

**Sun City Summerlin Computer Club  
Seminar**

**Quantum Computing 2026**

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# Agenda

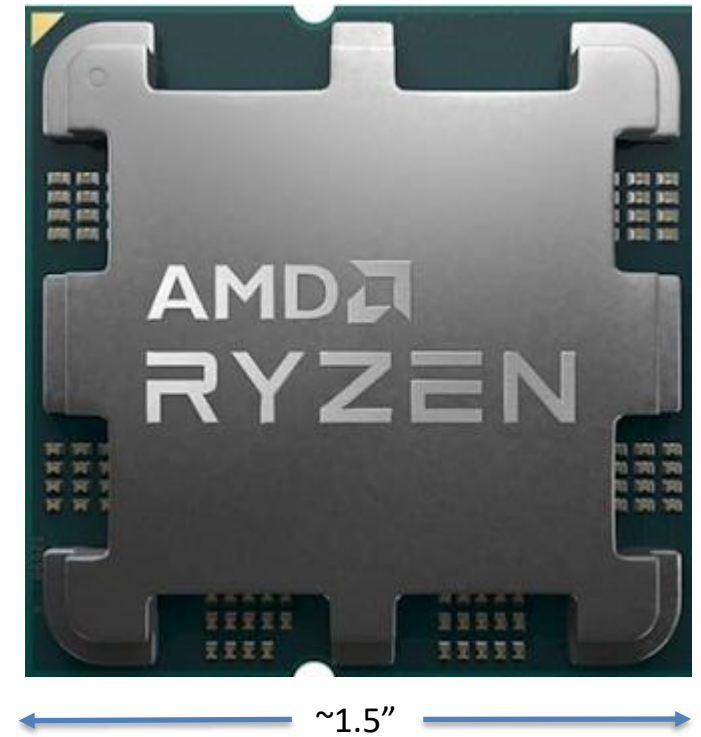
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- **Overview – Quantum Computing**
- **Classical Computers – How They Work**
- **Quantum Computers – How They Work**
- **Stability and Error Correction**
- **Quantum Computers – Cost Factors**
- **Companies Offering Quantum Computing**
- **Quantum Computers – Real World Applications**
  - *Pharmaceuticals & Materials Science*
  - *Financial Models*
  - *Logistics and Supply Chain*
  - *Code Cracking*
- **Future of Quantum Computing & Helpful Links**

# Classical Computers – How They Work

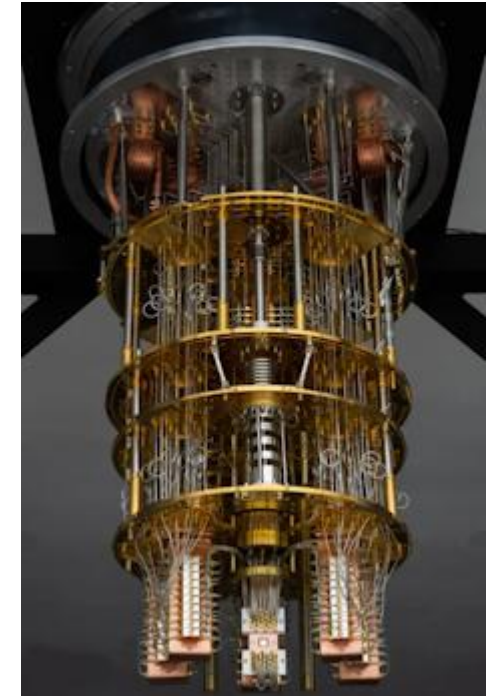
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- Digital CPU has billions of microscopic transistors
  - *Linked together to create logic elements that make up the CPU core(s)*
- CPU logic elements fetch, decode and execute simple instructions that constitute the program
  - *Instructions and data are all stored in dynamic memory accessible to one or more CPU cores.*
- Every logic element is *always* in one of two states: On (1) or Off (0)
  - *Digital computers use binary logic and calculate in base 2*
- Master clock sends pulses to every logic element that causes them to switch to the next state
  - *The master clock pulses up to 5 billion times a second*
- Typical modern processor: AMD Ryzen 7 8700G – 8 CPU cores, 16 concurrent instruction streams, GPU, NPU, 25 billion transistors
  - *Peak execution rate is about 40 billion instructions per second*
  - *Average instruction rate is 5 to 10 billion instructions per second.*
- Compare to Control Data Cyber 70 Super-Computer (circa 1970)
  - *Was rated about 1 million instructions per second*
  - *8 Feet high; took about 32 square feet on a raised floor.*



# Quantum Computers - How They Work

- Uses extremely tiny logic elements called Qubits.
  - Various physical implementations. All require super cooling to near absolute zero
  - IBM and Google use a capacitor and a Josephson junction in parallel to create “transmons”, artificial atoms that have desired quantum properties: Superposition and Entanglement.
- Superposition means a Qubit is simultaneously 0 and 1 and any intermediate values
  - When the value of a Qubit is measured, it collapses to either 0 or 1
- Entanglement means two or more Qubits are linked. Regardless of their distance, when one is measured and collapses to 0 or 1, its entangled partner also instantaneously collapses
- Qubits are controlled by Quantum gates
  - Gates can bias the probabilities a given Qubit will be measured as 1 or 0
  - Gates also act as Boolean logic operators: And, Or, Xor, Not
- As the number, n, of linked Qubits increases, the number of possible states that can be simultaneously represented increases as  $2^n$ 
  - 3 Qubits can represent 8 states, 12 Qubits can represent 4096 states, 16 Qubits can represent 65,536 states
  - Google’s latest Willow Quantum chip has 105 Qubits
- Videos:
  - <https://www.youtube.com/watch?v=Qndz54SGCAs> IBM Quantum System Two
  - [https://www.youtube.com/watch?v=W7ppd\\_RY-UE](https://www.youtube.com/watch?v=W7ppd_RY-UE) Google’s Willow Chip
  - <https://www.youtube.com/watch?v=jHoEjvuPoB8> How Quantum Computers Work



