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Quantum error correction and fault tolerant quantum computing.

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This is an excellent textbook introducing to and representing the title problem. It is written in a very clear language which motivates each step of the formal developments which are presented with mathematical rigor, formulating definitions, theorems, and proofs. Exercises help the reader to realize the material just presented. Each chapter ends with a collection of problems and a list of references. After the preface the introduction begins with a section on the historical background followed by sections on classical error correcting codes, how information can be stored in quantum systems, and the problem to stabilize quantum information processing in spite of the oo-cloning theorem. Here also a first pass through the methods of quantum error correcting codes is given which contains important fundamentals frequently referred to later on in the book. Chapter two, entitled 'quantum error correcting codes', begins introducing the concepts of operations, measurements, and the general channel concept as a operator-sum representation (replacing the concept of complete positive map which seems to be omitted). The depolarizing channel as the simplest error model and generalizations are considered. After some additional definitions to quantum error correcting codes introduced in section 1.4.2 the chapter closes describing the Calderbank-Shore-Steane code. Chapter three contains a detailed description of quantum stabilizer codes, their mathematical background, examples and different realizations of such codes. In chapter four the standard form of stabilizer codes is introduced. On this basis efficient encoding and decoding and the respective circuits are considered. The subject of chapter five is error correction with fault-tolerant quantum computing. The developments culminate in a set of fault tolerant encoded quantum gates sufficient for universal quantum computation using any quantum stabilizer code. Two examples are given. The use of quantum error correcting codes enlarges the algorithm n consideration and so new sources of errors arise. The question whether it is still possible to restrict remaining errors arbitrarily is answered by the accuracy threshold theorem which is subject to chapter six. Under certain assumptions it is proved that remaining errors can be omitted efficiently if the error probability due to storage registers and a universal set of gates is smaller than a certain value, called the accuracy threshold. In chapter seven several constructions of bounds for quantum error correcting codes are considered. Eventually, entanglement purification protocols for teleportation through a noisy channel are considered and compared with quantum error correcting codes. Three appendices concern the fundamentals of the theory of(discrete) groups, quantum mechanics, and the circuit model of quantum algorithms. - It shall be stated again that this book is an excellent introduction and representation of the material and can be best recommended. *K.-E. Hellwig (Berlin)*