School of Mathematics Spring 2020

QUANTUM COMPUTATION

Guide to examinable material

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As a general rule, content covered in lectures and non-optional exercises is all examinable, whereas content not covered in lectures and deferred to the lecture notes (e.g. additional proofs or remarks), or covered in optional exercises, is not examinable in itself. However, this content may provide useful background reading.

When an algorithm is listed below, you are not expected to remember all technical details in the definition of the algorithm or its proof of correctness. However, you are expected to understand and be able to reproduce the key points in the proof; to be able to give a high-level description of the algorithm; and to explain its key ideas.

If in doubt, please ask.

The following content is **examinable**:

1. **The quantum circuit model.**
   - Basic linear algebra (matrices, vectors, unitarity, eigenvalues, eigenvectors, etc.).
   - Dirac (bra-ket) notation.
   - The quantum circuit formalism (its meaning, standard gates, writing a circuit as a unitary operator, manipulating circuits, calculating the output from a circuit, writing an algorithm as a circuit).
   - Implementation of classical logic gates as quantum gates.
   - The query complexity model and oracle operators.
2. **Quantum algorithms.**
   - The Deutsch-Jozsa algorithm.
   - Grover's algorithm (for a unique marked element, and for multiple marked elements where the number of marked elements is known). The extensions to an unknown number of marked elements and amplitude amplification are not examinable.
   - The quantum Fourier transform (definition, efficient implementation as a quantum circuit).
   - The periodicity-determination algorithm.

- Shor's algorithm (overall factorisation algorithm, applying the QFT to determine an approximate period, using continued fractions to extract the period). Proofs of number-theoretic ingredients and proof of lower bound on probability of obtaining a good outcome are not examinable.
- Phase estimation algorithm and application to quantum counting. Proof of Theorem 6.1 is not examinable.
- Hamiltonian simulation.

3. **Noise, quantum channels and error-correction.**

   - The concept of quantum channels and Kraus representations. The Stinespring representation is not examinable.
   - Quantum channels as maps on the Bloch sphere.
   - The concept of quantum error-correction. The proof that correcting X and Z is sufficient to correct any single-qubit error is not examinable.
   - The bit-flip, phase-flip and 9-qubit codes.

The lecture on distinguishing knots using a quantum computer is not examinable.