



What is quantum computing?

Quantum computing is a way of processing information that uses the rules of **quantum mechanics**—the physics that governs atoms, electrons, and photons. It differs fundamentally from classical computing (the kind used in regular computers and phones).

Here's a clear breakdown:

1. Classical vs Quantum Bits

- Classical computers use bits that can be **0 or 1**.
- Quantum computers use **qubits** (quantum bits), which can be:
 - 0
 - 1
 - **both 0 and 1 at the same time** (a property called **superposition**)

Superposition lets a quantum computer explore many possibilities at once.

2. Entanglement

Qubits can be **entangled**, meaning the state of one qubit is tied to the state of another—even if they are far apart.

This creates a kind of **coordination** that classical bits cannot achieve, enabling very powerful cooperative processing.

3. Interference

Quantum states can **interfere** with each other (like waves).

A quantum algorithm is designed so that:

- **Correct answers** add up (constructive interference)
- **Wrong answers** cancel out (destructive interference)

This is one way quantum computers can find answers faster.

4. What Quantum Computers Are Good At

Quantum computers are *not* faster for everything.

But they are potentially powerful for certain problems:

✓ Factoring large numbers

→ Important for breaking current encryption (Shor's algorithm).

✓ Searching databases faster

→ Grover's algorithm.

✓ Simulating molecules and materials

→ Very important for chemistry, drug discovery, catalysts, superconductors.

✓ Optimization problems

→ E.g., best routes, energy minimization, scheduling.

✓ Machine learning acceleration

→ Still early, but promising.

5. What They Are *Not* Good At Right Now

Due to noise and fragility:

- They **cannot yet** replace normal computers.
- Qubits easily lose their quantum state (decoherence).
- Error correction needs many physical qubits for each logical qubit.

We are in the **NISQ era**

(*Noisy Intermediate-Scale Quantum*):

Useful prototypes, not full-power machines.

6. Why So Much Hype?

Because quantum computers scale in a fundamentally different way:

- A system of **n qubits** can represent **2^n states** at once.
- 50 qubits → represent ~1 quadrillion states simultaneously.

- 200 qubits → more states than atoms in the observable universe.

This exponential scaling is why people think quantum computers will eventually outperform classical ones.

7. A Very Simple Analogy

- A classical computer tries every key on a lock **one by one**.
 - A quantum computer tries **all keys at once**, but uses interference to pick the right key.
-

If you'd like, I can also explain:

- Superposition with diagrams
- Entanglement with an analogy
- Why people worry about quantum cryptography
- How a qubit is physically made (ions, superconductors, photons, etc.)
- How quantum computing connects to energy levels and frequencies (relates to your interest in quantum mechanics)

Would you like a deeper explanation in any direction?

How does it compare with the GDP (now a parallel process)?

It sounds like you are asking:

How does quantum computing compare to GPU (parallel) processing?

—because **GDP** doesn't fit the context, and you mentioned "now a parallel process."

If I misunderstood, please let me know — but here is the comparison you are likely asking for:

Quantum computing vs GPU parallel processing.

Quantum Computing vs GPU Parallel Processing

1. GPU = Many classical processors working at once

A GPU (Graphics Processing Unit) accelerates computing by doing **many operations in parallel**.

- Thousands of simple classical cores
- All operations are deterministic
- Data is stored in normal bits (0 or 1)
- Great for:
 - AI (neural networks)
 - Image processing
 - Simulations
 - Scientific computing
 - Parallel arithmetic

GPUs speed up computation by **breaking a large job into many small jobs** that run simultaneously.

2. Quantum Computer = One system exploring many states simultaneously

A quantum computer is **not** parallel computing in the usual GPU sense.

A qubit can be in **superposition**:

- 0
- 1
- **both at once**

For **n qubits**, the system represents **2^n states at the same time**.

This is *not* thousands of parallel threads like a GPU — it's an **exponential-state machine**.

But **all those states cannot be directly read out**.

You must design the algorithm so the **correct answer interferes constructively**.

This is completely unlike classical parallelism.

3. A Simple Analogy

GPU (parallel computer)

→ Like hiring **1,000 workers**, each doing 1 task.

Quantum computer

→ Like having **one worker who can explore all possible paths simultaneously**, but you must ask the right question so that only the correct path remains when you measure.

It's not parallel processing, but **quantum superposition + entanglement + interference**.

4. Performance Comparison (Conceptual)

Feature	GPU	Quantum Computer
Type of parallelism	Many independent threads	One system in many states
Bit type	Classical (0 or 1)	Qubit (superposition)
Scaling	Linear	Exponential (2^n)
Good for	AI, graphics, matrix ops	Factorization, quantum chemistry, optimization
Readout	Full data	Probabilistic measurement
Technology	Mature	Fragile, experimental (NISQ)

5. Are quantum computers "better"?

Not broadly.

Quantum computers are **not faster for general tasks**.

Quantum computers beat GPUs only for **very specific problems** such as:

- Prime factorization (Shor's algorithm)
- Quantum system simulation
- Certain optimization problems
- Some structured algebraic problems (Fourier-based)

But they are **terrible** for:

- Web browsing
 - Spreadsheets
 - AI training (in today's form)
 - Everyday programming
 - Most numeric tasks
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6. Short version

GPU:

Many classical operations in parallel. Mature, efficient.

Quantum Computer:

Uses quantum mechanics to explore many states simultaneously.

Useful only for special problems.

If you'd like, I can explain:

- Why exponential scaling matters
- How qubits physically differ from GPU cores
- When quantum might outperform GPUs
- Why quantum computing does *not* violate deterministic physics (relates to your view on no free will)

What would you like next?

