# **Quantum Computing: Definition, How It's Used, and Example**

## (https://www.investopedia.com/terms/q/quantum-computing.asp)

## What Is Quantum Computing?

Quantum computing is an area of computer science that uses the principles of quantum theory. Quantum theory explains the behavior of energy and material on the atomic and subatomic levels.

Quantum computing uses subatomic particles, such as electrons or photons. Quantum bits, or qubits, allow these particles to exist in more than one state (i.e., 1 and 0) at the same time.

Theoretically, linked qubits can "exploit the interference between their wave-like quantum states to perform calculations that might otherwise take millions of years."

Classical computers today employ a stream of electrical impulses (1 and 0) in a binary manner to encode information in bits. This restricts their processing ability, compared to quantum computing.

### **KEY TAKEAWAYS**

* Quantum computing uses phenomena in quantum physics to create new ways of computing.
* Quantum computing involves qubits.
* Unlike a normal computer bit, which can be either 0 or 1, a qubit can exist in a multidimensional state.
* The power of quantum computers grows exponentially with more qubits.
* Classical computers that add more bits can increase power only linearly.

## Understanding Quantum Computing

The field of quantum computing emerged in the 1980s. It was discovered that certain computational problems could be tackled more efficiently with quantum algorithms than with their classical counterparts.

Quantum computing has the capability to sift through huge numbers of possibilities and extract potential solutions to complex problems and challenges. Where classical computers store information as bits with either 0s or 1s, quantum computers use qubits. Qubits carry information in a quantum state that engages 0 and 1 in a multidimensional way.

Such massive computing potential and the projected market size for its use have attracted the attention of some of the most prominent companies. These include IBM, Microsoft, Google, D-Waves Systems, Alibaba, Nokia, Intel, Airbus, HP, Toshiba, Mitsubishi, SK Telecom, NEC, Raytheon, Lockheed Martin, Rigetti, Biogen, Volkswagen, and Amgen.

## Uses and Benefits of Quantum Computing

Quantum computing could contribute greatly to the fields of security, [finance](https://www.investopedia.com/terms/f/finance.asp), military affairs and intelligence, drug design and discovery, aerospace designing, utilities (nuclear fusion), polymer design, [machine learning](https://www.investopedia.com/terms/m/machine-learning.asp), artificial intelligence (AI), [Big Data](https://www.investopedia.com/terms/b/big-data.asp) search, and digital manufacturing.

Quantum computers could be used to improve the secure sharing of information. Or to improve radars and their ability to detect missiles and aircraft. Another area where quantum computing is expected to help is the environment and keeping water clean with chemical sensors.

Here are some potential benefits of quantum computing:

* Financial institutions may be able to use quantum computing to design more effective and efficient investment portfolios for retail and institutional clients. They could focus on creating better trading simulators and improve fraud detection.
* The healthcare industry could use quantum computing to develop new drugs and genetically-targeted medical care. It could also power more advanced DNA research.
* For stronger online security, quantum computing can help design better data encryption and ways to use light signals to detect intruders in the system.
* Quantum computing can be used to design more efficient, safer aircraft and traffic planning systems.

*Percentage of large companies planning to create initiatives around quantum computing by 2025, according to research by Gartner.*

## Features of Quantum Computing

Superposition and entanglement are two features of quantum physics on which quantum computing is based. They empower quantum computers to handle operations at speeds exponentially higher than conventional computers and with much less energy consumption.

### **Superposition**

According to IBM, it's what a qubit can do rather than what it is that's remarkable. A qubit places the quantum information that it contains into a state of superposition. This refers to a combination of all possible configurations of the qubit. "Groups of qubits in superposition can create complex, multidimensional computational spaces. Complex problems can be represented in new ways in these spaces."

### **Entanglement**

Entanglement is integral to quantum computing power. Pairs of qubits can be made to become entangled. This means that the two qubits then exist in a single state. In such a state, changing one qubit directly affects the other in a manner that's predictable.

Quantum algorithms are designed to take advantage of this relationship to solve complex problems. While doubling the number of bits in a classical computer doubles its processing power, adding qubits results in an exponential upswing in computing power and ability.

### **Decoherence**

Decoherence occurs when the quantum behavior of qubits decays. The quantum state can be disturbed instantly by vibrations or temperature changes. This can cause qubits to fall out of superposition and cause errors to appear in computing. It's important that qubits be protected from such interference by, for instance, supercooled refrigerators, insulation, and vacuum chambers.

