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தினம் ஒரு குறள்

குறள் எண் **336**
நிலையாமை

நெருநல் உளனொருவன் இன்றில்லை என்னும்
பெருமை உடைத்துஇவ் வுலகு.

நேற்று இருந்த ஒருவன் இன்று இல்லை என்று சொல்லும்படி நிலையாமையை உடையது இவ்வுலகம். — சாலமன் பாப்பையா

Have 'green' crackers brought down pollution?

Is 'reduced emission fireworks' a better term to describe such 'green' crackers? Who developed these fireworks?

Jacob Koshy

The story so far:

In the run-up to Deepavali, the Supreme Court legalised the sale of "green" crackers, in a bid to balance three competing interests: the "sentiments" of the people during the festive season; the pollution caused due to the burning of firecrackers; and livelihood concerns of those employed in the firecracker industry. The largely small-scale informal sector has been hit by the cracker ban in the National Capital Region since 2018.

How are 'green' crackers made?

In 2018, the Nagpur-based CSIR-National Environmental and Engineering Research Institute (NEERI) initiated the development of "green" crackers that reportedly cut particulate emissions by a minimum of 30%, and sometimes up to 80%, while maintaining brightness, safety, and shelf-life. This was largely achieved by three major chemical-formulation changes: the use of additives such as 'zeolite'; water-releasing molecules such as boron-based reagents to act as dust suppressants; and the addition of metallic composites to enhance combustion temperature and improve combustion efficiency. Traditionally, firecrackers have been made with barium nitrate, antimony and a range of metals that, over the years, have been linked to respiratory diseases and even cancer.

The claim of NEERI, which initiated the development of 'green' crackers, is that they reduce particulate matter pollution by 30%

The green avatar of the 'flower pot', one of the most popular fireworks, has a mixture of water and lime that is chemically stored in the cracker. When lit, the effulgence also triggers water, and the moisture, its makers contend, wets the dust-and-smoke particles making it settle rather than becoming airborne. NEERI claims that tests in its labs have seen a reduction of nearly 30% in particulate matter and also reduced the release of sulphur dioxide as well as nitrous oxide emissions when these flower pots are burnt. Green sparklers use 32% potassium nitrate, 40% aluminium powder, 11% aluminium chips, and 17% "proprietary additives" to reduce PM10 and PM2.5 to 30%.

Similarly, a new formulation of a 'bomb' named 'SWAS' uses 72% of a "proprietary additive," 16% potassium nitrate oxidiser, 9% aluminium powder, and 3% sulphur to reduce PM10 and PM2.5. Since these crackers were developed, there have been demonstrations by NEERI at major fireworks manufacturing units such as Sivakasi in Tamil Nadu.

What has been the uptake?

NEERI, according to the Commission for Air Quality Management (Delhi-NCR), had also developed a Standard Operating Procedure (SOP) to register green cracker manufacturers and to provide technology transfer of the formulations for manufacturing such crackers. The list of green crackers have been put on the website of NEERI for registration and grant for individual products. It would require the manufacturer to get multiple registrations from NEERI based on the number of products. Only manufacturers with an explosive licence from the Petroleum and Explosives Safety Organisation (PESO) would be granted registration by NEERI. This year, there were nearly 1,500 applicants who procured a licence to manufacture these crackers with the vast majority of them from Tamil Nadu, followed by West Bengal. The term "green" cracker, strictly speaking, is a misnomer as green usually refers to zero-emission-or-smoke products. An electric vehicle, for instance is 'green,' as it is powered by a battery with no carbon emissions. In an academic article from 2023, scientists from NEERI when evaluating the results from such crackers referred to them as 'Reduced Emission Fireworks,' a more accurate term. However, the SC order refers to these products as "green".

Are green crackers less polluting?

