INSTITUT TEKNOLOGI SEPULUH NOPEMBER (ITS)
FAKULTAS TEKNOLOGI ELEKTRO DAN INFORMATIKA CERDAS
DEPARTEMEN TEKNIK ELEKTRO
Program Studi Sarjana (S1) Teknik Telekomunikasi

1	**Nama Mata Kuliah**	:	Komputasi Kuantum dan Informasi Kuantum Informasi
2	**Kode Mata Kuliah**	:	EL234713
3	**Kredit**	:	3 SKS
4	**Semester**	:	Pilihan

Deskripsi Mata Kuliah

Komputasi kuantum telah ditunjukkan secara teoritis mempunyai keunggulan yang signifikan dibanding komputasi klasik dan hal ini berpotensi diterapkan pada berbagai bidang: kriptografi, machine learning, finansial, simulasi fenomena alam yang kompleks dll. Sebagai sinerji dari fisika kuantum, komputasi dan teori informasi, bidang ini mengalami perkembangan yang pesat, yang ditandai antara lain diumumkannya komputer 127 qubit oleh IBM pada Oktober 2021, dan semakin banyaknya perusahaan baru didirikan untuk mengembangkan teknologi ini. Pada beberapa tahun terakhir telah dibangun berbagai komputer kuantum pada tahap awal yang dapat diakses oleh publik. Hal ini berdampak dibutuhkannya tenaga kerja di bidang ICT yang relatif baru ini, antara lain: programmer, engineer dan peneliti di bidang komputasi kuantum.

Pada mata kuliah ini akan dipelajari prinsip-prinsip komputasi dan representasi informasi berbasis mekanika kuantum. Topik-topik yang akan dibahas antara lain: qubit, ruang Hilbert, entanglement, superposition, reversible circuit, kompleksitas komputasi, gerbang logika kuantum, algoritma Grover, algoritma Shor, quantum error-correction dan dasar arsitektur komputer kuantum. Selain itu mahasiswa juga akan mempelajari simulasi komputasi kuantum dan pemrogramannya dengan Qiskit pada komputer kuantum IBM.

Capaian Pembelajaran Lulusan (CPL) Yang Dibebankan Mata Kuliah

1. (CPL-02) Mampu mengkaji dan memanfaatkan ilmu pengetahuan dan teknologi dalam rangka mengaplikasikannya pada bidang Teknik Telekomunikasi, serta mampu mengambil keputusan secara tepat dari hasil kerja sendiri maupun kerja kelompok dalam bentuk laporan tugas akhir atau bentuk kegiatan pembelajaran lain yang luarannya setara dengan tugas akhir melalui pemikiran logis, kritis, sistematis dan inovatif.
2. (CPL-04) Mampu menerapkan ilmu pengetahuan alam dan matematika serta teknologi dan rekayasa informasi untuk memperoleh pemahaman komprehensif pada bidang Teknik Telekomunikasi.
3. (CPL-08) Mampu mengetahui dan mengaplikasi metode dan keahlian sesuai perkembangan terkini di bidang ilmu pengetahuan dan teknologi untuk menyelesaikan permasalahan di bidang Teknik Telekomunikasi dengan mengedepankan nilai-nilai universal

Capaian Pembelajaran Mata Kuliah

1. Mampu menjelaskan prinsip dan konsep dasar mekanika kuantum dan 4 postulat yang terkait informasi kuantum
2. Mampu menjelaskan quantum state sebagai qubit, baik dalam bentuk tunggal dan ganda, evolusinya; Mampu menjelaskan gerbang kuantum, rangkaian kuantum
3. Mampu menjelaskan algoritma-algoritma kuantum yang diusulkan, antara lain: algoritma Grover, algoritma Shor, Quantum Fourier Transform, quantum key distribution.
4. Mampu memprogram rangkaian kuantum dan algoritma tertentu, baik secara simulasi dan pada kuantum komputer riil
5. Mampu menjelaskan teknologi-teknologi kuantum yang digunakan untuk membangun komputer kuantum

Pokok Bahasan

1. Pengantar komputasi kuantum
2. Dasar-dasar mekanika kuantum. 4 postulat
3. Probabilitas, aljabar linier dan ruang Hilbert
4. Qubit dan gerbang kuantum
5. Multiqubit dan sirkuit
6. Kompleksitas komputasi
7. Simulasi komputasi kuantum: Quirk
8. Pemrograman kuantum: Qiskit
9. Algoritma pencarian Grover
10. Quantum Fourier Transform dan periodisitas.
11. Faktorisasi bilangan bulat dan algoritma Shor
12. Kriptografi kuantum
13. Quantum error-correction dan komunikasi kuantum. Algoritma Shor
14. Arsitektur komputer kuantum

Prasyarat

Aljabar Linier dan Variabel Kompleks, Probabilitas dan Statistik

Pustaka

Utama:

1. Thomas G. Wong, “Introduction to Classical and Quantum Computing,” Rooted Grove, 2022. (versi e-book tersedia gratis di www.thomaswong.net)
2. Ray LaPierre, “Introduction to Quantum Computing,” Springer, 2021.

