

Contents

Preface — V

1 Quantum technologies: An overview — 1

- 1.1 Quantum computing — 1
- 1.2 Quantum simulation — 7
- 1.3 Quantum sensors — 10
- 1.4 Quantum communication — 15

2 Physical foundations — 19

- 2.1 Evolution of quantum physics — 19
- 2.2 More recent developments — 22
- 2.3 Atoms and their spectra — 26
- 2.4 Josephson junctions and superconducting qubits — 30
- 2.5 Light and photons — 31

3 Using quantum physics — 37

- 3.1 The double-slit experiment — 37
- 3.2 The basic rules of quantum physics — 38
- 3.3 Anticoincidence experiments with single photons — 48
- 3.4 States and measurements — 52
- 3.5 Time evolution and qubit operations — 60
- 3.6 Observables and measurements — 63
- 3.7 Indeterminacy — 70
- 3.8 Visualization with the Bloch sphere — 74
- 3.9 More complex quantum systems — 76
- 3.10 Decoherence and Schrödinger's cat — 79
- 3.11 The density matrix formalism — 84
- 3.12 The quantum mechanical measurement process — 88
- 3.13 Bell's inequality — 90
- 3.14 Entanglement — 95

4 Quantum sensors — 103

- 4.1 Measuring with NV centers — 103
- 4.2 Interaction-free quantum measurement — 106
- 4.3 Quantum imaging — 108
- 4.4 Interferometry at the quantum limit — 111
- 4.5 Quantum logic spectroscopy — 113

5 Quantum information and communication — 116

- 5.1 Impossible machines — 116

5.2	Quantum cryptography —	121
5.3	Quantum teleportation —	128
5.4	Quantum repeaters and quantum networks —	131
6	Quantum computing and quantum algorithms —	136
6.1	Basic principles of quantum computing —	136
6.2	A simple quantum algorithm: Quantum Penny Flip —	142
6.3	Quantum database search with the Grover algorithm —	147
6.4	Implementing the Grover algorithm with quantum gates —	154
6.5	Quantum Fourier Transform —	164
6.6	Factorization of large numbers: Shor algorithm —	175
6.7	Quantum phase estimation —	184
6.8	Linear systems of equations: the HHL algorithm —	190
6.9	Quantum error correction —	196
6.10	NISQ algorithms —	201
A	Common quantum gates —	205
	Image credits —	207
	Bibliography —	209
	Index —	213