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Quantum Computers: Principles, Progress and the Distance to Practical Use

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Abstract:
A quantum computer is not simply a faster version of the machine on a desk. It is a device that stores information in the quantum state of matter and steers that state through a carefully designed sequence of operations, so that the probabilities of wrong answers cancel out and the probability of the right answer grows. This paper explains the underlying physics in plain terms, describes the main families of quantum algorithms and the hardware platforms that attempt to run them, and examines why building a useful machine has proved so much harder than the early optimism suggested. The second half concentrates on the engineering bottleneck: decoherence, gate errors and the move from noisy intermediate-scale devices towards fault-tolerant systems, with reference to published industrial roadmaps and to the 2025 Nobel Prize in Physics, which honoured the circuit-level physics on which superconducting qubits rest. The paper closes by separating defensible claims about quantum advantage from claims that outrun the evidence.

Keywords: Bottleneck, Decoherence, Superconducting, Outrun, Evidence

1. Introduction: what problem is being solved

Classical computing is extraordinarily successful, but it rests on an assumption that is so natural it is rarely stated: the state of the machine can always be written down, bit by bit, and read off at the end. A quantum computer breaks that assumption at both ends. Its working state cannot be described by a list of bits during the computation, and the answer cannot be read out directly, because measurement destroys the very superposition that made the computation possible. What the programmer actually gets back is a set of samples from a probability distribution.

This changes the economics of the device. A quantum computer is only worth building for a problem whose solution can be encoded in a pattern of interference, and whose answer can be extracted through a small number of measurements. For most everyday computing tasks, from word processing to accounting, no such encoding is known, and a classical processor remains far cheaper and more reliable. The honest way to describe quantum computing is therefore narrow: it is a specialised instrument for a small set of problems in simulation, number theory, search and optimisation, not a general replacement for existing machines.

2. The physics of the qubit

The unit of quantum information is the qubit. Where a classical bit is either zero or one, a qubit can be prepared in a superposition, a combination of both possibilities carrying relative amplitude and phase. Two further features do the real work. Entanglement links the qubits so that the joint state cannot be factorised into independent descriptions, and interference allows the amplitudes of different computational paths to add or cancel. Superposition alone makes a device sound impressive but buys very little; it is interference between entangled paths that allows a quantum algorithm to concentrate probability on correct outputs.

The fragility of this state is the central engineering fact of the field. A qubit couples to stray electric fields, thermal radiation, material defects and control noise, and each coupling degrades the stored phase. The result is decoherence, a gradual loss of quantum information that sets a hard deadline on how long a circuit may run. Modern superconducting processors are operated in dilution refrigerators at temperatures of a few thousandths of a kelvin, colder than interstellar space, precisely to suppress thermal excitation to negligible levels (Nobel Prize, 2025).

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3. From gates to algorithms

about the square root of the search space. Useful, but not transformative. Factorising the same million-entry problem, by contrast, would drop from a computation lasting longer than the age of the universe to one that a fault-tolerant machine could finish in hours. The gap between these two examples is the gap between quantum computing as a curiosity and quantum computing as a strategic technology. A quantum program is expressed as a circuit: state preparation, a sequence of unitary gates drawn from a small universal set, and measurement. Because gates are reversible, computation is built from rotations and entangling operations rather than from irreversible logic. The classical compiler then translates this circuit into microwave or laser pulses specific to the hardware.

Only a handful of algorithmic families have survived scrutiny. Shor's algorithm for integer factorisation and the discrete logarithm problem gives an exponential speed-up and is the reason governments care about the field, since it threatens widely deployed public-key cryptography. Grover's search gives a quadratic speed-up, which is less dramatic than it sounds but still meaningful for unstructured search. Hamiltonian simulation, in which a quantum system models another quantum system, is widely regarded as the most natural and probably the earliest defensible application, because the cost of classical simulation grows exponentially with the number of interacting particles. A fourth family covers linear algebra, differential equations and Monte Carlo integration, where the speed-ups are conditional on data-loading assumptions that are often unfavourable in practice.

A worked illustration makes the difference between the families clear. To find one marked item among a million possibilities, a classical computer may need to check all million entries in the worst case. Grover's algorithm needs roughly a thousand iterations, because the amplitude of the marked item is amplified by

4. Hardware platforms in competition

Platform	Strength	Main weakness
Superconducting circuits	Fast gates, mature fabrication, largest ecosystems	Millikelvin cooling, wiring density, qubit size in millimetres
Trapped ions	Very high fidelity, long coherence, all-to-all connectivity	Slow gates, scaling of optics and laser control
Neutral atoms	Thousands of atoms in arrays, flexible reconfiguration	Loss and reloading, gate speed and fidelity
Photonic	Room-temperature links, natural fit for networking	Photon loss, probabilistic gates, weak memory
Topological / Majorana	Error protection built into the physics	Experimental status still disputed and unproven

Table 1. Principal qubit technologies and their trade-offs, summarised from the review literature.

The superconducting approach, which dominates commercially, received a scientific stamp of authority in 2025 when the Nobel Prize in Physics went to John Clarke, Michel Devoret and John Martinis for demonstrating macroscopic quantum tunnelling and energy quantisation in an electrical circuit. Working at Berkeley in 1984 and 1985 with a circuit about a centimetre across, built from superconductors separated by an insulating barrier, they showed that billions of Cooper pairs behave as a single quantum object that can tunnel between states and absorb energy only in discrete quanta (Nobel Prize, 2025). Martinis later used exactly this quantised circuit as an artificial atom, and therefore as a qubit. The prize is a reminder that the platform is not an engineering accident but a direct consequence of measured physics.

