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Basic Functionalities of Quantum Computing

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Abstract
With a wide range of potential uses and ramifications for businesses and markets, quantum computing has the potential to be the next disruptive technology. Superposition and entanglement are two aspects of quantum physics that quantum computers use to encode data and conduct operations on it. Quantum computers are able to answer very precise, difficult problems much more quickly than conventional computers thanks to both of these principles. The hardware, system software, and application layers of a quantum computer are briefly described in this fundamental against this background. We also discuss prospective applications for quantum computing as well as future lines of inquiry for the study of information systems.

Keywords Quantum computing, Quantum physics, Cloud computing, Emerging technology, Information systems

Introduction
With a wide range of potential uses and ramifications Quantum computing has the potential to be the next revolutionary technology for industries and marketplaces. The fields of finance, chemistry, pharmaceuticals, and automobiles would make up the majority of the $1 trillion global market for quantum computing by 2035, according to a recent McKinsey research (Hazan et al., 2020). The largest technology companies in the world today, including Google, IBM, Microsoft, Amazon, and Alibaba, have already made significant investments in the study and development of quantum computing. These companies also provide limited access to these systems to the general public via cloud infrastructures. Governments invest in the industry as well, as seen by China's USD 10 billion investment in a national quantum computing laboratory, the USD $1 billion contribution from the US government, and the USD 1 billion total budget from the EU.

Quantum computers employ entanglement and superposition from quantum physics to represent data and perform operations on it. Quantum computers are able to answer very precise, difficult problems much more quickly than conventional computers thanks to both of these principles. Additionally, interference is crucial, particularly when receiving data from a quantum computer (Aaronson, 2008). Instead of sequentially, quantum computers may simultaneously calculate and test several combinations of hypotheses (S. S. Li et al., 2001). Furthermore, compared to their classical equivalents, some quantum algorithms can solve problems in a lot less steps (their complexity is lower). Due to this, quantum computing may in the next years represent a substantial advancement in contemporary IT and help usher in the "5th industrial revolution" (Hadda & Schinasi Halet, 2019).

The results of the first trials are encouraging, as demonstrated by the experiment conducted by Google in 2019 and in which the corporation asserts to have attained so-called quantum supremacy (IBM "quantum advantage") (Arute et al., 2019). They were able to show through an artificial experiment that a programmable quantum device was capable of solving a problem that a classical computer was unable to do so in a reasonable length of time. The work completed by Google's quantum computer, however, was made specifically for the quantum hardware employed and has no practical uses. However, it served as a crucial proof of concept. Additionally, Chinese researchers claimed to have created a quantum computer in 2020 that is 100 trillion times quicker than the most sophisticated supercomputer in the world at performing specified operations Zhong et al., 2020.

Experts believe that quantum computing, given its current state of development, could offer previously unheard-of benefits, particularly in the fields of simulation, artificial intelligence, and optimization (Langione et al., 2019; Ménard et al., 2020). The first practical uses of quantum computers will probably be molecular simulations for the chemical and pharmaceutical sectors. This is because modelling molecules using quantum computers is the most natural way to do it because molecules directly obey the laws of quantum mechanics. The financial sector, logistics and transportation, the global energy and materials sector, but also fields like meteorology or cybersecurity, could also soon profit (Gerbert & Ruess, 2018; Langione et al., 2019; Ménard et al., 2020). However, there are numerous unresolved problems in physics and computer science related to quantum computing, including issues with hardware architectures, data management, application software, and algorithms. This calls for basic study in all of these fields as well as others (Almudever et al., 2017).

This Fundamental presents the fundamental ideas of quantum computing and illustrates research potential in order to inform information systems (IS) research. As a result, we give a brief overview of the hardware, system software, and application layers that make up a quantum computer system in our second part. Potential areas for using quantum computing are introduced in the third part. 1 We relate to each of these layers by outlining prospective research opportunities in the context of electronic markets, building on these and the previously mentioned conceptual layer view on quantum computing. A completely new ecosystem centred on quantum computing technology is already starting to take shape, raising concerns about (1) the evolution of business models and process innovation, (2) the difficulties facing IT organisations, or (3) the use of start-ups, full-stack vendors like Google, IBM, Microsoft, or Alibaba, as well as individual development.