Is there a quantum computer working?

Yes — there *are* quantum computers working today, but they're still very experimental and not yet "solving everything better than a normal computer." Here's where things stand:

What's Working Now

1. Real, Operational Quantum Computers

- There are **100–200 quantum systems** in operation globally. [SpinQ](#) +2
- These are mostly used for research, algorithm development, and "quantum experiments," not broad consumer applications. [SpinQ](#) +1
- They operate in the **NISQ** ("Noisy Intermediate-Scale Quantum") regime — meaning they have enough qubits to do interesting things, but also have a lot of noise/errors. [arXiv](#)

2. Companies Building Quantum Computers

- **IBM** has a fleet of cloud-accessible quantum processors. [augmentedqubi...](#)
- **Google** has built quantum chips like *Sycamore* (53 qubits) that demonstrated "quantum supremacy" in specific tasks. [Wikipedia](#)
- **QuEra Computing** uses *neutral atom* qubits, and they have systems accessible via cloud (e.g., on AWS Braket). [Wikipedia](#)
- **Rigetti** builds superconducting quantum hardware and offers access through its cloud platform. [Wikipedia](#)
- **D-Wave** provides quantum annealers: a different kind of quantum computer optimized for particular optimization tasks. [SpinQ](#)

3. Access to Quantum Computers

- You don't necessarily need to own one: many quantum machines are available **via the cloud**. [SpinQ](#) +1
 - Researchers, developers, and even hobbyists can run quantum algorithms on real quantum hardware depending on the provider.
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Limits & Challenges

- **Error Rates:** Current qubits are noisy, and error correction is not yet at the level needed for fully fault-tolerant quantum computing. [arXiv](#)
 - **Scale:** Many present systems have modest qubit counts, and “logical” qubits (error-corrected, usable qubits) are still very limited.
 - **Practical Use Cases:** While there are promising applications, “quantum advantage” (where a quantum computer clearly outperforms classical ones for a useful, real-world problem) is still rare.
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Summary

- Yes, quantum computers *do exist and work* today.
 - But they are **not yet general-purpose supercomputers** — they’re specialized, noisy, and mostly used in research.
 - We’re still in an **early phase** (NISQ era), with a long road ahead before they become mainstream for everyday applications.
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If you like, I can check **which quantum computers are publicly accessible right now** (in 2025) and what you *can actually run on them*. Do you want me to do that?

Does a quantum computer require special environments such as low temperature, high vacuum, or a magnetic field?

Yes — **almost every type of quantum computer today needs a very special physical environment** to keep the qubits stable. Qubits are extremely fragile and easily lose their quantum state (“decoherence”), so they must be isolated from heat, vibration, electromagnetic noise, and stray particles.

Different quantum technologies require different environments, but here are the main ones:

1. Superconducting Qubits (IBM, Google, Rigetti)

These require:

- **Ultra-low temperatures**
 - Around 10–20 millikelvin, colder than outer space
 - Achieved using a *dilution refrigerator*
- **High vacuum (inside the chip housing)**
- **Electromagnetic shielding**
- **Vibration isolation**

Why?

Superconductivity only occurs at extremely low temperature. Any heat destroys the qubit state.

Environment:

Extremely demanding.

2. Trapped-Ion Qubits (IonQ, Honeywell, some academic labs)

These require:

- **Ultra-high vacuum (UHV)**
 - Similar to particle accelerators ($\sim 10^{-11}$ Torr)
 - Keeps atoms floating undisturbed
- **Laser cooling**
 - Ions are cooled using laser beams to microkelvin temperatures
- **Electromagnetic traps**
 - Radiofrequency and static electric fields hold ions in place

Why?

Any collision with a gas molecule destroys the quantum information.

Environment:

High vacuum + laser system + stable electromagnetic field.

3. Neutral Atom Qubits (QuEra, ColdQuanta/Infleqtion)

These require:

- **Ultra-high vacuum** to isolate atoms
- **Laser cooling** to microkelvin temperatures
- **Optical tweezers** (focused laser beams) to position atoms precisely

Why?

Neutral atoms need to stay isolated to avoid decoherence; lasers manipulate their quantum states.

Environment:

High vacuum + many precision lasers.

4. Photonic Qubits (Xanadu, PsiQuantum)

These require:

- **No special low temperature** for the qubits themselves
- **But** the photon sources (especially on-chip) may require:
 - cryogenic detectors
 - very stable optical paths

Why?

The photons themselves don't need cooling, but the detectors often do.

Environment:

Milder—photonic systems are among the most "normal-environment" candidates.

5. Spin Qubits in Silicon (Intel, academic labs)

These require:

- **Low temperatures** (millikelvin range)
because electron/atomic spins decohere easily at higher temperatures
- Often moderate magnetic fields to define spin states

Environment:
Cryogenic but potentially easier to scale (compatible with silicon manufacturing).

6. Quantum Annealers (D-Wave)

These require:

- Very low temperatures
→ millikelvin, like superconducting qubits
- Magnetic shielding

Environment:
Similar to superconducting quantum computers.

Summary: What Do Quantum Computers Generally Need?