The stated claim of the makers is that they reduce particulate matter pollution by 30%. However, these are numbers computed by the lab themselves and have not been verified in real-world conditions. The Supreme Court in its order noted that relative to 2018 and 2024, there was "not much improvement" in the overall air quality. However, it used this to conclude that, therefore, permitting green crackers for Deepavali, though with restrictions on their use, could not make the deteriorating air quality much worse than it already was. On October 20 and 21, air quality deteriorated to 'very poor', according to readings from sensors through the NCR. In the days leading up to the festival, the air quality was already on a decline. This is not unusual in mid-October, given dipping temperatures and a drop in wind speed. Several sensors recorded particulate matter concentrations well over 1,000 microgram/cubic metre. A contributor to this was also stubble burning in Punjab but there is no official or independent scientific measurement available yet of their relative contribution.

Topic:

Supreme Court Legalises “Green Crackers” — Balancing Festivity, Pollution, and Livelihoods

Source:

The Hindu, October 2025

Relevance:

- **GS Paper 3:** Environment, Pollution Control, Science & Technology, Judicial Interventions
- **GS Paper 2:** Government Policies, Environmental Governance, Judiciary

Linked Topics:

- Air Pollution (Delhi NCR, Stubble Burning)
- Supreme Court’s Environmental Jurisprudence
- Role of CSIR-NEERI
- Sustainable Technology & Innovation
- Livelihood vs Environment Debate

Context:

Ahead of Deepavali 2025, the **Supreme Court** allowed the **sale of “green crackers”** developed by **CSIR–NEERI**, attempting to balance:

- Public sentiments during festivals,
- Pollution concerns, and
- Livelihoods of workers in the firecracker industry (especially Sivakasi, Tamil Nadu).

This follows a **2018 ban** on traditional crackers in the NCR due to severe air pollution.

Curiosity Question:

Can technology-led innovations like “green crackers” truly balance economic livelihood and environmental sustainability in India’s festivals?

Analytical Overview:

- **Green crackers** are formulated to cut **particulate emissions (PM10, PM2.5)** by **30–80%**, with reduced sulphur dioxide and nitrogen oxide output.
- Chemical innovation:
    - Use of **zeolite** and **boron-based reagents** as dust suppressants.
    - Inclusion of **metallic composites** to improve combustion efficiency.
    - Some designs (e.g., "flower pots") release **water vapour and lime** to settle dust.
- NEERI's **SOP for registration** ensures only licensed manufacturers (via PESO) can produce these.
- Yet, real-world pollution reduction remains **unverified**, with **Delhi-NCR air quality** still deteriorating in October due to multiple factors (weather, stubble burning, cracker use).
- The **term "green"** is technically a **misnomer**, as the products are not zero-emission. NEERI scientists prefer the term *"Reduced Emission Fireworks."*

Constitutional / Policy Linkages:

- **Article 21:** Right to life and clean environment.
- **Article 48A & 51A(g):** Duty of the State and citizens to protect the environment.
- **Environment (Protection) Act, 1986.**
- **Air (Prevention and Control of Pollution) Act, 1981.**
- **National Green Tribunal (NGT)** and **Commission for Air Quality Management (CAQM)** jurisdiction.
- **Judicial balancing:** Fundamental Rights (livelihood under Article 19(1)(g)) vs. right to clean air (Article 21).

Way Forward / Recommendations:

- Independent **real-world emission verification** of "green crackers."
- Encourage **eco-friendly festivities** and **community firework zones**.
- **Diversify livelihoods** in Sivakasi and other regions dependent on fireworks.
- Promote **public awareness** campaigns to shift cultural perception towards sustainable celebration.
- **Strict enforcement** of limited-hour bursting and licensing norms.

Prelims Pointers:

- **Green Crackers:** Developed by **CSIR–NEERI** (Nagpur).
- **Key chemicals:** Zeolite, boron-based reagents, metallic composites.
- **SWAS Bomb:** Reduced emission cracker (72% proprietary additive, 16% potassium nitrate).
- **PESO:** Petroleum and Explosives Safety Organisation — regulates explosive licences.
- **CAQM:** Commission for Air Quality Management (Delhi-NCR).

