Computational Complexity & Physics: Exam Standards

Models of computation

For good grade be comfortable with the notions: finite state machine, Turing machine (what kind of data is needed to specify it), languages, decision problems, Church-Turing-Thesis.

For excellent grade in addition: be able to explain limits to FSM model, be capable of writing TM program.

Literature: Arora & Barak ([AB]).

Computability

Good: Turing number, UTM, Halting Problem

Excellent: Understand concepts of Gödel's Theorem

Literature: [AB] sufficient, could look into *A Mathematical Introduction to Logic* by Enderton (but not required).

Ising model and graph theory concepts

OK: Understand Ising ground state problem, concept of frustration.

Ex.: have some intuition about "why" Ising suspected to be hard, understand the tree-case, have an idea of how reduction to graph problems works (but not the actual proof).

Not necessary: Poly-time algorithm for planar graphs.

Literature: Could use `scholar.google.com` to locate a copy of *Finding a maximum cut of a planar graph in polynomial time* by Hadlock, but not required.

Time Complexity

OK: Def. of P, NP, PH; idea behind reductions, and complete problems; examples of NP-complete problems; SAT, basic ideas of Cook-Levin proof [AB], one example of Σ_2^p. Randomized Turing machines.

Ex.: "Why" we resort to reductions (rather than just prove things to be hard); use and limitations of "P" as model for "tractable"; a bit more details of Cook-Levin (though I certainly won't ask for the proof); notion of "collapse" of PH – name either the example of IntegerFactorization (easier) or GraphIsomorphism (more difficult). Place BPP in PH.

Literature: AB.

Randomness & Bell

OK: Idea of Bell, why would some people claim that it proves "true randomness is physical"?

Ex.: state Bell inequality precisely; be comfortable with various assumptions made in the argument.

Literature: The book *Quantum Mechanis: Concepts and Methods* by Asher Peres is a good source.

Quantum circuits

OK: Hamiltonians and unitaries; X, Z, H-gates and notion of "controlled gates"; read circuit diagrams; be able to analyze simple circuits.

Ex.: be comfortable with simple relations among X, Y, Z, H; Bloch sphere picure.

Not: memorize *any* circuit!

Literature: Nielsen-Chuang.

Quantum algorithms & Simple Crypto

OK: BQP. Factoring and Order Finding problem statements; Deutsch-Josza; Quantum Fourier Transform. Diffie-Hellman key exchange. Discrete logarithm problem.

Ex.: Quantum Period Finding algorithm.

Literature: NC.