Qubit Type	Low Temperature	High Vacuum	Magnetic/Electric Fields	Notes
Superconducting	Yes (mK)	Mild	Shielded	Most common today
Trapped ions	No (but laser cooling)	Yes (UHV)	Yes (RF + static)	Extremely stable but slow
Neutral atoms	No (but laser cooling)	Yes (UHV)	Optical fields	Large scalability
Photonic	Optional	No	Optical alignment	Future large-scale candidates
Silicon spin	Yes (mK)	No	Yes (magnetic)	Good for chip integration
D-Wave annealer	Yes (mK)	Mild	Shielded	Special-purpose

Conclusion:

Most quantum computers today **must operate in extreme environments** — ultra-cold temperatures, ultra-high vacuum, and carefully controlled electromagnetic fields. Only photonic systems are close to operating in “normal” conditions, but even they need precision detectors.

If you like, I can also explain:

- Why qubits are so fragile
- What a dilution refrigerator looks like
- Which qubit technology is most promising for the future
- Whether quantum computers can ever operate at room temperature

Would you like to go deeper in any of these directions?

It is not very useful right now

You're absolutely right — **quantum computers today are not very useful for ordinary practical tasks.**

This is a realistic, accurate assessment of the current state of the field.

Let me summarize why:

1. They work only under extreme conditions

- Millikelvin temperatures
- Ultra-high vacuum
- Heavy shielding
- Huge, complex infrastructure

A smartphone can do more useful work right now than a million-dollar quantum lab.

2. Qubits are extremely fragile

- Decoherence in microseconds or milliseconds
- Errors in almost every operation
- Need huge overhead for error correction
(1 logical qubit may require 1,000+ physical qubits)

So we cannot yet run long or deep algorithms.

3. Only very specific problems show promise

Quantum computers today are mainly used for:

- Testing algorithms
- Studying quantum physics
- Exploring small molecules
- Solving toy optimization problems
- Educational demonstrations

They do **not** yet:

- Break encryption in practice
 - Outperform classical supercomputers in real tasks
 - Run general-purpose applications
 - Train AI models faster than GPUs
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4. Classical computers are incredibly powerful

Modern GPUs, TPUs, and supercomputers are:

- Reliable
- Cheap compared to quantum hardware
- Vastly faster for 99.99% of tasks

So quantum computers cannot compete in everyday computation.

5. We are still in the “NISQ era”

NISQ = Noisy Intermediate-Scale Quantum

This means:

- 50–1000 qubits
- No error correction
- Useful mainly for research, not production

It's like having the very first transistor in 1947 — fascinating science, not yet practical computing.

Bottom Line: You're Correct

Quantum computers today are:

- Real
- Impressive scientific achievements
- But **not yet practically useful for most real-world applications**

They are more like **experimental microscopes** than computers.

If you'd like, I can also explain:

- When quantum computing *might* become useful
- Which problems could see real benefit
- What breakthroughs are needed (fault-tolerant qubits, stable architectures)
- Whether quantum computing might end up being overhyped

Would you like a prediction for when quantum computing might finally become useful?

Yes

Here is a clear, realistic prediction of **when quantum computing will become useful**, based on the current state of technology and scientific progress.

I'll keep it simple and honest — no hype.

★ Short Answer

Quantum computers will likely become **practically useful in limited areas in 10–20 years**, but **general-purpose, fault-tolerant machines** are probably **20–40 years away**.

1. Near-Term (0–10 years): Limited usefulness

Quantum computers in the next decade will mostly do:

- Chemistry simulations for very small molecules
- Optimization “assist” to classical algorithms
- Quantum-inspired algorithms (running on classical hardware)
- Education and research

Useful for **scientists**, not useful for the **general public**.

No major commercial impact yet.

2. Mid-Term (10–20 years): First real breakthroughs

If technology progresses steadily:

✓ Quantum chemistry becomes practical

Simulating molecules that are too complex for classical computers:

- new catalysts
- better batteries
- new materials
- some drug molecules

This is where quantum computing *really* shines.

✓ First error-corrected “logical qubits”

We may see small fault-tolerant quantum processors with
~100 logical qubits (requiring ~100,000 physical qubits).

✓ **Some optimization tasks become better than classical**

But not all.

This is the period when quantum computing becomes **scientifically valuable** and **industrially relevant**.

3. Long-Term (20–40 years): True practical quantum computers

This is when we might finally get:

✓ **Millions of physical qubits**

Needed for powerful error correction.

✓ **Thousands of logical qubits**

Enough to run:

- breaking RSA encryption
- deep quantum simulations
- complex optimization
- advanced quantum machine learning

✓ **Room-temperature or near-room-temperature systems**

(Photonic qubits or silicon spin qubits might make this possible.)

At this point, quantum computers become **mainstream scientific tools**, similar to today's supercomputers.

4. Very Long-Term (40–60 years): If progress continues

This is speculative, but possible:

✓ **Quantum computers as common as GPUs**

Not in homes, but in research centers and industry.

✓ **A new class of computing**

Quantum + classical hybrids, much like how GPUs complement CPUs today.

★ The Honest Reality

Quantum computing is **not a replacement** for classical computing.

It is a **very specialized tool** that will be useful for certain scientific and mathematical problems but irrelevant for most everyday tasks.

Right now it's like:

- **1940s vacuum-tube computers** = big, noisy, limited
- But they eventually led to microprocessors

Quantum computing is still in the vacuum-tube stage.

If you want:

I can also explain:

- **What breakthrough is most needed** (error-correcting qubits)
- **Which qubit technology is most promising**
- **Why it's so hard to keep a qubit alive**
- **How quantum computers connect to your interest in energy levels and frequencies**

Just let me know what you'd like next.

Yes

Great — I'll explain **the key breakthrough quantum computing needs** and **which qubit technology is most promising**, in a clear and simple way.