Mains Keywords:

Green Crackers • Air Pollution • Supreme Court Intervention • Sustainable Technology • CSIR-NEERI • Reduced Emission Fireworks • Environmental Governance • Livelihood vs Environment

Mains Practice Question (with Dimensions):

Question: *"The introduction of 'green crackers' reflects India's attempt to reconcile cultural traditions with environmental imperatives." Critically evaluate.*

Dimensions:

- Historical background of cracker bans (2018–2025)
- Science & innovation by NEERI

- Judicial role in environmental regulation
- Effectiveness in reducing real-world emissions
- Socio-economic implications for workers and industry
- Policy alternatives for sustainable celebrations

One Line Takeaway:

“Green crackers” symbolize India’s ongoing experiment to balance **festive freedom, pollution control, and livelihood protection** — yet their real-world impact remains uncertain.

What is Google's 'quantum advantage' leap?

How does quantum information become hidden in complex systems? How can a quantum computer retrieve it? What real-world applications does this ability have? What are the challenges of establishing quantum advantage?

Vasudevan Mukunth

The story so far:

In two papers published in *Nature* on October 22, researchers from Google, MIT, Stanford, and Caltech reported what they called a verifiable display of quantum advantage using the company's Willow quantum processor. That is, the teams said they have shown that Willow clearly outperforms existing supercomputers on solving a specific problem.

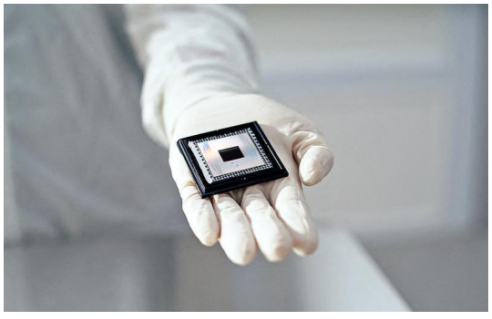
How does a quantum computer work?

Imagine waves moving in a pond. When two wave crests meet, they combine to make a bigger wave. When a crest meets a trough, they cancel each other out. This is called interference. At the quantum level, particles can behave like waves and their "wave functions", which describe their probabilities, can be made to interfere with one another. By controlling this interference, scientists can amplify the probability of finding the right answer to a problem while cancelling out the wrong ones. This is what a quantum computer does.

In one of the two new studies, researchers introduced a quantum algorithm designed to solve optimisation problems, which are puzzles where the goal is to find the best possible solution among many. The research team called it Decoded Quantum Interferometry (DQI).

DQI uses a quantum version of the Fourier transform to manipulate the wave-like nature of particles that the quantum computer uses as its bits. This process is engineered such that the waves corresponding to good solutions interfere constructively, reinforcing each other to create a strong signal. Meanwhile, the waves for bad solutions interfere destructively and fade out. By measuring the final state, the algorithm will have a higher chance of landing on a 'high-quality' answer. The researchers showed that for the optimal polynomial intersection problem, the DQI algorithm could find a good approximation much faster than any known classical computer.

> The experiment involved circuits so intricate that simulating them on the world's second fastest supercomputer would have taken more than three years



Big breakthrough: Google Quantum AI's 'Willow' chip. REUTERS

What is scrambling?

In the second study, the authors measured how information becomes scrambled in a complex quantum system. Say you drop a small amount of dark blue dye into a still swimming pool. At the first moment, the 'information' is simple and local. "The blue dye is right here," you can say. But the dye doesn't stay there: it spreads out. The information is no longer in one place but distributed across a larger volume of water. After a few hours, the entire pool has a faint, uniform blue tint. You can no longer see the original drop. The information seems to be gone – but it isn't. It's been scrambled. Every single water molecule in the pool now carries an almost imperceptible piece of that "blue" information.

This is what happens in a quantum system. A piece of information, initially stored in one quantum bit, gets spread out across all the other bits as they interact. The information becomes 'hidden' in the complex relationships between all the particles. So the challenge is: how do you measure a pattern that's so intricately hidden?

