications
 - Jamming Protection (Frequency-Hopping Spread Spectrum and Direct-Sequence Spread Spectrum)
 - Jamming (Spot Jamming, Sweep Jamming and Barrage Jamming)
 - Current Status of *Quantum Networks*:
 - *Quantum Internet*
 - *Quantum Key Distribution Networks*

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 20 (Lecture/Lesson 27):**
 - **Lecture/Lesson 27 - Quantum Networks, Communications, Security and Cryptography (Quantum Communications and Quantum Channels):**
 - Quantum Communications:
 - Quantum Capacity in Communications:
 - Quantum Capacity in Communications vs. Classical Capacity in Communications
 - Superdense Coding
 - Local Operations and Classical Communication (L.O.C.C.)
 - Entanglement Distillation (Variation of Local Operations and Classical Communication)

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 20 (Lecture/Lesson 27):**
 - **Lecture/Lesson 27 - Quantum Networks, Communications, Security and Cryptography (Quantum Communications and Quantum Channels):**
 - *Quantum Channels:*
 - *Quantum Teleportation in Quantum Channels*
 - *Entanglement-Assisted Classical Capacity*

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 21 (Lecture/Lesson 28):**
 - **Lecture/Lesson 28 - Quantum Networks, Communications, Security and Cryptography (Quantum Security and Cryptography - Part I):**
 - Introduction to *Quantum Security and Cryptography*
 - *Quantum Key Distribution (Q.K.D.):*
 - *BB84 (Bennett-Brassard-1984)*
 - *SARG04 (Variation of BB84)*
 - *Three-Stage Quantum Cryptography Protocol (Kak's Three-Stage Protocol)*
 - *E91 (Ekert-1991)*

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 22 (Lecture/Lesson 29):**
 - **Lecture/Lesson 29 - Quantum Networks, Communications, Security and Cryptography (Quantum Security and Cryptography - Part II):**
 - *Quantum Coin Flipping*
 - *Quantum Commitment*
 - *Bounded (and Noisy) Quantum-Storage Model (B.Q.S.M.)*
 - *Position-Based Quantum Cryptography*
 - *Property of Device-Independent Quantum Cryptography*

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 23 (Lecture/Lesson 30):**
 - **Lecture/Lesson 30 - Quantum Networks, Communications, Security and Cryptography (Quantum Security and Cryptography - Part III):**
 - Algorithms in Post-Quantum Cryptography:
 - Lattice-Based Quantum Cryptography
 - Multivariate Quantum Cryptography
 - Hash-Based Quantum Cryptography
 - Code-Based Quantum Cryptography
 - Supersingular Elliptic Curve Isogeny Quantum Cryptography
 - Symmetric Key Quantum Resistance

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 24 (Lecture/Lesson 31):**
 - **Lecture/Lesson 31 - Quantum Networks, Communications, Security and Cryptography (Quantum Security and Cryptography - Part IV):**
 - Security Reductions in Post-Quantum Cryptography:
 - Lattice-Based Quantum Cryptography – Ring-LWE Signature
 - Lattice-Based Quantum Cryptography – NTRU, BLISS
 - Multivariate Quantum Cryptography – Rainbow
 - Hash-Based Quantum Cryptography – Merkle Signature Scheme

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 24 (Lecture/Lesson 31):**
 - **Lecture/Lesson 31 - Quantum Networks, Communications, Security and Cryptography (Quantum Security and Cryptography - Part IV):**
 - Security Reductions in Post-Quantum Cryptography:
 - Code-Based Quantum Cryptography – McEliece
 - Code-Based Quantum Cryptography – RLCE
 - Supersingular Elliptic Curve Isogeny Quantum Cryptography
 - Quantum Readout

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 25 (Lectures/Lessons 32 and 33):**
 - **Lecture/Lesson 32 - Quantum Electronics, Sensors and Actuators:**
 - Quantum Electronics
 - Quantum Sensors
 - Quantum Image Processing
 - **Lecture/Lesson 33 - Quantum Physical Implementations [1/2]:**
 - Ultracold Atoms:
 - Trapped Ion Quantum Computer

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Course overview | Core 3 - Applying the Quantum Computing [12 Weeks | 15 Lectures/Lessons]

- **Week 25 (Lectures/Lessons 32 and 33):**
 - **Lecture/Lesson 33 - Quantum Physical Implementations [2/2]:**
 - Spin-Based:
 - Nuclear Magnetice Resonance Quantum Computer (N.M.R. Q.C.)
 - Kane Quantum Computer
 - Loss-DiVicenzo Quantum Computer
 - Superconducting Quantum Computing:
 - Charge Qubit
 - Flux Qubit
 - Phase Qubit
 - Transmon

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Week 0 - July, 2019 | Lecture/Lesson 1

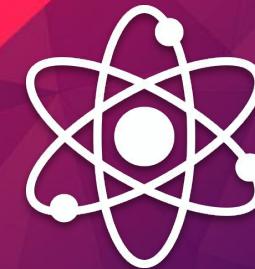
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Learning Quantum Computing



Course overview | Core 4 - Practicing the Quantum Computing [4 Weeks | 7 Lectures/Lessons]

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Credits and special thanks

- Ultimately, some credits and special thanks to:
 - TODO

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Thank you, I hope you enjoy it!!!