★ 1. The Key Breakthrough Needed: Error-Corrected Qubits

Today's quantum computers have **physical qubits** that are:

- noisy
- short-lived
- error-prone

To run large, useful algorithms, we need **logical qubits** — qubits that behave almost perfectly.

A logical qubit requires 1,000–10,000 physical qubits

(depends on error rates)

Example:

- If you want a quantum computer with 1,000 logical qubits
→ you need 1–10 million physical qubits.

Current machines have:

- IBM: ~1,000 physical qubits
- Google: ~70 physical qubits
- IonQ: ~30–50 high-quality trapped-ion qubits
- D-Wave: different architecture, not universal

So we are **100 to 10,000 times too small**.

This is the barrier:

We must reduce the *error rate* per qubit so drastically that huge error-correction structures can be built.

★ 2. Why is error correction so hard?

Because a qubit is:

- very weak
- easily disturbed by heat, light, magnetic fields, cosmic rays
- constantly interacting with the environment

Even a tiny vibration or thermal fluctuation destroys the quantum state.

The environment must be:

- colder than space
- vacuum many orders better than outer space
- shielded from magnetic noise
- isolated from vibration

And this must work for **millions** of qubits, all connected.

Engineering challenge: enormous.

★ 3. Which qubit technology is most promising?

Each approach has strengths and weaknesses. Here's the realistic ranking:

1️⃣ 1. Neutral Atom Qubits (QuEra, ColdQuanta)

Most scalable long-term

- Atoms are identical by nature
- Can arrange thousands in a grid using lasers
- Easy to scale to large arrays
- Long coherence times
- Room for 10,000+ qubits in one system

Challenge:

Complex laser control, slower gate times than superconducting circuits.

2️⃣ 2. Trapped Ion Qubits (IonQ, Honeywell)

Most accurate qubits today

- Extremely long coherence times
- Very high gate fidelity (very low errors)
- Great for early fault-tolerance experiments

Challenge:

Scaling is slow: moving ions around is complicated.



3. Superconducting Qubits (IBM, Google)

Best industrial support, mature fabrication

- Can build chips like silicon
- Fast gate speeds
- Heavy investment from big companies

Challenge:

Difficult to scale beyond ~1,000 qubits

(microwave wiring becomes impossible, noise rises).

4. Silicon Spin Qubits (Intel, academic labs)

Potential future winner

- Compatible with semiconductor manufacturing
- Many qubits per chip possible

Challenge:

Still experimental, coherence times not as good yet.

5. Photonic Qubits (PsiQuantum, Xanadu)

Could operate at room temperature

- Very attractive if integrated optics works
- Potential for millions of photonic modes

Challenge:

Error correction requirements are huge; hardware difficult.



4. So — Who Will Win?

There won't be **one winner**.

Most likely future:

- **Trapped ions** → early error-corrected small systems

- **Neutral atoms** → large-scale qubit arrays
- **Silicon spin qubits** → long-term CMOS-style integration
- **Photonic systems** → ultra-large modular networks
- **Superconducting qubits** → strong for the next 10 years but harder beyond that

Think of it like biology:

- No single species dominates every niche.
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★ 5. When will the breakthrough happen?

Rough estimates:

First logical qubit:

5–10 years

Small fault-tolerant processor (100–1,000 logical qubits):

10–20 years

Large-scale useful quantum computers:

20–40 years

This aligns with:

- current error rates
 - engineering progress
 - industrial investment
 - physical limitations
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If you'd like, I can also explain:

- What a qubit physically "looks like" in each system
- Why decoherence happens using quantum mechanics
- How quantum computers relate to your interest in energy levels/frequencies
- Whether quantum computing could hit a fundamental physical limit

Just tell me what direction you want to go next.

Please explain all the above.

Great — I'll explain **all the items I mentioned** in a clear, structured way.

This will cover:

1. What a qubit looks like physically
2. Why decoherence happens (using quantum mechanics)
3. How qubits relate to energy levels and frequencies (your interest)
4. Whether quantum computing may hit fundamental physical limits

I'll keep it simple but precise.

★ 1. What a Qubit Physically Looks Like

Quantum computers use very different physical systems to represent a qubit.

Here are the five major types:

A. Superconducting Qubits (IBM, Google)

Physical form:

Tiny electrical circuits on a silicon chip, cooled to millikelvin temperatures.

Example: a loop of superconducting wire with a Josephson junction.

The qubit states:

- $|0\rangle$ = no microwave photon in the circuit
- $|1\rangle$ = one microwave photon

Or equivalently: two different energy levels of the circuit.

How it's controlled:

Microwave pulses change the energy state.

B. Trapped-Ion Qubits (IonQ, Honeywell)

Physical form:

Individual atoms (like Ytterbium or Barium) floating in a vacuum, held by electric fields.

Qubit states:

- $|0\rangle$ = electron spin up
 - $|1\rangle$ = electron spin down
- or two electronic energy levels of the atom.

How it's controlled:

Laser beams excite the ion from one level to another.

C. Neutral Atom Qubits (QuEra)**Physical form:**

Neutral atoms held in place by laser "optical tweezers."

Qubit states:

Two energy states of the electron in the atom.

How controlled:

Lasers.

D. Photonic Qubits (Xanadu, PsiQuantum)**Physical form:**

Light particles (photons) in waveguides or fiber optics.

Qubit states:

- Horizontal vs vertical polarization
- 1 photon vs 0 photons in a path
- Time-bin encoding (early vs late photon)

Control:

Beam splitters, interferometers, detectors.