System for quantum computing Paul Benioff imagined the idea of a quantum touring machine, or the hypothetical notion of a quantum computer, in 1980. (Benioff, 1980). Richard Feynman proposed the efficient modelling of quantum systems as the initial use case for a quantum computer in 1982. (Feynman, 1982). A quantum computer is a general-purpose computing device that transforms information by taking advantage of very special quantum mechanical phenomena. Information is stored in objects called quantum bits (or qubits) (Ding & Chong, 2020). The qubits' various states, such as superposition, interference, and entanglement, are collected by the quantum computer to carry out calculations known as quantum computing (Grumbling & Horowitz, 2019). The fact that quantum computers are not intended to work independently as general-purpose computers should not be overlooked. They will be incredibly specialised instruments that are far faster than traditional computing at doing specific tasks. For loading input/output data, retrieving calculation results, and managing the electronic and internal operations of the quantum computer, operating quantum computers will undoubtedly require a classical computer.

In order to do quantum computation, a quantum computing system made up of both classical and quantum computers is necessary. We choose the model proposed by Ding and Chong (2020) to represent the many layers of a quantum computing system for three reasons. First, it enables us to analytically separate the primary constituents of a quantum component system in order to clarify the basic principles and elements. The distinction between hardware, system software, and applications is based on analytics, and in modern perspectives of computing architectures, such as cloud computing (infrastructure as a service, platform as a service, and software as a service) or the

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layered modular architecture of digital technologies, reflect this (Yoo et al., 2010). Third, when describing the state of the art, the difficulties facing modern organisations, and the operation of quantum computing systems, our expert informants made distinctions between related layers as well. Figure 1 depicts a quantum computing system that combines a classical van Neumann computing architecture with a quantum computer with its three-layer architecture.

Superconductors conduct electric current without resistance or energy dissipation. Their uses range from powerful electromagnets for particle accelerators and medical MRI devices to ultrasensitive magnetic sensors to quantum computers. Superconductivity is a spectacular display of quantum mechanics in action on a macroscopic scale. It all comes down to the electrons. When the repulsion between electrons is strong, however, they pair up in higher angular momentum states so that they can't get too close, resulting in, for example, a d-wave superconductor. This is the case with materials made from copper and oxygen (cuprates) and it plays a starring role in the Nature Physics research and its future potential. . Think of it as nine silicon atoms in a single layer, with three tin atoms—placed farther apart—stacked in another layer on top. The system is engineered such that the repulsion between the tin electrons is so strong that they can't move and won't superconduct.

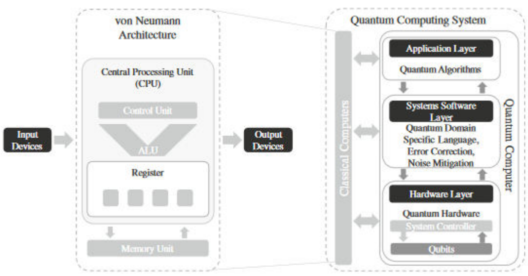

Fig. 1 Depicting a quantum computing system made out of a conventional computer (with a von Neumann architecture; taken from Ding and Chong (2020))

Hardware layer

How information is stored on conventional and quantum computers differs fundamentally. In contrast to classical computers, which utilise bits to store information, quantum computers use quantum bits (or qubits), which may concurrently hold any linear combination of zero and one (Steane, 1998). Qubits take advantage of quantum mechanics' benefits, particularly the influence of superposition.

Superposition In a broad sense, a qubit's probability of being either zero or one, rather than its specific value of zero or one, describes it. So a qubit may be 60% zero and 40% one with equal chance. Importantly, the qubit only "collapses" to the single classical specified value of either zero or one at the point of measuring its state (Bosch, 2020; Ding & Chong, 2020). A quantum computer with only four qubits may represent 16 four-digit numerals simultaneously thanks to the superposition characteristic. A classical computer can only represent a single four-digit number using a sequence of four bits, whereas the number of representable states doubles with each additional qubit. The ability to execute an exponential number of calculations at once is the true benefit of quantum computing. Although only one calculation's answer can be read at the end of every programme, it is feasible to create a quantum algorithm that increases the likelihood that the outcome will be the one you are looking for. For instance, we might be looking for any turbulence that might occasionally occur and cause a plane to crash. We could simply test nearly all potential read aloud only the outcome that leads the plane to crash under all the current air conditions on a quantum computer, saving us from having to simulate billions of permutations of air conditions on a conventional computer and examine their individual outcomes.

