IIT Mandi

Course Name	: **Engineering Foundations of Quantum Technologies**
Course Number	: QT 509
Credits	: 3-0-0-3
Prerequisites	: Engineering Mathematics (Linear Algebra, Complex algebra, basics of 2nd of ODEs and initial value problems, 2nd order PDEs and boundary value problems, Probability and Statistics, Random variables). Maxwell's equations and EM theory at the level of the core physics syllabus from AICTE model
Curriculum Intended for	: UG/PG/PhD
Distribution	: Elective PG/Elective UG
Semester	: Odd/Even

Preamble: This course is meant to cover topics in electrical, electronics and communication engineering, as well as in computer science that are relevant to Quantum computation, Communications and Sensing. This is a survey course and not meant for a rigorous treatment of each topic. Students of this course learn (i) Relevant topics from Electrical Networks to design and analyse analog circuits, (ii) Relevant topics from RF and Microwave Engineering to design systems, (iii) Relevant topics in Theory of computation to benchmark algorithms, (iv) Relevant topics in analog and digital communications, (v) Basics of cryptography

Course Content and syllabus:

- Electrical Networks (4 hours)
  - Analog RLC circuits – resonances, impedances, quality factors
  - Transmission line basics (2 hours)
    - Telegrapher equations, wave impedance, impedance matching, transmission line resonators
- Computer Science (15 hours)
  - Basics of computer architecture (1 hour)
    - Arithmetic Logic Unit
    - Memory
  - Abstract models of computation (12 hours)
    - Finite State Machine
    - Turing Machines
    - Overview of Hierarchy of languages – Regular, Context-Free, Turing Decidable and Turing Recognisable
  - Complexity Theory (2 hours)
    - Time and Space complexity
    - P vs NP, NP-completeness
- Electrical Communications (1 hour)
  - Analog Communications (1 hour)
    - Quadrature amplitude modulation
    - Heterodyne and Homodyne demodulation
- Noise and Signals (6 hours)
  - Characterising Noise

        - Types of Noise
            - Shot Noise
            - Johnson-Nyquist Noise
            - Telegraphic noise or flicker or 1/f noise
        - Signal conditioning and noise mitigation
        - Amplification and Added Noise
            - Linear Amplifier theory
            - Signal-Noise Ratio, Added Noise, Noise Figure of amplification
            - Dynamic Range
            - Noise temperature
            - Quantum limits on noise in linear amplifiers
    - Digital Communications (4 hours)
        - Information entropy
        - Noiseless channel encoding
        - Noisy channel encoding
    - Basics of cryptography (6 hours)
        - Basics of Number Theory
        - Random Number Generation
        - One time pad, Private key, public key, symmetric and asymmetric cryptography protocols
        - RSA and DH
        - Post Quantum Cryptography (PQC)

Course Outcomes:

Students of this course learn

1. Relevant topics from Electrical Networks to design and analyse analog circuits
2. Relevant topics from RF and Microwave Engineering to design systems
3. Relevant topics in Theory of computation to benchmark algorithms
4. Relevant topics in analog and digital communications
5. Basics of cryptography

Course References:

1. Art of Electronics, Paul Horowitz and Winfield Hill, 3rd edition, Cambridge University Press (2015)
2. Digital Design, Morris Mano, Michael D. Cilletti, 6th edition, Pearson Education (2018)
3. Microwave Engineering, David Pozar, 4th edition, Wiley (2013)
4. Information Theory, Robert B. Ash, Dover Publications (2003)
5. Introduction to the Theory of Computation, Michael Sipser, 3rd edition, Cengage India Pvt. Ltd. (2014)
6. Protecting Information – From Classical error correction to quantum cryptography, Susan Loepp and William K. Wootters, Cambridge University Press (2006)