5. Noise, error correction and the fault-tolerance threshold

Every real device is noisy. Published noise studies identify three dominant contributions: imperfect gates, errors in state preparation and measurement, and thermal decoherence and dephasing of the physical qubits. Because a quantum

algorithm's output is probabilistic, an error does not merely corrupt a digit; it shifts probability mass away from the correct answer, and enough errors make the result indistinguishable from noise.

The remedy is quantum error correction, which spreads one logical qubit across many physical qubits and repeatedly measures parity checks that reveal errors without revealing the encoded data. This works only below a threshold: if the physical error rate is low enough, adding more physical qubits per logical qubit reduces the logical error rate. Demonstrating that downward slope is the field's most important experimental milestone, because it converts error correction from theory into an engineering curve. IBM reports that early error-correction techniques already show effective error rates about ten times lower than the underlying hardware, and its published roadmap targets IBM Quantum Starling in 2029 as a large-scale fault-tolerant machine with 200 logical qubits running 100 million operations, followed by Blue Jay at 2,000 qubits and one billion operations in the 2033 timeframe. In 2026 the company committed more than ten billion dollars to that path and reported linking two cryogenic modules that cooled below 15 millikelvin, an engineering step towards multi-module systems.

These figures should be read carefully. A roadmap is a plan, not a result, and the number of logical qubits matters far more than the number of physical ones. Still, the direction of travel is informative: the industry has stopped promising broad speed-ups on current hardware and started promising reliable machines later, which is a more defensible kind of claim.

6. Where the value is likely to appear

Four application areas attract most of the serious attention. First, chemistry and materials: simulating molecular ground states and reaction pathways, where quantum computers offer a natural representation that classical methods approximate at exponential cost. Second, optimisation, particularly combinatorial problems in logistics, scheduling and network design, although here the evidence for advantage over well-tuned classical heuristics remains thin. Third, cryptanalysis and its defensive twin, post-quantum cryptography, which is being standardised now rather than waiting for the machines. Fourth, fundamental science, including problems in high-energy physics and data-intensive engineering, where agencies such as NASA have run structured benchmark programmes comparing quantum and hybrid algorithms against the best classical methods.

A teaching application deserves separate mention. Because several providers offer free cloud access to real processors and graphical circuit builders, the quantum penny-flip game can be used in a classroom to show, with a few clicks and no installation, that a quantum strategy wins a game no classical strategy can win. For educators this is the most immediately usable part of the field: the concepts of superposition and interference become demonstrable rather than asserted.

7. The limits, stated plainly

Quantum advantage means beating the best classical method on a problem someone actually cares about, at a cost that makes sense. Demonstrations on contrived sampling problems satisfy the first half of that definition and not the second. Optimisation algorithms on near-term hardware have been shown to suffer from barren plateaus, flat regions of the cost landscape where training stalls, and there is an unresolved debate about whether such models are classically simulable anyway. Data-loading costs can consume the whole theoretical speed-up. And the classical competition does not stand still: every year of delay erases part of the quantum lead.

The fairest summary is that quantum computing is a genuine physical capability with a narrow proven scope and a wide speculative one. The proven part is small-scale simulation, quantum-enhanced sampling, and the demonstration of error-corrected logical qubits. The speculative part is large-scale commercial advantage, which depends on machines that do not yet exist. A paper that claims otherwise would be repeating marketing rather than reporting science.

8. Conclusion

Quantum computing earns its importance from a single asymmetry: certain problems have structure that a classical machine must explore case by case, while a quantum machine can arrange for wrong paths to cancel. Exploiting that asymmetry requires protecting fragile quantum states long enough to run a circuit, which is why the field's centre of gravity has shifted from qubit count to error correction. The 2025 Nobel Prize honoured the circuit physics that made the leading platform possible; the industrial roadmaps of 2026 point to fault-tolerant systems at the end of the decade.

Between those two facts lies the honest research agenda: better qubits, better codes, and benchmarks that compare quantum machines to the strongest classical alternatives rather than to convenient ones.

References

1. Royal Swedish Academy of Sciences. (2025). The Nobel Prize in Physics 2025: popular information and press release, for the discovery of macroscopic quantum mechanical tunnelling and energy quantisation in an electric circuit. nobelprize.org.

2. IBM. (2026, June 2). IBM commits more than $10 billion to quantum computing, funding its roadmap to fault-tolerant systems. IBM Newsroom.

3. IBM. (2026). Quantum roadmap: Nighthawk, Kookaburra, Starling and Blue Jay milestones. ibm.com/roadmaps/quantum.

4. IBM. (2026, September 15). The continuous path from error mitigation to fault-tolerant quantum computing. IBM Quantum Blog.

5. Rieffel, E. G., Asanjan, A. A., et al. (2024). Assessing and advancing the potential of quantum computing: a NASA case study. arXiv:2406.15601.

6. Muller, R., and Greinert, F. (2021). Playing with a quantum computer. arXiv:2108.06271.

7. Georgopoulos, K., Emary, C., and Zuliani, P. (2021). Modelling and simulating the noisy behaviour of near-term quantum computers. arXiv:2101.02109.

8. Scholten, T., et al. (2024). Assessing the benefits and risks of quantum computers. arXiv:2401.16317.

9. Herbert, S. (2022). Quantum computing for data-centric engineering and science. Data-Centric Engineering, doi:10.1017/dce.2022.36.

10. Kadowaki, T. (2025). Quantum computing and AI: perspectives on advanced automation in science and engineering. arXiv:2505.10012.