

Why you should care about quantum physics

Quantum physics is good for more than inspiring movie plots. A grasp of quantum technology will be important for the future of the economy.

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For *The Straits Times*

Quantum physics seems to be everywhere in popular culture these days. Have you seen the movie *Avengers: Endgame*? If so, you encountered the quantum realm with the film's heroes.

Did you watch *Interstellar*? Then you'll know about "quantum data". Have you read the sci-fi novels of author Liu Cixin? Then you'll have come across "quantum entanglement".

As a principal investigator at the Centre for Quantum Technologies (CQT), I find that when my field's jargon is used to motivate the powers of superheroes or provide a critical plot point, it's likely I will find the story a good laugh. However, understanding what quantum physics is, and what technologies it enables, is becoming increasingly important not only for scientists, but also for the economy, in critical domains like computing, data and cyber security.

Quantum physics is the branch of science that deals with the behaviour of matter at the atomic scale. It describes the origin of a wide variety of phenomena: some very physics-y for sure, like everything about elementary particles, but also much more mundane ones.

To answer why elements are arranged in the periodic table, why some molecules form while others do not, why iron is magnetic and copper is a conductor of electricity, where the energy of a star comes from, you need quantum physics.

That knowledge is already used in technologies like lasers, semiconductors, the global positioning system, and magnetic resonance imaging scanners. But these are quantum technologies version 0.1.

A semiconductor, in a nutshell, is an insulator that can turn into a conductor by applying a very small voltage. That's why a semiconductor is useful, and you can understand what it means without any knowledge of quantum physics. That knowledge is needed only if you want to describe how an assembly of atoms and electrons may create such a material.

Physicists, computer scientists and engineers are currently designing new technologies for sensing, communication and computing, which exploit the most mind-boggling features of quantum objects: their possibility of being in "superposition" and "entangled".



The IBM Q System One quantum computer in Yorktown Heights, New York. Physicists, computer scientists and engineers are designing new technologies for sensing, communication and computing, which exploit the most mind-boggling features of quantum objects. PHOTO: NYTIMES

You'll likely have come across the enticing idea of a "quantum computer" before. It's not a device you can currently buy; actually, even in the best laboratories, including those at big companies like Google and IBM, only small machines have been built so far. But evidence that quantum computers could dramatically accelerate important calculations in everything from finance to drug discovery is driving this research forward.

Just this week, Google announced it had achieved a quantum breakthrough called "quantum supremacy", which can revolutionise computing at speeds now inconceivable.

Quantum computing is not easy to explain, but I can try to explain what quantum has to do with cryptography, the art of secret communication. For this, you need to add to your knowledge a quantum fact: any measurement modifies the properties of an atom or a photon.

Now, think about the following situation: I am communicating with a friend by sending one photon at a time (quantum technology). If someone wants to spy on what I am saying, he'll have to read the information and that is to measure the photons. I will notice it, because the properties of the photons have been modified. Hence, my message will be modified, and my friend will receive gibberish. Thanks to the quantum features of photons, my quantum communication cannot be tapped.

There are other ways to argue for the security of cryptography. I worked a lot in basing the security of cryptography on another quantum

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phenomenon, called Bell nonlocality, which is an observable consequence of "entanglement". This phenomenon has fascinated me since my undergraduate days. It has been 25 years since I first heard of it, and the reference book I have written on the subject has just arrived on my desk from Oxford University Press, but I'll leave out the details about the book for this piece.

So, we may not be extracting quantum data from a black hole, as in *Interstellar*, but in a quantum computer we can store and process data encoded in atoms and superconducting circuits; and with quantum cryptography, we can share this data with unprecedented privacy.

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There's growing commercial

interest in a Singaporean quantum ecosystem too. For example, Singtel has partnered the National University of Singapore (NUS) to test quantum cryptography on its fibre network, and SGInnovate, a company supporting local deep tech, has quantum technologies as one of its focus areas.

To build a "quantum-ready" workforce here in Singapore that understands these exciting new opportunities, we need to offer the right technical training. For this reason, when I was appointed deputy head of the NUS Department of Physics to be in charge of education, I teamed up with some colleagues to set up a new specialisation in quantum technologies within the physics major. The Ministry of Education approved this option this year.

Physics students can now choose to learn in greater detail the aspects of quantum physics that are essential to the future of computing and cyber security. To the best of our knowledge, this specialisation is unique worldwide at the undergraduate level.

That's not to say you can start learning quantum only at university, however. There are easier entry points, and I have devoted some effort to exporting quantum physics outside academia.

In 2010, for example, I co-authored with two NUS High School of Math and Science students an introductory textbook on quantum physics for students with only high-school-level mathematics.

Quantum physicist and author Chris Ferrie aimed at an even younger audience. He wrote *Quantum Physics For Babies*, made famous when Facebook's chief

executive Mark Zuckerberg shared a photo of his baby reading it.

Similarly, to get a wide audience interested in quantum physics, a new exhibition recently opened at Science Centre Singapore.

Quantum: The Exhibition aims to introduce the real science to visitors of all ages. It is supported by six local organisations with a stake in the future of quantum science and technology – CQT, NUS, Agency for Science, Technology and Research, Nanyang Technological University, National Research Foundation, and National Supercomputing Centre.

Overall, the exhibition combines travelling exhibits built by the Institute for Quantum Computing at the University of Waterloo in Canada with new displays about work happening in Singapore.

Ultimately, I hope that Singaporeans, whatever age they are starting from, will feel excited to explore the extraordinary field of quantum mechanics. We may not have found a way to use quantum technologies to travel through time – despite what happened in *Avengers* – but there's much more to quantum physics than what you learn from movies.

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• Quantum: The Exhibition is open at Science Centre Singapore until Jan 2 next year. More information at <https://bit.ly/quantum-exhibition>