Quantum Information Theory: Exam Standards

Basics

For good grade know about density matrices, POVM measurements, and Kraus operators. Be able to compute reduced density matrices for simple examples. Know the ingredients to teleportation (but I won't ask you to do the full calculation during an exam). Be able to explain the CHSH inequality.

For excellent grade in addition: know about complete positivity, how to realize a CPTP maps using unitaries on an enlarged system, be able to explain an example that shows positivity $\neq$ complete positivity. Be able to relate Bell inequalities to phenomena like "no cloning" or uncertainty relations.

Entanglement theory

Good: Be able to detect entanglement in pure bi-partite states. Understand "entropy of entanglement", how to compute it, and what its interpretation is. Explain the process of entanglement distillation and dilution.

Excellent: Relate the distillation protocols to notions of information theory: i.i.d. sources, entropy, typical sequences. What is majorization and how does it relate to entanglement theory?

Not necessary: The detailed proof that distillation / dilution protocols work.

Error correction

OK: Give simple example of classical communication channels and how to code against errors there. Why not use repetition codes in QM? Explain the three-qubit code: Code space, which error it protects against and why. Which circuit generates it?

Ex.: What is a stabilizer code? A stabilizer group? How does one do syndrome measurements in stabilizer codes? What is the toric code (c.f. exercise sheet).

Quantum Key Distribution

OK: What is the goal of QKD? How does the protocol work on a high level? What measurements do Alice and Bob perform? What do they announce publically and what do they keep private? Why do they end up with a shared key in case they perform the protocol on singlets?

Ex.: Explain the basic idea of how Alice and Bob ensure that the are operating on the right state? What is the role of quantum error correcting codes in this context?

Not: The detailed proof.

Quantum Computing

OK: Be able to draw / read circuit diagrams. Be familiar with common gates: X, Y, Z, H and CNOT. On a high level, what does Simon's algorithm do?

Ex.: Explain Simon's algorithm in detail; how does a classical computer handle this problem? On a conceptual level: What are the complexity classes P & NP and how do they relate to quantum computers? What does Shor's algorithm do?

Not: The daunting details of Shor's algorithm.