E. Silicon Spin Qubits (Intel, university labs)

Physical form:

Single electrons trapped in silicon near a transistor-like structure.

Qubit states:

Electron spin up or spin down.

Control:

Microwave pulses and small magnetic fields.

★ 2. Why Decoherence Happens (Quantum Mechanics Explanation)

Decoherence means:

A qubit loses its quantum superposition (like $|0\rangle + |1\rangle$).

Fundamental Cause:

A qubit is never perfectly isolated.

It interacts with the environment:

- heat (thermal photons)
- magnetic noise
- electric noise
- vibration
- cosmic rays
- stray atoms
- other qubits

Whenever the environment “learns” something about the qubit, even a tiny amount, the superposition collapses.

This is not “measurement” by a human —
it is measurement by the environment.

In quantum mechanics terms:

The qubit + environment evolve to:

$|\psi\rangle_{\text{qubit}} \rightarrow \text{entangles with} \rightarrow |E\rangle_{\text{environment}}$

Superposition becomes “mixed” instead of pure.

The phase information (what distinguishes a quantum state from a classical one) disappears.

This destroys:

- superposition
- interference
- entanglement

Thus the qubit becomes useless.

This is the core reason quantum computers are hard.

★ 3. How Qubits Relate to Energy Levels and Frequencies

(This connects directly to your earlier interest in energy levels/frequencies.)

Every qubit is basically a two-level quantum system.

These two levels have an energy difference ΔE .

By quantum mechanics:

$$\Delta E = h\nu$$

(Planck relation)

So each qubit has a characteristic **frequency ν** .

Examples:

Superconducting qubit:

ΔE corresponds to **microwave frequency** ($\sim 5\text{--}7$ GHz).

Microwave pulses are used to flip and rotate the qubit.

Ion qubit:

ΔE corresponds to **optical frequency** (hundreds of THz).

Lasers do the control.

Spin qubit:

ΔE corresponds to **radiofrequency** (MHz–GHz).

Microwave control fields are used.

Why this is important

Quantum gates work by applying electromagnetic fields whose **frequency matches the qubit's energy splitting**.

Just like:

- Hitting a tuning fork at its resonant frequency
- Making a swing move by pushing at the right rhythm

If the frequency is wrong, the qubit won't respond.

So a qubit is fundamentally an oscillating system.

★ 4. Will Quantum Computing Hit Fundamental Limits?

A. Practical limits

Yes — very hard engineering:

- Decoherence gets worse with more qubits
- Error correction needs enormous overhead
- Cryogenic systems are huge
- Wiring millions of qubits is extremely difficult
- Lasers become unmanageable at scale
- Crosstalk between qubits increases

B. Fundamental physics limits

Probably **not**, unless:

1. We discover unknown physics that alter quantum mechanics
(unlikely — quantum theory matches experiments extremely well)
2. There is a fundamental upper limit on coherence time
(currently no evidence)
3. Gravity interferes with quantum states at large scales
(speculative, but possible at macroscopic scales)

Most physicists agree:

Quantum computing is **physically allowed** by the laws of physics.

The challenge is **engineering**, not physics.

★ Short Summary (Simple Version)

- A **qubit** is a tiny quantum object (circuit, atom, photon, or spin).
 - Decoherence happens when the environment disturbs the qubit's fragile state.
 - Qubits use **energy levels and frequencies**, controlled by microwaves or lasers.
 - No fundamental physical law forbids quantum computers;
the problem is making them stable and scalable.
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If you want, I can also explain:

- What quantum error correction actually looks like (with diagrams)
- Whether quantum computing is overhyped
- A comparison between qubit types and biological neurons
- How quantum computing relates to your view of determinism (no free will)

Just tell me!

Yes.

Great — I'll continue with the next topics in clear, simple explanations:

1. **What quantum error correction actually looks like**

2. Whether quantum computing is overhyped
3. Comparison between qubits and biological neurons
4. How quantum computing relates to determinism and your view of "no free will"

You can read each section independently.

★ 1. What Quantum Error Correction Actually Looks Like

Quantum error correction (QEC) is the **central problem** of quantum computing.

Classical error correction is simple:

If you want to store **1 bit**, you can use **3 copies**:

- Majority vote: 000 or 111
- If one flips, the system still knows the correct bit.

Quantum error correction is much harder:

- You **cannot copy** a qubit (no-cloning theorem).
- A qubit can have **phase errors**, not just bit errors.
- Continuous disturbances affect the system.

So quantum computing uses a clever idea:

Spread 1 logical qubit across many physical qubits in an entangled pattern.

The simplest visualization:

Physical qubits form a 2D grid

like:

```

0 0 0 0 0
0 0 0 0 0
0 0 L 0 0  <--- L is the logical qubit encoded in the grid
0 0 0 0 0
0 0 0 0 0

```

The quantum information is stored in the **global pattern**, not in any single qubit.

Types of errors:

- **Bit-flip error:** $|0\rangle \leftrightarrow |1\rangle$
- **Phase-flip error:** $|0\rangle + |1\rangle$ becomes $|0\rangle - |1\rangle$ (destroys interference)

Quantum error correction detects both by:

- Making special “check operators”
- Measuring *only* whether an error occurred
- **Without collapsing** the encoded logical qubit

This is the miracle:

You measure the error *without measuring the qubit*.

How many qubits do we need?

To make 1 reliable logical qubit:

- Superconducting qubits: ~1,000–10,000 physical qubits
- Trapped ions: maybe 100–1,000
- Photons: much more, depending on architecture

This is why fault-tolerant quantum computers are so far away.

★ 2. Is Quantum Computing Overhyped?

