



## Majorana Zero Modes

**For Prelims: Majorana Zero Modes, [Quantum Computing](#), Qubits, [Supercomputer](#), Antiparticle, Fermions, Positrons, Neutrinos.**

**For Mains: Majorana Zero Modes and its potential advantages in Quantum Computing.**

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### Why in News?

Recently, Microsoft researchers announced a significant breakthrough in the creation of **Majorana Zero Modes**, a type of particle with potential implications for revolutionizing quantum computing.

- Microsoft researchers engineered a topological superconductor composed of an aluminium [Superconductor](#) and an indium arsenide [Semiconductor](#).
- Their device passed a stringent protocol, including measurements and simulations, **indicating a high probability of hosting Majorana zero modes.**
- The topological gap protocol and observation of the conductance peak are considered strong evidence for Majorana zero modes.

### What are Majorana Zero Modes?

- **Majorana Fermions:**
  - All subatomic particles that **make up matter are called fermions.**
  - In 1928, physicist Paul Dirac developed the **Dirac equation to understand how quantum mechanics** and the special theory of relativity could coexist.
    - The Dirac equation described the behaviour of subatomic particles that moved at **near the speed of light.**
  - This equation predicted the **existence of antiparticles for each particle**, leading to the discovery of the first antiparticle, the positron (or the anti-electron) in 1932.
  - In 1937, physicist Ettore Majorana found that the Dirac equation allowed for particles that satisfied **certain conditions to be their own antiparticles** to be their own antiparticles.
  - In his honour, fermions that are **their own antiparticles are called Majorana fermions.**
    - Neutrinos are one type of particle that physicists believe could be **Majorana fermions**, although experimental proof is still lacking.
- **Majorana Zero Modes:**
  - Fermions possess four quantum numbers, with one of them being quantum spin, which only has half-integer values.
  - Bound states of fermions that are their own antiparticles are called **Majorana zero modes.**
  - Majorana zero modes have been a subject of research for over two decades.
  - Their unique characteristics make them **promising for topological quantum**

computing.

## What can be the Potential Advantages of Majorana Zero Modes in Computing?

- Majorana zero modes possess unique properties that **make [Quantum Computers](#) more robust and computationally superior**. Quantum computers currently use individual electrons as qubits, but they are fragile and susceptible to decoherence.
- Majorana zero modes, composed of an electron and a hole, can be used as **more stable qubits**.
- Even if one of the entities is disturbed, the **overall qubit does not decohere, protecting the encoded information**.
- Majorana zero modes offer **topological degeneracy**, allowing for the storage and retrieval of information from different topological properties, without easily losing the encoded information.
  - Topology is the study of those properties of matter that **don't change when it undergoes continuous deformation** – i.e., when it's stretched, folded, twisted, etc., but not ruptured or glued to itself.

## What is Quantum Computing?

- Quantum computing uses **phenomena in quantum physics** to create new ways of computing.
  - Quantum physics explains the behavior of energy and material on the atomic and subatomic levels.
- Quantum computing involves **qubits**. Unlike a normal computer bit, which can be either 0 or 1, a **qubit can exist in a multidimensional state**.
- The power of quantum computers **grows exponentially with more qubits**.
  - Classical computers that add more **bits can increase power only linearly**.
- Quantum computing has the capability to sift through huge numbers of possibilities and extract **potential solutions to complex problems** and challenges.
- The basic properties of quantum computing are superposition, entanglement, and interference.
  - **Superposition:**
    - It is the ability of a quantum system to be in multiple states simultaneously.
    - The example of superposition is the flip of a coin, which consistently lands as heads or tails—a very binary concept. However, when that coin is in mid-air, it is both heads and tails and until it lands, heads and tails simultaneously. Before measurement, the electron exists in quantum superposition.
  - **Entanglement:**
    - It means the two members of a pair (Qubits) exist in a single quantum state. Changing the state of one of the qubits will instantaneously change the state of the other one in a predictable way. This happens even if they are separated by very long distances.
    - Einstein called spooky 'action at a distance'.
  - **Interference:**
    - Quantum interference states that elementary particles (Qubits) can not only be in more than one place at any given time (through superposition), but that an individual particle, such as a photon (light particles) can cross its own trajectory and interfere with the direction of its path.

**UPSC Civil Services Examination Previous Year Question (PYQ)**

**Prelims**

**Q. Which one of the following is the context in which the term "qubit" is mentioned?**

- (a) Cloud Services
- (b) Quantum Computing
- (c) Visible Light Communication Technologies
- (d) Wireless Communication Technologies

**Ans: (b)**

**Exp:**

- **Quantum Supremacy**
- Quantum computers compute in 'qubits' (or quantum bits). They exploit the properties of quantum mechanics, the science that governs how matter behaves on the atomic scale.

**Hence, option (b) is correct.**

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