# Stability and Error Correction

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- **Qubits Entanglement and Superposition are very sensitive to external influences:**
  - *EM fields, heat, cosmic rays, random fluctuations of the quantum background field can cause decoherence*
  - *Quantum computers require cooling to near absolute zero*
  - *Quantum computers must operate in heavily shielded rooms*
  - *Coherence times of 100 microseconds are currently considered good*
- **Because Qubits are probabilistic, even when the Qubits and gates are set up correctly, the final measured result may fall on a *low-probability state*, giving an incorrect answer**
- **To detect and correct such errors, quantum chips implement *Logical Qubits* using a collection of physical Qubits**
  - *The value of a Logical Qubit is determined by consensus: taking a majority or super-majority of the measured results of physical Qubits*
  - *A Logical Qubit may be associated with 10 or even 100 physical Qubits*
- **Logical Qubits offer a high probability of attaining a correct or near optimal solution.**
- **Once set up, a problem may be run many times – each run is called a *Shot***
  - *For each run, the measured results are collected*
  - *The collection of results is analyzed statistically to see which are the most frequent*
  - *For some problems (like optimizations), it's enough to get a “good” result.*

# Quantum Computing - Cost Factors

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- **Cooling a Quantum Computer to near absolute zero consumes a lot of power**
- **To “program” the quantum computer requires an expensive, high-performance digital computer**
  - *The problem has to be analyzed*
  - *The precise setup of the Qubits and gates has to be worked out, possibly even simulated*
  - *The physical Qubits and gates then must be properly configured with Superpositions and Entanglements*
  - *The “results” of the shots (runs of the setup) must be measured, saved and tabulated.*
- **Quantum programmers need special training**
  - *New branch of Computer Science – students majoring in Quantum Computing*
- **The industry is finding a hybrid approach often works better:**
  - *A classical digital computer program can invoke a quantum computer to work on parts of a problem that are best solved using quantum methods.*

# Companies Offering Quantum Computing

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- **IBM Quantum – Uses “transmons”; Quantum Network offers QaaS**
- **Google Quantum – Uses “transmons”; Offering QaaS via Google Cloud**
- **Microsoft Azure Quantum – Offers various vendors’ QC via Azure cloud**
- **Amazon Braket – Offers various vendors’ QC via AWS cloud**
- **Nvidia – Offers interfaces to QC via their CUDA AI language**
- **IonQ – QC hardware using “trapped ion” technology**
- **Quantinuum – QC hardware using “trapped ion” technology**
- **Xanadu – QC hardware using “photonic quantum computing” technology**
- **Rigetti Computing – Offering superconducting processors for hybrid QC**
- **D-Wave Quantum – Specialized in optimization solutions using Quantum Annealing**

# Real-World Quantum Applications

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- **Pharmaceuticals:**
  - *Simulating molecular structures and their behavior*
  - *Virtual screening of molecules that might be drug candidates*
  - *Analyzing personal genomes to determine disease risk and best prevention & treatment*
- **Banking & Finance:**
  - *Trading optimization – superior Monte Carlo simulations and portfolio optimization*
  - *Fraud prediction and detection – much faster analysis of many indicators*
  - *Risk Analysis - calculating Value-at-Risk (VaR) more quickly with higher precision*
- **Logistics:**
  - *Real-time fleet routing (post office, material delivery, port logic optimization)*
  - *“Traveling salesman problem” – shortest route or fastest route*
  - *Supply chain management & optimization (manufacturing, retail, military ops, ...)*
  - *Warehouse optimization*
  - *Preventive maintenance prediction by analyzing sensor data (trucking, aircraft, power plants, ...)*

# Cybersecurity – Quantum Code Cracking

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- **[Peter] Shor's Algorithm:**
  - *Theoretically capable of breaking RSA and ECC encryption by factoring public keys into their component prime numbers*
- **The Threat: 'Harvest Now, Decrypt Later' strategies by adversaries**
  - *Record securely encrypted transmissions now in expectation of decrypting them later using Quantum methods*
- **Governments are very concerned**
  - *NIST finalized first set of Post-Quantum Cryptography (PQC) standards*
  - *Migration to lattice-based encryption for crypto-agility*

# The Future of Quantum Computing

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- Quantum Computing is evolving from academic experiments to commercial scale and stability
- There's lots of hype
  - *Viability depends on whether benefits outweigh the massive costs*
- Likely to evolve into a niche specialization
  - *Best suited for specific classes of intractable problems*
- High costs and technological demands mean Quantum Computing as a Service is the likely model
  - *Big providers will own and operate quantum computing servers*
  - *End users will access these servers on a fee-for-service basis*
- Tutorials and research links available for deeper study:
  - [https://en.wikipedia.org/wiki/Quantum\\_computing](https://en.wikipedia.org/wiki/Quantum_computing) *Wikipedia article*
  - <https://www.youtube.com/watch?v=B3U1NDUiwSA> *Quantum Computers Explained*
  - <https://www.youtube.com/watch?v=Kv8N9alyYnc> *Quantum Computers Explained*
  - <https://www.youtube.com/watch?v=Qndz54SGCAs> *IBM Quantum System Two*
  - [https://www.youtube.com/watch?v=vSFv\\_i\\_FAXg](https://www.youtube.com/watch?v=vSFv_i_FAXg) *IBM Quantum Programming Tutorial (part 1 of 4)*
  - <https://www.youtube.com/watch?v=N-9muK0mv5w> *Sabine Hossenfelder – Dissenting view*