To do this, the researchers used a clever experiment. Imagine you're standing in a large, empty warehouse. You shout. The sound waves spread out instantly, bouncing off every wall, the floor, and the ceiling. This is the scrambling: the sound's information is now everywhere. Now, while your shout is still echoing around, your friend on the far side of the warehouse strikes a large metal bell with a hammer. This 'kick' doesn't stop the echoes but it changes them. Any sound wave from your shout that happens to hit that specific bell at that exact moment now gets a little 'imprint' in the form of a faint metallic ring. Then, the researchers did the equivalent of hitting a magical rewind button that caused all the sound waves to travel perfectly backward. All the normal echoes, the ones that didn't hit the bell, trace their paths back perfectly and cancel each other out upon returning, resulting in complete silence.

However, the imprinted echoes are now slightly off-course. When they travel backward, they don't cancel out properly, and the researchers are left hearing a very faint, jumbled echo – one carrying the imprint of the kick. That leftover sound is the OTOC measurement, and this process of different paths mixing and cancelling (or not) is called interference.

By measuring the faintness and character of that leftover echo, the scientists could tell exactly how much the information had spread out and interacted with that specific part of the system (the bell). This is how they successfully measured the subtle, hidden patterns of scrambled information.

How do you show quantum advantage?

The second experiment involved circuits so intricate that researchers estimated simulating them on the world's second fastest supercomputer would have taken more than three years. The Willow processor completed the same task in about two hours. This said, while the first paper described a quantum algorithm that solved a puzzle much faster than any known classical computer, researchers haven't mathematically proven that a clever trick for a regular computer to solve the same puzzle quickly doesn't exist. New research will be needed to prove the problem is permanently hard for all non-quantum computers.

Likewise, while the second paper showed a quantum computer solving a complex problem, the next step will be for an independent team to use the same method to solve an actual unsolved problem in, say, physics or chemistry.

Finally, while the two studies mark a decisive step, their applications remain largely prospective. These are still lab-designed tasks whose outputs don't yet translate to scientific discoveries. The next stage will depend on improving other parts of quantum computing, including error correction and scaling to thousands of reliable quantum bits. These are widely expected to take several years more.

What did Google claim in 2019?

In a 2019 experiment, Google researchers used a quantum system to attempt to solve a problem called random circuit sampling. Here, its Sycamore processor ran a random programme generating a list of answers, with the challenge of predicting which of those answers would appear most frequently. However, researchers can't check a single answer in random circuit sampling, if the statistical distribution of all the answers looks correct. On the other hand, the problem the new test solved concerned a scientifically meaningful physical quantity.

The result was also said to be "verifiable" because the same problem can be run on a classical computer or another quantum computer, and verifying the answer doesn't depend on statistical patterns. One likely early application of the findings is in Hamiltonian learning, the process of inferring unknown parameters of a physical system by comparing experimental data with simulated outcomes. The same principles that this year's physics Nobel Prize laureates developed are what make processors like Willow possible. One of the laureates, Michel Devoret, is the chief scientist of quantum hardware at Google Quantum AI. The new studies built on the laureates' work to solve an optimisation problem and then to track how information spreads in quantum systems.

Topic:

Google's Willow Quantum Processor Demonstrates Quantum Advantage (2025)

Source:

The Hindu / Nature Journal, October 2025

Relevance:

- **GS Paper 3:** Science & Technology — Quantum Computing, Research Innovation
- **GS Paper 2:** Global Technological Developments & Their Implications for India
- **Prelims:** Basic Concepts of Quantum Computing, Interference, Qubits

Linked Topics:

- Quantum Computing
- Quantum Interference & Fourier Transform
- Google's Sycamore (2019) & Willow (2025) Processors
- Decoded Quantum Interferometry (DQI) Algorithm
- Information Scrambling in Quantum Systems
- India's National Quantum Mission (2023–2031)

Context:

In October 2025, researchers from **Google, MIT, Stanford, and Caltech** published two landmark papers in *Nature* claiming a **verifiable display of quantum advantage** using Google's new **Willow Quantum Processor.**
It showed that **Willow outperformed the world's best supercomputers** in solving specific scientific problems, strengthening claims of practical progress in **quantum supremacy.**

Curiosity Question:

If quantum computers can process information exponentially faster than supercomputers, could they one day *break encryption systems* or *revolutionise AI simulations*?