## Limitations of Quantum Computing

Quantum computing offers enormous potential for developments and problem-solving in many industries. However, currently, it has its limitations.

* Decoherence, or decay, can be caused by the slightest disturbance in the qubit environment. This results in the collapse of computations or errors to them. As noted above, a quantum computer must be protected from all external interference during the computing stage.
* Error correction during the computing stage hasn't been perfected. That makes computations potentially unreliable. Since qubits aren't digital bits of data, they can't benefit from conventional error correction solutions used by classical computers.
* Retrieving computational results can corrupt the data. Developments such as a particular database search algorithm that ensures that the act of measurement will cause the quantum state to decohere into the correct answer hold promise.
* Security and quantum cryptography is not yet fully developed.
* A lack of qubits prevents quantum computers from living up to their potential for impactful use. Researchers have yet to produce more than 128.

According to global energy leader Iberdola, "quantum computers must have almost no atmospheric pressure, an ambient temperature close to absolute zero (-273°C) and insulation from the earth's magnetic field to prevent the atoms from moving, colliding with each other, or interacting with the environment."

"In addition, these systems only operate for very short intervals of time, so that the information becomes damaged and cannot be stored, making it even more difficult to recover the data."

## Quantum Computer vs. Classical Computer

Quantum computers have a more basic structure than classical computers. They have no memory or processor. All a quantum computer uses is a set of superconducting qubits.

Quantum computers and classical computers process information differently. A quantum computer uses qubits to run multidimensional quantum algorithms. Their processing power increases exponentially as qubits are added. A classical processor uses bits to operate various programs. Their power increases linearly as more bits are added. Classical computers have much less computing power.

Classical computers are best for everyday tasks and have low error rates. Quantum computers are ideal for a higher level of task, e.g., running simulations, analyzing data (such as for chemical or drug trials), creating energy-efficient batteries. They can also have high error rates.

Classical computers don't need extra-special care. They may use a basic internal fan to keep from overheating. Quantum processors need to be protected from the slightest vibrations and must be kept extremely cold. Super-cooled superfluids must be used for that purpose.

Quantum computers are more expensive and difficult to build than classical computers.

In 2019, Google proved that a quantum computer can solve a problem in minutes, while it would take a classical computer 10,000 years.

## Quantum Computers in Development

### **Google**

Google is spending billions of dollars to build its quantum computer by 2029. The company opened a campus in California called Google AI to help it meet this goal. Once developed, Google could launch a quantum computing service via the cloud.

### **IBM**

IBM plans to have a 1,000-qubit quantum computer in place by 2023. For now, IBM allows access to its machines for those research organizations, universities, and laboratories that are part of its Quantum Network.

### **Microsoft**

Microsoft offers companies access to quantum technology via the Azure Quantum platform.

### **Others**

There’s interest in quantum computing and its technology from financial services firms such as JPMorgan Chase and Visa.

## What Is Quantum Computing in Simplest Terms?

Quantum computing relates to computing made by a quantum computer. Compared to traditional computing done by a classical computer, a quantum computer should be able to store much more information and operate with more efficient algorithms. This translates to solving extremely complex tasks faster.

## How Hard Is It to Build a Quantum Computer?

Building a quantum computer takes a long time and is vastly expensive. Google has been working on building a quantum computer for years and has spent billions of dollars. It expects to have its quantum computer ready by 2029. IBM hopes to have a 1,000-qubit quantum computer in place by 2023.

## How Much Does a Quantum Computer Cost?

A quantum computer cost billions to build. However, China-based Shenzhen SpinQ Technology plans to sell a $5,000 desktop quantum computer to consumers for schools and colleges. Last year, it started selling a quantum computer for $50,000.

## How Fast Is a Quantum Computer?

A quantum computer is many times faster than a classical computer or a supercomputer. Google’s quantum computer in development, Sycamore, is said to have performed a calculation in 200 seconds, compared to the 10,000 years that one of the world’s fastest computers, IBM's Summit, would take to solve it. IBM disputed Google's claim, saying its supercomputer could solve the calculation in 2.5 days. Even so, that's 1,000 times slower than Google's quantum machine.

## The Bottom Line

Quantum computing is very different from classical computing. It uses qubits, which can be 1 or 0 at the same time. Classical computers use bits, which can only be 1 or 0.

As a result, quantum computing is much faster and more powerful. It is expected to be used to solve a variety of extremely complex, worthwhile tasks.

While it has its limitations at this time, it is poised to be put to work by many high-powered companies in myriad industries.