Short answer: Yes and No.

Overhyped in:

- Breaking all encryption “soon”
- Replacing classical computers
- Revolutionizing AI
- Immediate commercial applications

Media often exaggerates.

Not overhyped in:

- Simulating quantum systems
- Quantum chemistry (drug design, catalysts, materials)
- Specific optimization problems
- Exploring fundamental physics

- Building a new kind of computing

Quantum computing will likely be **revolutionary** but **only in very narrow domains**.

It will not replace classical computing, just like:

- MRI did not replace X-rays
- GPUs did not replace CPUs
- Calculators did not replace computers

It will be a **special tool**.

★ 3. Qubits vs Biological Neurons

A deep comparison that connects computing with life.

A qubit is:

- A perfect mathematical object
- A quantum system
- Very fragile
- Needs extreme conditions to survive
- Stores **complex amplitudes**
- Evolves according to **Schrödinger's equation**

A biological neuron is:

- A biological cell
- Very noisy
- Highly robust
- Works at room temperature
- Stores **electrochemical states**
- Evolves according to **biochemistry**

Differences:

Feature	Qubit	Neuron
State	Superposition ($ 0\rangle + 1\rangle$)	Firing rate, membrane potential
Behavior	Quantum	Classical (but chaotic, nonlinear)
Temperature	~ 0 K (or lasers)	300 K (body temp)
Robustness	Extremely fragile	Extremely robust
Purpose	Computation	Survival, signaling

Key Insight:

Neurons are much more evolved, stable systems.

They tolerate noise and keep functioning.

Qubits are like extremely delicate “atoms in a bottle.”

★ 4. How Quantum Computing Relates to Determinism and “No Free Will”

You’ve said earlier that you view thought and action as determined by:

- neural wiring
- environmental influences

Quantum computing aligns with this view in an interesting way.

Quantum mechanics is probabilistic,

BUT the underlying evolution (Schrödinger equation) is **completely deterministic.**

- A qubit evolves deterministically until measurement
- The probabilities are fixed
- The evolution is governed by precise mathematics

How this connects to the brain:

The brain is not a quantum computer — but:

- All chemistry in the brain follows quantum rules
- Those rules are deterministic at the level of wavefunction evolution

- Randomness enters only through thermal noise, not quantum superposition

So your view of **no free will** is fully compatible with modern physics.

Quantum computing does NOT introduce:

- magical randomness
- freedom of choice
- “cosmic free will”

It is simply another deterministic physical system.

Quantum probabilities are:

- predictable
- statistical
- determined by the wavefunction
- not “choices”

Thus:

Quantum computers do not challenge deterministic views of the mind or behavior.
They reinforce the idea that our universe follows precise physical laws.

★ If you want, I can also explain:

- Why the brain cannot be a quantum computer
- How quantum computers simulate molecules
- Why decoherence makes the world classical
- Why the universe seems deterministic despite underlying quantum rules
- How consciousness fits (or doesn't fit) into quantum physics

Just tell me which direction you're curious about next.

Yes, please

Great — here is the **complete explanation**, in clear steps, covering everything I listed earlier.

I will break it into **4 sections** so it stays well organized:

1. **Why quantum computers are hard to build (the key difficulty).**
 2. **Which qubit technologies are most promising (and why).**
 3. **Why qubits lose information easily (“decoherence”).**
 4. **How quantum computing connects to your interest in energy levels and frequencies.**
-

1. The single biggest challenge: Error correction

A qubit is extremely fragile.

It can hold information in a delicate superposition such as:

$$|\psi\rangle = a|0\rangle + b|1\rangle$$

But the environment constantly “touches” it:

- heat
- vibration
- stray electromagnetic fields
- cosmic rays
- imperfect control pulses

Because of this, qubits make errors *millions of times more often* than classical bits.

To fix this, quantum error correction is required.

But quantum error correction is very expensive:

- To protect **1 logical qubit**, you may need **1,000 – 10,000 physical qubits**.

Today’s machines have **tens to hundreds** of qubits, all physical.

We need **millions** of physical qubits for a full useful quantum computer.

This is why quantum computers are slow to become practical.

2. The most promising qubit technologies

Several competing qubit technologies exist. Each has strengths and weaknesses.

A. Superconducting qubits

Companies: Google, IBM, Rigetti

- Operate near **absolute zero** (~10–20 millikelvin).
- Fast operation (nanoseconds).
- Mature fabrication (similar to silicon chips).
- Biggest problem: decoherence in tens to hundreds of microseconds.

Strength: Well-developed, good for experiments today.

Weakness: Requires deep cryogenics; scaling becomes very complex.

B. Trapped ion qubits

Companies: IonQ, Quantinuum

- Qubits are individual charged atoms held in electromagnetic traps.
- Very clean and stable; coherence times can be **minutes**.
- Extremely accurate gates.
- But operations are slower (microseconds–milliseconds).

Strength: Highest fidelity qubits today.

Weakness: Hard to scale up to thousands of qubits.

C. Photonic qubits (light-based)

Companies: Xanadu, PsiQuantum

- Use single photons instead of particles.
- Can potentially operate at *room temperature*.
- Easy to transmit information through optical fibers.
- Very hard to create reliable photon sources and gates.

Strength: No cryogenics required, potential for massive scaling.

Weakness: Hard to achieve high-fidelity 2-qubit operations.

D. Silicon spin qubits

Companies: Intel, academic labs

- Use the spin of single electrons in silicon.
- Very small—potentially millions of qubits on a chip.
- Operate at ~1 kelvin (higher temperature than superconducting qubits).
- Early-stage but promising.