Pendukung:

1. Bernard Zygelman, “A First Introduction to Quantum Computing and Information,” Springer, 2018.
2. Weng-Long Chang & Athanasios V. Vasilakos, “Fundamentals of Quantum Programming in IBM’s Quantum Computers,” Springer, 2021.

INSTITUTE TECHNOLOGI SEPULUH NOPEMBER (ITS)
FACULTY OF INTELLIGENT ELECTRICAL AND INFORMATICS TECHNOLOGY
DEPARTMENT OF ELECTRICAL ENGINEERING
Undergraduate Study Program (S1) Telecommunication Engineering

1	**Course Name**	:	Quantum Computing and Quantum Information
2	**Course Code**	:	EL234713
3	**Credit**	:	3 CREDITS
4	**Semester**	:	Options

Course Description

Quantum computing has been theoretically shown to have significant advantages over classical computing and it has potential applications in many fields: cryptography, machine learning, finance, simulation of complex natural phenomena, etc. As a synergy of quantum physics, computing and information theory, this field is experiencing rapid development, characterized by, among others, the announcement of the 127 qubit computer by IBM in October 2021, and the growing number of new companies established to develop this technology. In recent years, many early-stage quantum computers have been built that are accessible to the public. This has resulted in the need for workers in this relatively new field of ICT, including programmers, engineers and researchers in the field of quantum computing.

This course will study the principles of quantum mechanics-based computation and information representation. Topics that will be discussed include: qubits, Hilbert space, entanglement, superposition, reversible circuit, computational complexity, quantum logic gates, Grover algorithm, Shor algorithm, quantum error-correction and basic quantum computer architecture. In addition, students will also learn quantum computing simulations and programming with Qiskit on an IBM quantum computer.

Graduate Learning Outcomes (SLOs) Charged Courses

1. (CPL-02) Able to study and utilize science and technology in order to apply it in the field of Telecommunication Engineering, and be able to make decisions appropriately from the results of their own work and group work in the form of a final project report or other forms of learning activities whose output is equivalent to the final project through logical, critical, systematic and innovative thinking.
2. (CPL-04) Able to apply natural science and mathematics as well as technology and information engineering to gain a comprehensive understanding of the field of Telecommunication Engineering.
3. (CPL-08) Able to know and apply methods and expertise according to the latest developments in the field of science and technology to solve problems in the field of Telecommunication Engineering by prioritizing universal values.

Course Learning Outcomes

1. Able to explain the principles and basic concepts of quantum mechanics and 4 postulates related to quantum information
2. Able to explain the quantum state as a qubit, both in single and double form, its evolution; Able to explain quantum gates, quantum circuits
3. Able to explain the proposed quantum algorithms, including: Grover algorithm, Shor algorithm, Quantum Fourier Transform, quantum key distribution.
4. Able to program quantum circuits and certain algorithms, both in simulation and on real quantum computers.
5. Able to explain the quantum technologies used to build quantum computers

Subject matter

1. Introduction to quantum computing
2. Fundamentals of quantum mechanics. 4 postulates
3. Probability, linear algebra and Hilbert space
4. Qubits and quantum gates
5. Multiqubits and circuits
6. Computational complexity
7. Quantum computing simulation: Quirk
8. Quantum programming: Qiskit
9. Grover's search algorithm
10. Quantum Fourier Transform and periodicity.
11. Integer factorization and Shor's algorithm
12. Quantum cryptography
13. Quantum error-correction and quantum communication. Shor's algorithm
14. Quantum computer architecture

Prerequisites

Linear Algebra and Complex Variables, Probability and Statistics

Library
Main: 1. Thomas G. Wong, "Introduction to Classical and Quantum Computing," Rooted Grove, 2022. (e-book version available for free at www.thomaswong.net) 2. Ray LaPierre, "Introduction to Quantum Computing," Springer, 2021. Supporters: 1. Bernard Zygelman, "A First Introduction to Quantum Computing and Information," Springer, 2018. 2. Weng-Long Chang & Athanasios V. Vasilakos, "Fundamentals of Quantum Programming in IBM's Quantum Computers," Springer, 2021.