Entanglement The only thing specific to quantum computing is qubits. Another characteristic of quantum mechanics is entanglement. When one qubit's state is influenced by the state of another qubit, this is known as entanglement (Steane, 1998). As a result, each flip or rotation of

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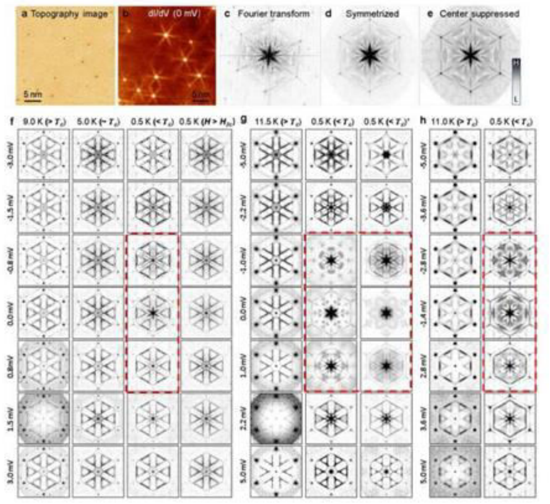
one of two entangled qubits would cause the other qubit to undergo the identical change (Einstein et al., 1935; Schrödinger, 1935). The state of both qubits collapses to either one or zero when either of the two qubits' states is measured (depending on their probabilities).

Even when the qubits are far off from one another, this is the case. The benefit of entanglement is that when one qubit affects those around it, they all work together to find a solution. Qubits can therefore be coupled in a way that standard computer bits cannot. This creates new opportunities and enables the quantum computer to process data in a way that is fundamentally different from a classical computer (Mooney et al., 2019). One such instance is superdense coding, which involves employing one entangled qubit to carry two conventional bits of information (A. Harrow et al., 2004). For secure quantum key distribution, this procedure is particularly intriguing (Bennett & Brassard, 2014). Using quantum entanglement and other quantum phenomena, this secure communication technique implements a cryptographic system. In order to encrypt and decrypt messages, it allows two parties to create a shared random secret key (entangled qubit) that is only known to them (Scarani et al., 2009).

The methods for physically representing and manipulating qubits are now discussed in light of the principles of quantum physics. The methods can be broadly divided into two groups: a) analogue quantum computing and b) digital gate-based quantum computing (Ding & Chong, 2020).



Results of an experimental QPI. Data and processing methods for the QPI (a–e). an STM image of a (3-3-)-Sn surface (p = 0.1) with many surface flaws visible as black spots (Vs = 0.1 V, It = 0.1 nA). b) The associated dI/dV image at T = 0.5 K. The dazzling, star-like characteristics in panel an are concentrated where the flaws exist. c) A symmetrical and rotated version of the power spectrum from panel b. In order to emphasise the high frequency features, the middle region is then suppressed, as seen in panel e. For p=0.1, 0.08, and 0.06, respectively, f–h show 4, 3, and 2 sets of QPI findings produced from (3–3–Sn) surfaces. As seen on the left, each column displays QPI images that were acquired in a fixed spatial region but with various biases. Data are displayed for temperatures above and below Tc, with measurement temperatures listed above each column. Only when the sample is in a superconducting condition and the measurement bias is within the superconducting gap (between 1.5 mV, 2.2 mV, and 3.6 mV in f, g, and h, respectively) do the centre flower leaves appear. The dashed red rectangles contain these QPI photos. The QPI results are displayed in Panel f at either T=5 K (which is somewhat higher than Tc=4.7 K for this sample) or at 0.5 K in an 8 T B-field (H2c=3 T). The considerably diminished flower leaf characteristic in this data could be due to superconducting variations. The "0.5 K (c)" data in panel g are QPI results from a sample that had interstitial Sn adatoms and was deposited at 120 K. The flower-leaf features in the Brillouin zone's core are significantly improved by the presence of interstitial Sn. Image source: Nature Physics (2023). DOI: 10.1038/s41567-022-01889-1.