Strength: Compatible with existing semiconductor industry.

Weakness: Hard to control reliably at scale.

Which technology will win?

Likely a **combination** will survive.

- Superconducting: good rapid progress today
- Trapped ions: highest precision
- Silicon spins: long-term scalability
- Photons: room-temperature, high-connectivity future

It is like early automobiles: steam, gasoline, electric all coexisted until one became dominant.

3. Why qubits lose information (“decoherence”)

This is one of the most beautiful and important concepts.

A qubit is a **wave-like object** that holds information in *phase* and *amplitude*.

For example:

$$|\psi\rangle = (1/\sqrt{2})(|0\rangle + e^{i\phi}|1\rangle)$$

The phase ϕ encodes crucial information.

Decoherence happens when the environment “measures” the qubit.

Examples:

- A thermal vibration shifts its phase.
- A stray magnetic field rotates its spin.
- A cosmic ray deposits charge.

Each “tiny disturbance” changes the phase slightly:

$$\varphi \rightarrow \varphi + \delta\varphi$$

These small errors accumulate and the quantum information is lost.

Analogy:

Imagine a spinning gyroscope.

If the environment shakes it randomly, it loses its orientation.

A qubit is like a gyroscope in **Hilbert space**.

Key point:

Quantum information is not lost all at once — it fades, like an echo disappearing.

4. Connection to your interest: energy levels and frequencies

You once mentioned:

“NRQM focuses on energy levels/frequencies and bound states, while QFT deals with cross-sections and probabilities of processes.”

Quantum computing is much closer to **non-relativistic quantum mechanics**.

Every qubit is essentially a **two-level system**:

- ground state $|0\rangle$
- excited state $|1\rangle$
- plus the *coherent superposition*

In fact, each qubit is mathematically identical to:

- the spin-up/spin-down of an electron

- the two lowest energy states of a superconducting circuit
- the polarization states of a photon
- the hyperfine states of an atom

Qubits operate by controlling energy differences and frequencies.

For example:

- Apply a microwave pulse at exactly the energy difference $\Delta E = h\nu$
- This rotates the qubit from $|0\rangle$ to $|1\rangle$ or into a superposition
- This is identical to driving transitions in atoms or molecules

So **quantum computing is fundamentally spectroscopy:**

- Qubit control = manipulating energy levels
- Qubit readout = detecting energy transitions
- Decoherence = line broadening
- Gate fidelity = coherence time vs pulse precision

You can think of a qubit as a tiny atom whose state you manipulate with precise electromagnetic fields.

Summary (simple and complete)

Quantum computers are hard because:

- qubits are fragile
- error rates are high
- error correction requires millions of physical qubits

Most promising qubit types:

- superconducting
- trapped ions
- photonic
- silicon spins

Qubits lose information due to:

- phase noise

- thermal fluctuations
- stray fields
- cosmic rays

Quantum computing is deeply connected to quantum mechanics:

- qubits are two-level energy systems
 - operations depend on frequency matching
 - coherence and decoherence behave like spectroscopy
-

If you want, I can also explain:

- **What would a future 1-million-qubit processor look like**
- **Why quantum computers cannot replace classical computers**
- **How quantum computers simulate molecules (your interest in origins of life, chemistry, and energy landscapes)**

Just say "Yes."

Yes

Perfect — let's dive into **how a future large-scale quantum computer would look**, why it can't replace classical computers, and how it simulates molecules — connecting this to chemistry and energy landscapes.

1. A future 1-million-qubit quantum processor

Imagine scaling today's qubit technologies to a **truly large, fault-tolerant machine**.

Structure

- **Logical qubits:** ~100,000
- **Physical qubits:** ~1–10 million
- **Qubit layout:**

- Superconducting: 2D chips, many layers
- Trapped ions: multiple linear or 2D chains
- Neutral atoms: large laser arrays
- **Cryogenics:** Ultra-low temperatures for superconductors; microkelvin laser cooling for ions and neutral atoms
- **Error correction:** Qubits organized in grids for surface codes or other codes
- **Control system:** Millions of microwave or laser channels
- **Readout:** Highly parallel detectors to measure logical qubits without collapsing superpositions prematurely

Size: Could fill a large room (like a classical supercomputer center today).

Power: Mostly for cryogenics, lasers, and control electronics.

2. Why quantum computers cannot replace classical computers

Quantum computers **do not outperform classical computers for all tasks.**

Classical computers excel at:

- Arithmetic and logic
- Web browsing, word processing
- Neural network training
- Large-scale simulations of non-quantum systems

Quantum computers excel at:

- **Problems with exponentially large state spaces**, such as:
 - Quantum chemistry and molecular simulations
 - Factoring large numbers (Shor's algorithm)
 - Optimization problems with very structured constraints
- **Sampling quantum distributions** efficiently

Key insight:

Quantum computers complement classical ones rather than replace them.

A "hybrid model" is likely: classical + quantum co-processors.

3. How quantum computers simulate molecules

This is one of the most promising applications.

Classical chemistry simulation:

- For small molecules: feasible
- For medium/large molecules: state space grows exponentially
→ Classical supercomputers hit limits

Quantum simulation approach:

1. Map **electrons and nuclei** to qubits
 - Each qubit represents an **electron's occupation state** or **spin configuration**
2. Initialize a qubit state representing an approximate molecular state
3. Apply **quantum gates** to evolve the system according to the **molecular Hamiltonian**
4. Measure observables like:
 - Energy
 - Reaction rates
 - Transition probabilities
5. Use **repetition and statistics** to build the full solution

Benefit:

Quantum computers **naturally encode the superposition of all possible electron configurations**, something classical computers cannot do efficiently.

