⚛ QUANTUM COMPUTING CHEAT SHEET

Your Quick Reference Guide

Quantonic Legacy Innovations
quantonic.com.au

1. BASIC CONCEPTS

What is Quantum Computing?

Computing using quantum mechanical phenomena (superposition, entanglement) to perform calculations impossible for classical computers.

Key Terms

🎲 Qubit (Quantum Bit)
- → Basic unit of quantum information
- → Can be |0⟩, |1⟩, or superposition
- → Notation: |ψ⟩ = α|0⟩ + β|1⟩

🌀 Superposition
- → Multiple states simultaneously
- → Example: |+⟩ = (|0⟩ + |1⟩)/√2
- → Collapses when measured

🔗 Entanglement
- → Correlation between qubits
- → Measuring one affects the other
- → "Spooky action at a distance"

📏 Measurement
- → Collapses to definite state
- → Probabilistic: $|\alpha|^2 = P(|0\rangle)$
- → Destroys quantum information

⚠ Decoherence
- → Loss of quantum properties
- → Main challenge in QC
- → Requires error correction

3. QUANTUM ALGORITHMS

Deutsch-Jozsa
- → Function: constant or balanced?
- → 1 query vs. 2^(n-1) classical

Grover's Algorithm
- → Unstructured search
- → Speedup: O(√N) vs. O(N)
- → Database search, cryptanalysis

Shor's Algorithm
- → Integer factorization
- → Exponential speedup
- → Breaks RSA cryptography

QFT
- → Quantum Fourier Transform
- → Used in Shor's algorithm
- → Period finding

VQE
- → Variational Quantum Eigensolver
- → Hybrid quantum-classical
- → Chemistry, materials science

5. KEY EQUATIONS

Qubit State

```
|ψ⟩ = α|0⟩ + β|1⟩
where |α|² + |β|² = 1
```

Bloch Sphere

```
|ψ⟩ = cos(θ/2)|0⟩ + e^(iφ)sin(θ/2)|1⟩
θ ∈ [0, π], φ ∈ [0, 2π]
```

Hadamard Gate

```
H|0⟩ = (|0⟩ + |1⟩)/√2
H|1⟩ = (|0⟩ - |1⟩)/√2
```

Measurement Probability

```
P(|0⟩) = |α|²
P(|1⟩) = |β|²
```

Bell State

```
|Φ+⟩ = (|00⟩ + |11⟩)/√2
Cannot be written as |ψ⟩₁ ⊗ |ψ⟩₂
```

2. QUANTUM GATES

Single-Qubit Gates

X Gate (NOT)

- → Flips: |0⟩ ↔ |1⟩
- → Matrix: [0 1; 1 0]

Y Gate (Pauli-Y)

- → Rotation around Y-axis
- → Bit flip + phase flip

Z Gate (Phase)

- → Phase flip: |1⟩ → -|1⟩
- → Leaves |0⟩ unchanged

H Gate (Hadamard) ⭐

- → Creates superposition
- → |0⟩ → |+⟩ = (|0⟩ + |1⟩)/√2
- → Most important gate!

S & T Gates

- → S: 90° phase rotation
- → T: 45° phase rotation

Multi-Qubit Gates

CNOT (Controlled-NOT) ⭐

- → Flips target if control = |1⟩
- → Creates entanglement
- → Essential for circuits

SWAP

- → Exchanges two qubit states

Toffoli (CCNOT)

- → 3-qubit controlled-controlled-NOT
- → Universal for reversible computing

4. QUANTUM PHENOMENA

No-Cloning Theorem

- → Cannot copy unknown quantum state
- → Foundation of quantum cryptography

Quantum Teleportation

- → Transfer state via entanglement
- → Requires classical communication
- → No faster-than-light travel

Bell States

- → Maximally entangled 2-qubit states
- → |Φ±⟩ = (|00⟩ ± |11⟩)/√2
- → |Ψ±⟩ = (|01⟩ ± |10⟩)/√2

Error Correction

- → Protects against decoherence
- → Multiple physical → 1 logical qubit
- → Threshold: error rate < ~1%

6. APPLICATIONS

🧬 Drug Discovery
Molecular simulation, protein folding, catalyst design

🔐 Cryptography
QKD, post-quantum crypto, breaking RSA

📊 Optimization
Routes, portfolios, supply chains

🤖 Machine Learning
Quantum neural networks, SVMs, sampling

⚗ Materials Science
New materials, superconductors, batteries

💰 Finance
Risk analysis, option pricing, fraud detection

7. HARDWARE TYPES

Superconducting Qubits
→ Used by: IBM, Google, Rigetti
→ ✓ Fast gates, scalable
→ ✗ Needs extreme cooling (~20mK)

Trapped Ions
→ Used by: IonQ, Honeywell
→ ✓ High fidelity, long coherence
→ ✗ Slow gates

☆ Photonic Qubits
→ **Used by: Quantonic, Xanadu, PsiQuantum**
→ ✓ Room temperature operation
→ ✓ Easy networking via fiber
→ ✗ Probabilistic gates (solving)

Neutral Atoms
→ Used by: QuEra, Pasqal
→ ✓ Large arrays, reconfigurable
→ ✗ Short coherence times

Topological
→ Used by: Microsoft (in dev)
→ ✓ Inherent error protection
→ ✗ Not yet demonstrated

9. NOTATIONS

Bra-Ket Notation
→ $|\psi\rangle$ = ket (column vector)
→ $\langle\psi|$ = bra (row vector)
→ $\langle\varphi|\psi\rangle$ = inner product
→ $|\psi\rangle\langle\varphi|$ = outer product

Basis States
→ Computational: $|0\rangle$, $|1\rangle$
→ Superposition: $|+\rangle$, $|-\rangle$
→ Circular: $|L\rangle$, $|R\rangle$

Multi-Qubit
→ 2 qubits: $|00\rangle$, $|01\rangle$, $|10\rangle$, $|11\rangle$
→ n qubits: 2^n basis states
→ Tensor product: ⊗

8. QUANTONIC ADVANTAGE

Photonic Quantum Computing

- → ✓ Room temperature (no cryogenics)
- → ✓ Desktop-scale systems
- → ✓ Multi-user educational platform
- → ✓ Naturally low noise
- → ✓ Fiber optic networking
- → ✓ Scalable architecture

Perfect for Education

- → Standard classroom environment
- → Hands-on student access
- → Visual quantum phenomena
- → Real quantum hardware
- → Comprehensive curriculum

📞 Contact

Website: quantonic.com.au
Email: info@quantonic.com.au
Location: Melbourne, VIC, Australia

10. MISCONCEPTIONS

✗ Wrong: Always faster
✓ Right: Faster for specific problems only

✗ Wrong: Infinite information
✓ Right: Limited by measurement

✗ Wrong: Parallel universes
✓ Right: Quantum mechanics

✗ Wrong: Replace classical
✓ Right: Complement them

✗ Wrong: Consumer ready
✓ Right: Early development

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