The University of Tennessee's physicists have led a scientific team that found silicon—a mainstay of the soon-to-be trillion-dollar electronics industry—can host a novel form of superconductivity that could bring rapidly emerging quantum technologies closer to industrial scale production.

The findings are reported in Nature Physics and involve electron theft, time reversal, and a little electronic ambidexterity.

Couples on the superconducting dance floor

Superconductors conduct electric current without resistance or energy dissipation. Their uses range from powerful electromagnets for particle accelerators and medical MRI devices to ultrasensitive magnetic sensors to quantum computers. Superconductivity is a spectacular display of quantum mechanics in action on a macroscopic scale. It all comes down to the electrons.

Electrons are negatively charged and repel each other in a vacuum. However, in a solid-state medium—the realm of metals and semiconductors—there are roughly 1023 other electrons and positive ions that complicate the picture enormously. In a superconductor, conduction electrons overcome their mutual repulsion and become attracted to each other through interactions with the other particles. This interaction causes them to pair up like dancers at a ball, forming composite particles, or "Cooper pairs" (so named for Nobel laureate Leon Cooper).

Typically, the "glue" causing this pairing comes from the atom vibrations in a metal, but only if the electrons don't repel each other too strongly. The process is somewhat like two people (the electrons) on a soft mattress (the medium) that roll toward one another when the mattress is compressed in the center. The laws of quantum mechanics dictate that Cooper pairs (unlike single electrons) can all condense into a single coherent quantum state, where they move in lockstep. The condensate exhibits a rigidity as a result, allowing current to flow without interruption or dissipation; in other words: to superconduct. This mechanism leads to conventional (s-wave) superconductors such as aluminum, tin, or lead.

When the repulsion between electrons is strong, however, they pair up in higher angular momentum states so that they can't get too close, resulting in, for example, a d-wave superconductor. This is the case with materials made from copper and oxygen (cuprates) and it plays a starring role in the Nature Physics research and its future potential.

Stealing Electrons

In this work, Professor Hanno Weitering and Associate Professor Steve Johnston and their colleagues in the U.S., Spain, and China replicated cuprate-like physics by growing one-third of a monolayer of tin atoms on a substrate (base layer) of silicon. Think of it as nine silicon atoms in a single layer, with three tin atoms—placed farther apart—stacked in another layer on top. The system is engineered such that the repulsion between the tin electrons is so strong that they can't move and won't superconduct.

Weitering, Johnston, and their colleagues found a clever workaround by implanting boron atoms in the silicon layer's diamond-like crystal structure. The boron atoms proceeded to steal electrons from the tin layer (typically about 10 percent) in a process similar to techniques perfected by the semiconductor industry. This gave the remaining tin electrons the freedom to move about. The tin layer thus became metallic and even superconducting at a critical temperature exceeding that of nearly all elemental superconductors. Importantly, the phenomenon also scaled with the number of boron atoms or stolen electrons, behavior reminiscent of the cuprate superconductors.

Reversing Time and Quantum Computing Applications

While electron theft-based superconductivity is interesting in its own right, the research team found even more intriguing physics suggesting this tin-silicon material hosts chiral superconductivity. This highly exotic state of matter is heavily pursued, in part because of its potential for quantum computing.

In chiral systems, clockwise and counter clockwise rotations are the same and yet different—like how left and right hands are mirror images of each other that can't be superimposed. In quantum mechanics, the properties of single or paired electrons are encoded in a mathematical wave function that can be left-handed, right-handed, or "topologically trivial."

superconducting wavefunction in the tin layer turns out to be clockwise in parts of the sample and counter clockwise in other parts. If one were to rewind the clock, the clockwise wave function would become counter clockwise and vice-versa, but these two wave functions are still different, just like the left hand and right hand are different; as a physicist would say, time-reversal symmetry is broken.
Time-reversal symmetry breaking is a hallmark of chiral superconductivity. Another is that the system has two one-dimensional conduction channels that run like railroad tracks along the perimeter of the sample material. These channels host exotic particle-like entities where under certain conditions the particle and its antiparticle become indistinguishable. Majorana particles are topologically protected, impervious to what's going on in the environment around them. They've been envisioned as building blocks of future quantum computers, a rapidly emerging technology that could help solve problems too complex for classical computers. The use of Majorana particles implies a safeguard against decoherence, a critical requirement for quantum computation to succeed.