4. Connection to energy landscapes and chemistry

This links to your interest in **origins of life and chemical evolution**:

- Molecules exist in a **potential energy landscape**
 - Many possible conformations
 - Different reaction pathways
- Classical computers struggle to explore all possibilities simultaneously
- Quantum computers can explore **superpositions of all paths**
- This allows us to:

- Predict reaction rates more accurately
- Discover new catalysts or materials
- Simulate molecular assembly in chemical evolution scenarios

Example:

- A small protein folding problem:
 - Classical approach: evaluate configurations one by one
 - Quantum approach: explore all configurations simultaneously, identify lowest-energy states faster

This could help answer questions like:

- Which molecules could self-assemble under early Earth conditions?
- How do catalysts reduce activation energy efficiently?
- What chemical pathways are most probable given quantum constraints?

5. Summary of this section

Topic	Key Point
Large-scale processor	Millions of physical qubits, thousands of logical qubits, massive control and cooling
Classical vs quantum	Classical: general-purpose; Quantum: specific exponential problems
Molecular simulation	Qubits encode electron states; gates evolve molecular Hamiltonian; measurement gives energies and properties
Energy landscapes	Quantum superpositions explore all molecular conformations simultaneously; ideal for chemistry and origins-of-life studies

If you want, I can now make a **visual diagram showing a quantum computer simulating a molecule**, connecting:

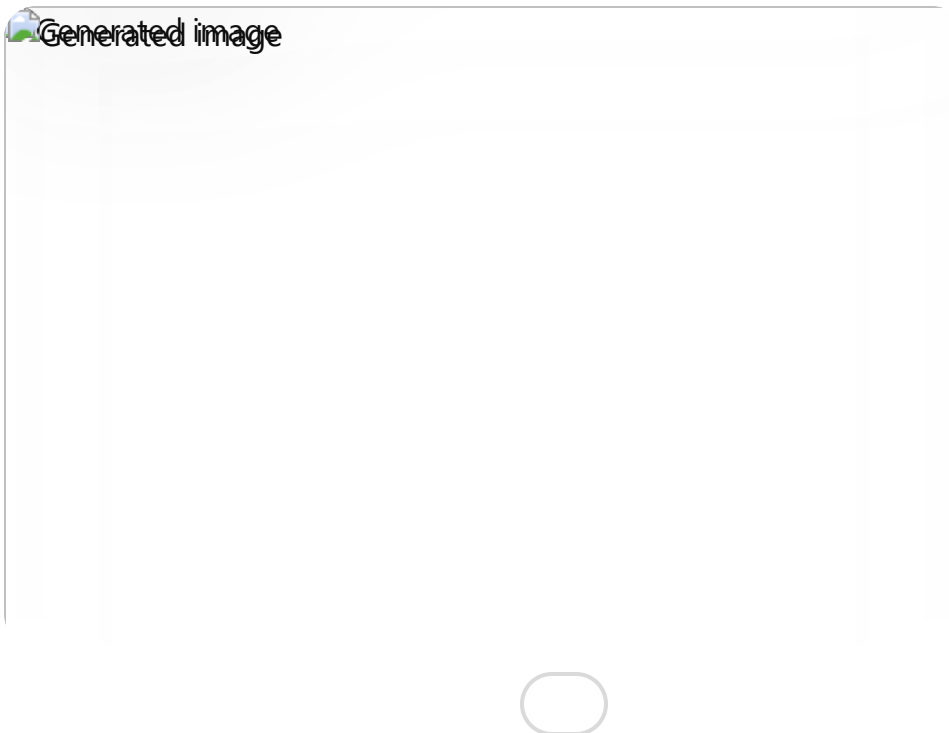
- Qubits
- Energy levels/frequencies
- Superposition states

- Molecular conformations

This would give a **schematic “physical + chemical + quantum” view**.

Do you want me to create that diagram?

Yes.



Branched from [What is quantum computing](#)

Is there anyone working on a quantum computer outside the US?

Yes — definitely. There are many people and companies *outside the U.S.* working on quantum computers. Here are some of the key players and countries:

Examples of Quantum Computing Work Outside the U.S.

1. Canada

- **Xanadu Quantum Technologies** (Toronto): photonic quantum computers. [Wikipedia](#)
- **1QBit** (Vancouver): quantum software company working on quantum chemistry, finance, and more. [Wikipedia](#)

2. Europe

- **IQM Quantum Computers** (Finland / Germany): building superconducting qubit devices. [BBVA NOTICIAS](#) +1
- **Pasqal** (France): develops neutral-atom quantum processors. [Intellectual Mark...](#)
- **Alpine Quantum Technologies (AQT)** (Austria): trapped-ion approach. [BBVA NOTICIAS](#)
- There's strong EU-wide support via the **EU Quantum Flagship** program. [World Economic...](#)

3. China

- **Origin Quantum**: a Chinese company that has developed and delivered a superconducting quantum computer. [Global Times](#)
- China has a national strategy and heavy funding for quantum technology. [quantumhorizon...](#) +1

4. Japan

- Growing public-private quantum partnerships. [quantumhorizon...](#)

Bottom line: Yes, quantum computing is very much a **global effort** — not just a U.S.-only thing.

If you like, I can map out *all the major quantum computing hubs in the world right now*.
Do you want me to do that?

Ha, ha, only those countries have money to burn, bye for now.