

## PLAGIARISM SCAN REPORT

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Past this year in October, we saw Google's first demonstration of "quantum supremacy". To achieve quantum supremacy, a quantum computer would have to do any computation that, for all possible purposes, a classical computer can't. But before we get to quantum supremacy, let me explain what a quantum computer is. All conventional computers work with quantum mechanics because their elements rely on quantum behavior like the electron. But the operations that a conventional computer makes are not quantum. Conventional computers store and handle information in form of bits that can take on two values, say 1 or 0 or up and down. A quantum computer, on the other hand, stores information in the form of quantum-bits or q-bits that can take on any combination of 0 and 1. Operations on a quantum computer can then entangle the q-bits, which allows a quantum computer to solve certain problems much faster than a conventional computer. In principle, properties like conductivity or rigidity, or even color, can be calculated from the atomic build-up of a molecule. We know the equations. But we cannot solve these equations with conventional computers. It would just take too long. To give an idea of how much more a quantum computer can do, think about this. One can reproduce a quantum computer on a standard computer just by numerically resolving the equations of quantum mechanics. If you do that, then the computational difficulty on the conventional computer increases exponentially with the number of q-bits that you try to reproduce. You can do 2 or 4 q-bits on a personal computer. But already with 50 q-bits, you need a group of supercomputers. Anything beyond 50 or so q-bits cannot presently be determined, at least not in any reasonable amount of time. So, what is quantum supremacy? Quantum supremacy is the event in which a quantum computer defeats the best conventional computers on a specific task. It needs to be a specific task because quantum computers are really special-purpose machines whose powers help with particular computations. So, how then do we test quantum supremacy? You let a quantum computer do what it does best, that is being a quantum computer. This is an idea proposed by Scott Aaronson. If you set up a quantum computer in a suitable way, it will produce probabilistic distributions of measurable variables — Scott Aaronson. You can try and reproduce those measurement outcomes on a standard computer but this would take a very long time. So by letting a standard computer battle with a quantum computer on this task, you can show that the quantum computer does something a classical computer just is not able to do. Exactly at which point someone will declare quantum supremacy is a little ambiguous because you can always argue that maybe one could have used better conventional computers or a better algorithm. But for practical purposes, this really doesn't matter all that much. The point is that it will show quantum computers really do things that are difficult to calculate with a standard computer. But what does that mean? Quantum supremacy sounds very convincing until you realize that most molecules have quantum processes that also surpass the computational limits of present-day supercomputers. That is, after all, the purpose we want quantum computers. And the creation of random variables that can be used to check quantum supremacy is not good to actually calculate anything useful. So that makes it sound as if the present quantum computers are really just new toys for scientists. What would it take to calculate anything useful with a quantum computer? Estimates about this vary between half a million and a billion, depending on just exactly what you think is "useful" and how optimistic you are that algorithms for quantum computers will improve. So let us say, realistically it would take a few million q-bits. When will we get to see a quantum computer with a few million q-bits? No one knows. The problem is that presently most dominant approaches are unlikely to scale. These approaches are superconducting q-bits and ion traps.

In neither case does anyone have any idea how to get beyond a few hundred. This is both an engineering problem and a cost-problem. And this is why, in recent years, there has been a lot of talk in the community about NISQ computers, which are the "noisy intermediate-scale quantum computers". This is really a term invented to make investors believe that quantum computing will have practical applications in the next decades or so. The trouble with NISQs is that while it is likely that they soon will be practically feasible, no one knows how to calculate something useful with them. As you may have probably

soon will be practically feasible, no one knows how to calculate something useful with them. As you may have probably noticed, I am not very optimistic that quantum computers will have practical applications any time soon. In fact, I am presently actually worried that quantum computing will go the same way as nuclear fusion, that it will remain forever promising but never quite work. Nonetheless, quantum supremacy is surely going to be super-exciting.

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