Taken together, the Nature Physics results suggest the possibility of integrating exotic properties with an easily scalable silicon-based materials platform. As such, this would bring futuristic quantum technologies closer to industrial scale production.

Quantum analogue computing In analogue quantum computing, the quantum state is gradually altered by quantum operations, resulting in information that is encoded in the final system that most likely corresponds to the intended result. Adiabatic quantum computers (Albash & Lidar, 2018), which allude to the concept of developing a kind of universal quantum computing, are an illustration of analogue quantum computing. Quantum annealing is a particular type of adiabatic quantum computing that uses a framework of algorithms and hardware to solve computation problems through quantum evolution towards the ground states (Vinci & Lidar, 2017).

The fact that physical systems attempt to reach the state with the lowest energy—for instance, heated objects cool off over time or objects roll downhill—is exploited by quantum annealing. Thus, the energetically optimal state in quantum annealing corresponds to the answer to the optimization problem (Albash & Lidar, 2018). The quantum annealer, in contrast to classical computers, is able to calculate all potential solutions simultaneously by taking advantage of the principle of superposition (Shin et al., 2014). Companies like D Wave use quantum annealing, which is best suited for optimization issues or probabilistic sampling. Albash and Lidar state that it is still unknown whether the quantum annealing process would ever result in a meaningful quantum speedup.

Quantum computing using digital gates In digital gate-based quantum computing, digital gates are used to modify the data encoded in qubits. In digital gate based quantum computers, the evolution of the quantum states is controlled and managed in terms of activity, as opposed to the analogue approach, in which you sample the spontaneous evolution of quantum states to identify the best state of low energy (Ding & Chong, 2020). In contrast to quantum annealing, the state of qubits is actively changed, giving it the benefit of being much more flexible and allowing it to be utilised to address a wide range of issues. Conceptually, quantum computing using digital gates is extremely similar to classical computation (Grumbling & Horowitz, 2019). On a computer, a traditional algorithm is executed as a set of instructions (gates such as AND, OR, NOT, ...). According to a set of rules, they manipulate single or pairs of classical bits by flipping them between the zero and one states. By rotating and shifting them between various superpositions of the zero and one states as well as various entangled states, quantum gates can directly manipulate one or more qubits. Examples of businesses adopting digital gate-based quantum computing include IBM, Google, and Rigetti.

A issue for IT companies and IT service providers is quantum computing. With the use of commercial IT services, business units are progressively developing their IT capabilities without consulting the IT department. This transformation is accelerated by quantum computing, as most businesses are likely to only have access to the first quantum computers through the cloud for the next few decades (Carrel Billiard et al., 2021). IT departments are therefore under pressure to govern the use of quantum computers in businesses, particularly with regard to transmitting the relevant data required for calculations based on quantum computing.

This is especially intriguing because, in the long term, data preparation, including data input and output, might be the bottleneck for quantum computing. Additionally, the danger to current encryption standards posed by quantum computing, particularly its capacity to prime factorise, presents enormous difficulties for the IT organisation. Even while previous data and communications can be decrypted backwards, new encryption methods can be deployed once quantum computers pose a serious threat to current encryption standards.

The following future research inquiries might be considered: What security measures may be taken to safeguard legacy IT using outdated encryption standards? Can real-time threat and anomaly detection be performed with AI and quantum computers? How can risk-cost analyses be performed using quantum computers to model potential incursions and cyberattacks? Due to the hyper connectivity of digital services, which creates a significant vulnerability for an infrastructure assault, the latter is particularly interesting.

Talents in quantum computing Information systems have traditionally served as a link between informatics and business. This job is becoming much more crucial in the era of quantum computing. At least three roles are necessary to fully utilise the promise of quantum computing (Carrel Billiard et al., 2021; Hughes et al., 2022): In order to transform difficulties into mathematical formulas, one must first possess mathematical and quantum physical skills.