Analytical Overview:

How a Quantum Computer Works:

- Classical computers use **bits (0 or 1)**; quantum computers use **qubits** — which can exist in multiple states simultaneously due to **superposition.**
- **Interference** is key: wave-like quantum states reinforce correct answers (constructive interference) and cancel wrong ones (destructive interference).
- Quantum algorithms manipulate this interference to find *optimal solutions* efficiently.

Study 1 — The DQI Algorithm:

- Introduced a new **Decoded Quantum Interferometry (DQI)** algorithm for **optimisation problems.**
- Uses a **quantum Fourier transform** to manipulate wave functions — making "good" solutions stronger and "bad" ones fade.
- Solved the **optimal polynomial intersection problem** significantly faster than any known classical computer method.

Study 2 — Measuring Quantum Scrambling:

- Explored how information spreads (or gets *scrambled*) across quantum bits.
- Developed an experiment analogous to sound echoes in a warehouse — using **Out-of-Time-Order Correlation (OTOC)** measurements to detect how data disperses through the system.
- This experiment proved Willow could track **information scrambling** — a phenomenon crucial in **quantum chaos** and **black hole physics.**

Demonstrated Quantum Advantage:

- The quantum circuit task that would take **a top supercomputer >3 years** was completed by **Willow in ~2 hours.**
- This is considered **verifiable quantum advantage** because results can be cross-checked by other quantum systems or classical simulations.5

Challenges & Limitations:

- The advantage is **problem-specific**, not universal.
- No proof yet that classical algorithms can't catch up.
- Still limited by **error correction, decoherence**, and **scaling** issues — stable thousands of qubits are still years away.
- Applications are **prospective**, not yet practical for real-world chemistry or AI problems.

Constitutional / Policy Linkages (India Context):

- **National Quantum Mission (NQM), 2023–2031** — ₹6,000 crore initiative to build 1,000-qubit systems by 2031.
- Supports **Make in India for advanced computing**, with implications for national security, data encryption, and drug discovery.
- Quantum research aligns with **Atmanirbhar Bharat** and **Digital India** goals.

Way Forward / Recommendations:

- **Global collaboration** to standardise quantum protocols and verification.
- **Investment in quantum-safe encryption** and post-quantum cryptography.
- Build **quantum-ready workforce** through higher education reforms.
- Strengthen **academic–industry partnerships** for algorithmic innovation and error correction.
- Expand India's **Quantum Research Hubs** under NQM.

Prelims Pointers:

- **Qubit:** Basic unit of quantum information.
- **Superposition & Entanglement:** Core quantum phenomena.
- **Quantum Advantage vs Supremacy:**
    - *Advantage* → Quantum computer outperforms classical ones for a meaningful, verifiable task.

- *Supremacy* → Quantum computer performs a task *no classical computer can feasibly do*.

- **OTOC (Out-of-Time-Order Correlator):** Metric to study quantum information scrambling.
- **Fourier Transform (Quantum Version):** Tool for manipulating wave interference in quantum algorithms.
- **Willow Processor:** Google's 2025 quantum chip demonstrating quantum advantage.
- **Sycamore (2019):** Google's earlier chip claimed unverified "quantum supremacy."

Mains Keywords:

Quantum Computing • Quantum Advantage • Interference • Qubits • DQI Algorithm • Information Scrambling • OTOC • Google Willow Processor • CSIR-NEERI • National Quantum Mission

Mains Practice Question:

Question: *"The claim of quantum advantage by Google marks a milestone in computing history but not yet a revolution."* Discuss.

Dimensions:

- Principle of quantum computation
- Meaning of "quantum advantage"
- Overview of Willow processor experiments
- Challenges in scalability, verification, and application
- India's preparedness under National Quantum Mission

One Line Takeaway:

Google's **Willow quantum processor** marks a verifiable step toward real-world **quantum advantage**, but large-scale practical breakthroughs remain years away.