

Popular Science Abstract

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May 26, 2023

By the end of the 19th century, the field of physics was considered by many as complete. Thanks to the insights developed by Isaac Newton in the 17th century, together with the development of the theory of electromagnetism and that of thermodynamics, most macroscopical systems could be characterized by a handful of parameters, and their evolution could be determined. It is therefore not surprising that, to date, we record quotes of 19th century physicists stating that "most of the grand underlying principles have been firmly established and that further advances are to be sought chiefly in the rigorous application of these principles". However, this could have not been further from the truth. Right at the beginning of the 20th century, the discovery of the electron, together with the investigation of this and other extremely small particles, led to development of a field now known as "quantum mechanics".

The development of this new framework unveiled a new layer of reality, one that would change the axioms that physicists and many scientists alike thought to be true. Quantum mechanics challenged many of the fundamental understandings of the universe that had remained undisputed for centuries. The most fundamental blocks of matter seemed to behave in ways that contradicted the notion of realism and locality. Quantum mechanics describes these particles as being able to simultaneously occupying multiple states, often times in contradiction with the current understanding of reality. Particles are not found to be in a definite position, rather, quantum mechanics predicts that a single particle can be often described to be in a superposition of being in multiple places at once. In addition, quantum mechanics also introduced the notion of entanglement. This property of a set of particles describes a level of correlation among these that cannot be achieved by systems described by previously established classical laws.

In recent years, the study and exploitation of such properties has enabled the development of several technologies. One such technologies is the transistor contained in the entirety of modern digital systems. Within transistors, the study of quantum mechanics has allowed an understanding of how to mitigate unwanted effects, thus allowing for a higher performance of these devices. In addition, the development of quantum mechanics has sprouted new areas of research, such as that of quantum computation and quantum cryptography. In these, the properties of entanglement and superposition are leveraged to perform tasks that would otherwise be unachievable by any classical system. In

particular, the generation, storage, and control of entanglement have become central challenges in various areas of quantum physics. Among these, preserving entanglement is a critical challenge in quantum information processing, as the coupling of entangled systems with external environments can quickly degrade the established correlations within the system.

In this thesis, we try to address the challenges imposed by the generation of entanglement. To this end, we study extremely simple quantum engines, which are autonomously capable of generating long lasting amounts of entanglement. The entanglement generated by these systems is however far too weak to perform any meaningful task. Our objective is then to develop a feedback protocol capable of enhancing the entanglement generation properties of these engines. The developed protocol is capable of doing just that, thus allowing these systems to produce far higher amounts of entanglement, that could in practice be used to perform otherwise unachievable tasks.