In order to incorporate the business challenge within the mathematical framework, domain expertise is also required. Third, a bridge between the two roles must be created via an intermediate (Gartner, 2019). The entrance barrier to the field of quantum computing is substantially greater than for conventional "coding" due to the high complexity and high specialisation of the job kinds (e.g., error correction specialist, quantum algorithm creator). A lack of STEM (Science, Technology, Engineering, and Mathematics) graduates has also existed for some time, which may intensify the competition for expertise in quantum computing (OECD, 2021). However, businesses like IBM, Google, or academic institutes like ETH are working to create programming languages and compilers in which a device will determine whether an application is appropriate for a quantum computer. Experts say that this will take years, though. The following future research inquiries might be considered: What kind of mediating role may information systems play in the adoption of quantum computing technologies? Should the information systems curriculum cover quantum computing? How can future information systems administrators be prepared to understand the potential of quantum computing, given how crucial quantum computing expertise is from a strategic standpoint? How can management make the most of the promise of the quantum computing platforms, methods, and methodologies currently in use? How can infrastructure access and knowledge gaps be minimised?

Foundational knowledge and representation of digital systems as a basis for quantum computing application cases and ecosystems A basic requirement for the widespread use of quantum computing as a generative technology for calculations with enormous speedups is that the problem that a quantum computing approach will attempt to solve must be replicated in the form of digital data, on which basis a calculation becomes possible in the first place. The enterprises of today are already being challenged by emerging technologies like machine learning. The fundamental issue is that it is difficult to analyse company processes and economic behaviour when they are represented digitally. Datafication is one way to describe this phenomenon (Lycett, 2013). Therefore, a necessary prerequisite is the dematerialization of the physical world into digital data as a representation (Recker et al., 2021). One can only utilise quantum computing to calculate the physical world based on its datafied digital representation if this condition is met.

To assess, comprehend, and appreciate the usefulness of quantum computing in comparison to other computing philosophies, it is necessary to achieve a sufficient digital representation of the relevant quantum computing problem (e.g., high performance computing). Additionally, quantum computing might also be a catalyst for process innovation. For instance, it might be intriguing for process mining-related research fields, like analysing and optimising process configurations or simulating contexts for processes or configurations for processes (Mendling et al., 2020). (vom Brocke et al., 2021). While electron theft-based superconductivity is interesting in its own right, the research team found even more intriguing physics suggesting this tin-silicon material hosts chiral superconductivity. This highly exotic state of matter is heavily pursued, in part because of its potential for quantum computing.

Research on use case analysis, and in particular methods for finding, describing, and analysing use cases in a systematic and comprehensive way, is therefore of utmost importance. The following could be potential study questions: What methods might be used or created to examine business issues and so make use of quantum computing's potential? How may these issues be mathematically described? What design tenets could be used to describe use cases in artefacts? How would QC affect the transition from binary to multidimensional quantum states in the modelling of a social and economic reality. The superconducting wave function in the tin layer turns out to be clockwise in parts of the sample and counter clockwise in other parts. If one were to rewind the clock, the clockwise wave function would become counter clockwise and vice-versa, but these two wave functions are still different, just like the left hand and right hand are different; as a physicist would say, time-reversal symmetry is broken.

Conclusion

We give an overview of the key ideas underlying quantum computing in this Fundamentals essay. The hardware, system software, and application layers of a quantum computer are briefly described in this fundamental against this background. We suggest many key areas for researching the socio-technical consequences of quantum computing for the establishment of new ecosystems or their extensions as well as for ecosystem participants themselves based on this information and our access to top specialists in quantum computing.

The disruptive nature of quantum computing will cause numerous changes in all socio-technical organisational components as well as in ecosystems associated to IS. As a result, we anticipate a significant impact on the IS discipline in research, practise, and instruction. Nevertheless, we are conscious that quantum computing is still in its infancy, both as a subject of study for IS research and in terms of its growth into a recognised and well-recognized computing approach. In light of this, our goal is to provide guidance and inspiration for research on the critical role of data as well as the socio-technical peculiarities of quantum computing at the ecosystem level or level of electronic markets (for example, quantum computing ecosystems as a new networked business), the organisational level (for example, the role of IT organisations and service provider for establishing quantum computing), the individual level (for example, quantum computing skills), and the ecosystem level or level of electronic markets (for example, quantum computing ecosystems as a new networked business) (i.e., digital understanding).

Time-reversal symmetry breaking is a hallmark of chiral superconductivity. Another is that the system has two one-dimensional conduction channels that run like railroad tracks along the perimeter of the sample material. These channels host exotic particle-like entities where under certain conditions the particle and its antiparticle become indistinguishable. Majorana particles are topologically protected, impervious to what's going on in the environment around them. They've been envisioned as building blocks of future quantum computers, a rapidly emerging technology that could help solve problems too complex for classical computers. The use of Majorana particles implies a safeguard against decoherence, a critical requirement for quantum computation to succeed.

References

1. Aaronson, S. (2008). THE LIMITS OF Quantum. Scientific American, 298(3), 62–69. http://www.jstor.org/stable/26000518. Accessed 3 June 2021
2. Albash, T., & Lidar, D. A. (2018). Adiabatic quantum computation. Reviews of Modern Physics, 90(1), 015002-1-0150026–4.
3. https://doi.org/10.1103/RevModPhys.90.015002
4. Almudever, C. G., Lao, L., Fu, X., Khammassi, N., Ashraf, I., Iorga, D., Varsamopoulos, S., Eichler, C., Wallraff, A., Geck, L., Kruth, A., Knoch, J., Bluhm, H., & Bertels, K. (2017). The engineering challenges in quantum computing, Design, Automation & Test in Europe Conference & Exhibition (DATE), 2017, 836–845. https://doi.org/10.23919/DATE.2017.7927104
5. Arute, F., Arya, K., Babbush, R., Bacon, D., Bardin, J. C., Barends, R., Biswas, R., Boixo, S., Brandao, F. G. S. L., Buell, D. A., Burkett, B., Chen, Y., Chen, Z., Chiaro, B., Collins, R., Courtney, W., Dunsworth, A., Farhi, E., Foxen, B., & Martinis, J. M. (2019).
6. Benioff, P. (1980). The computer as a physical system: A microscopic quantum mechanical Hamiltonian model of computers as represented by Turing machines. Journal of Statistical Physics, 22(5), 563–591. https://doi.org/10.1007/BF01011339
7. Bennett, C. H., & Brassard, G. (2014). Quantum cryptography: Public key distribution and coin tossing. Theoretical Computer Science, 560, 7–11. https://doi.org/10.1016/j.tcs.2014.05.025
8. Boehringer-Ingelheim. (2021). Partnership in quantum computing for Pharma R&D | Press.
9. https://www.boehringer-ingelheim.com/press-release/partnering-google-quantum-computing. Accessed 3 June 2021
10. Bosch, S. (2020). Quantum algorithms for linear algebra and optimization [Master Thesis, École polytechnique fédérale de Lausanne]. Library catalog. https://www.academia.edu/43923193/Quantum Algor ithms_ for_ Linear_ Algebra_ and_ Optim izati on? source=swp_share. Accessed 3 June 2021
11. Braun, M. C., Decker, T., Hegemann, N., Kerstan, S. F., & Schäfer, C. (2021). A quantum algorithm for the sensitivity analysis of business risks. http://arxiv.org/pdf/2103.05475v1. Accessed 3 June 2021
12. Budde, F., & Volz, D. (2019). The next big thing? Quantum computing's potential impact on chemicals. https://www.mckinsey.com/ industries/chemicals/our-insights/the-next-big-thing-quantumcomputings-potential-impact-on-chemicals. Accessed 3 June 2021
13. Carrel-Billiard, M., Treat, D., Dukatz, C., & Ramesh, S. (2021). Accenture get ready for the quantum

impact. https://www.accenture. Com /_acnmedia /PDF-144 / Accenture-Get-Ready-for-the-Quantum -Impact.pdf. Accessed 3 June 2021

14. Chakrabarti, S., Krishnakumar, R., Mazzola, G., Stamatopoulos, N., Woerner, S., & Zeng, W. J. (2021). A threshold for quantum advantage in derivative pricing. Quantum, 5, 463–504. https:// doi.org/10.22331/q-2021-06-01-463
15. Ciliberto, C., Herbster, M., Ialongo, A. D., Pontil, M., Rocchetto, A., Severini, S., & Wossnig, L. (2018). Quantum machine learning: A classical perspective. Proceedings Mathematical, Physical, and Engineering Sciences, 474(2209), 20170551. https:// doi. org/10.1098/rspa.2017.0551
16. DeBenedictis, E. P. (2018). A future with quantum machine learning. Computer, 51(2), 68–71. https://doi.org/10.1109/MC.2018. 1451646
17. Dendukuri, A., & Luu, K. (2018). Image processing in quantum computers. http://arxiv.org/pdf/1812.11042v3. Accessed 3 June 2021
18. Ding, Y., & Chong, F. T. (2020). Quantum computer systems: Research for noisy intermediate-scale quantum computers. Synthesis lectures on computer architecture. Morgan & Clay-pool.
19. https://doi.org/10.2200/S01014E D1V01Y202005CAC051
20. Egger, D. J., Gambella, C., Marecek, J., McFaddin, S., Mevissen, M., Raymond, R., Simonetto, A., Woerner, S., & Yndurain, E. (2020). Quantum computing for finance: State-of-the-art and future prospects. IEEE Transactions on Quantum Engineering, 1, 1–24. https://doi.org/10.1109/TQE.2020.30 30314
21. Einstein, A., Podolsky, B., & Rosen, N. (1935). Can quantum mechanical description of physical reality be considered complete? Physical Review, 47(10), 777–780. https:// doi. org/ 10.1103/PhysRev.47.777
22. Feynman, R. P. (1982). Simulating physics with computers. International Journal of Theoretical Physics, 21(6–7), 467–488.https://doi.org/10.1007/BF02650 179
23. Gambetta, J. (2020). IBM's Roadmap for scaling quantum technology. https://www.ibm.com/blogs/research /2020/09/ibm-quantum-roadmap/. Accessed 3 June 2021
24. Gao, X., Zhang, Z.-Y., & Duan, L.-M. (2018). A quantum machine learning algorithm based on generative models. Science Advances, 4(12), eaat9004. https:// doi. org/ 10. 1126/ sciadv. aat9004
25. Gartner. (2019). The CIO's guide to quantum computing. https:// www. gartn er. com/ smart erwit hgart ner/ the- cios- guide- to- quant um-computing. Accessed 3 June 2021
26. Gerbert, P., & Ruess, F. (2018). The next decade in quantum computing and how to play. https://www.bcg.com/publications/2018/ next- decade- quant um- compu ting- how- play. Accessed 3 June 2021
27. Grover, L. K. (1996). A fast quantum mechanical algorithm for database search. In Proceedings of the twenty-eighth annual ACM symposium on Theory of Computing, pp. 212–219. https://doi.org/10.1145/237814.2378 66
28. Grumbling, E., & Horowitz, M. (2019). Quantum computing: Progress and prospects (2019). National Academies Press. https://doi.org/10.17226/25196
29. Hadda, M., & Schinasi-Halet, G. (2019). Quantum computing: A technology of the future already present. https://www.pwc.fr/fr/assets/ files/pdf/2019/11/en-france-pwc-poin t-of-view-quantum-computing-2019.pd f. Accessed 3 June 2021
30. Hann, C. T., Zou, C.-L., Zhang, Y., Chu, Y., Schoelkopf, R. J., Girvin, S. M., & Jiang, L. (2019). Hardware-efficient quantum random access memory with hybrid quantum acoustic systems. PhysicalReview Letters, 123(25), 250501. https://doi.org/10.1103/PhysRevLett.123.2 50501
31. Harrow, A., Hayden, P., & Leung, D. (2004). Superdense coding of

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quantum states. Physical Review Letters, 92(18), 187901. https://doi.org/10.1103/PhysRevLett.92.187901
32. Harrow, A. W., Hassidim, A., & Lloyd, S. (2009). Quantum algorithm for linear systems of equations. Physical Review Letters, 103(15), 150502.