The Quantum Principles Challenge

A unique opportunity to contribute to a fundamental question in quantum physics

What is the Quantum Principles Challenge?

We are at a pivotal moment in understanding how quantum systems reveal themselves. Recent experimental data indicate that the duration of observation plays a decisive role: short measurement times reveal quantum behavior, while longer measurement times yield classical responses. Although the exact thresholds require careful definition, the trend is robust and supported by multiple datasets [1, 2].

To explore this phenomenon further, we launched the Quantum Principles (QP) Challenge in 2026. The goal is simple yet scientifically meaningful: **replicate the below current–voltage (IV) curve** in which segments measured at short times (0.64 ms) and long times (20 ms) display distinct quantum and classical characteristics [3]. The first group to publish a successful replication in a peer reviewed journal wins the challenge. The corresponding data is to be made public on platforms such as Zenodo or OSF.

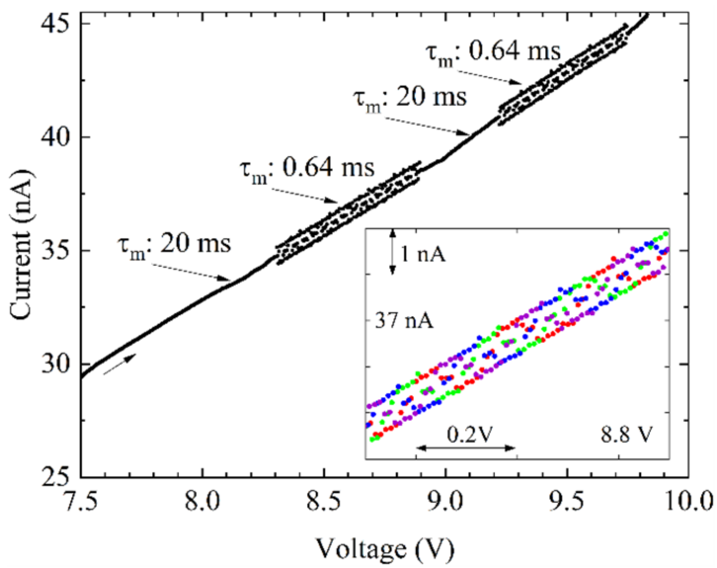

Figure 1: The IV curve to be replicated [3]

The experiment uses a single molecule positioned between two electrodes, with a microscopic fluid layer lining the electrode-molecule-electrode junction. Although this may sound delicate, I want to emphasize — based on having built these structures hundreds of times — that the process is reproducible when following a well defined, standardized protocol. This challenge is not about intuition or luck; it is about disciplined execution.

Why Participate? A Shared Scientific Mission

The QP Challenge offers research groups a rare opportunity to rally around a focused, time bounded scientific goal. It encourages collaboration across specialties — from fabrication to electronics to data interpretation — and can energize a department in a way few projects can.

Smaller institutes and universities are especially encouraged to join. This challenge is not about prestige, or resources; it is about teamwork, craftsmanship, and scientific curiosity. The best organized and most collaborative group will reach the finish line first.

What needs to be done?

All experiments are performed at ambient conditions. The main effort lies in:

1. Fabricating the device and the MCB setup
Using a bending beam assembly (BBA) with an attached glass cell, mounted in a mechanically controlled break junction (MCB) setup.

2. Preparing the measurement system
Because the device is temporary (∼10 minutes), the electronics must be validated and routinely operated beforehand. This includes:

- verifying sub nA level current levels in IV curves at high voltages 7.5-10 V with 1-2 mV resolution
- testing with a resistance bench and/or comfirming performance using a 50 MΩ resistor at the BBA location

3. Performing the IV measurements
Once the MCB and electronics are validated, the BBA can be mounted and the measurement executed. If the protocol is followed correctly, the required molecular junction will self assemble.

Required Competencies

A well rounded team will include:

- Sample fabrication specialists (BBA + glass cell)
- Mechanical/electronics workshop support (MCB setup)
- Experimental physicists (IV measurement preparation, experimental design and execution)
- Physicists (interpretation of the data, interpretation of theory)
- Project coordination (workflow, bottlenecks, scheduling)

Dividing participants into these five basic groups provides a strong starting structure.

Cost Considerations

The financial cost is modest. All materials are commercially available, and the experiment runs at ambient conditions. The most significant investment is the IV measurement equipment with adjustable scan speed and measurement time. Instruments such as the HP4155 (despite its age) are suitable, and many institutions already possess comparable but newer equipment.

The primary cost is not monetary — it is the collective effort and time of the team.

Low risk, High Scientific Value

Do not be discouraged by claims that this work is too difficult or time consuming. The physics is accessible, and the standardized protocol is reproducible. If I can perform these experiments at home repeatedly 100's of times, your institute can certainly do so in a professional environment.

The group that succeeds will make a meaningful contribution to our understanding of quantum measurement principles and will write history accordingly. I will personally visit the winning team (my expense) to give a talk and engage with students and researchers. The winning team receives a $10.000 replication grant.

If you need clarification or guidance, I am available to help. I also have a limited number of high quality unused BBAs and will provide one to each new participating team as long the supply lasts.

May the best team win. — *Chris Muller*

FAQ - Quantum Principles Challenge (MCB/BBA Experiment)

1) Fabrication & Materials

Q1. *How difficult is it to fabricate the central MCB section?*
A. It is straightforward in a well equipped workshop: the brass central section can be produced within a few days. Detailed CAD/SolidWorks drawings are available (see Ref. [4, 5]); for comparison, the drawn cell has a 4 mm outer and a 2 mm inner diameter.
Q2. *How critical is the half cured Stycast for fixing the notched Au filament on the bending beam assembly?*
A. It is critical. The two central Stycast contacts must not touch—otherwise the bending beam loop closes. Run a small design of experiments (DOE) around the suggested 2h 45min curing time, varying in 5-10 min intervals to optimize for your specific setup and hot plate temperature [6, 7].
Q3. *Is ∼0.5 mm of Kapton on each side of the cell sufficient for liquid rubber attachment to a Kapton isolated bending beam?*
A. No. During manufacturing, first surface the bending beam with a Stycast layer on a hot plate; then press the beam upside down onto a Kapton strip 10 mm wide (thickness **200 µm**) to bond firmly. After attaching the cell, remove excess Kapton but retain a few mm overhang at the beam center to provide adequate area for liquid rubber adhesion [6].

2) Measurement Protocol & Timing

Q4. *The team cannot be dedicated full time, what is the realistic project duration?*
A. About one month. The project end point is well defined; a few hours per day across the team yields substantial progress. Keep the effort time bound and manage foreseen bottlenecks efficiently to avoid wasted team time.
Q5. *Which start criterion is primary: the ∼100 nA current level or visual inspection of the cell bottom?*
A. Prioritize visual inspection. The goal is to capture a ∼10 minute window near the top of the drying curve; if the cell bottom is clean (no liquid rubber intruding), use the disappearance of the moisture liner around the Stycast contacts as the trigger—start measurement immediately once the liner vanishes [6].

3) Measurement Design & Data Characteristics

Q6. *Why is the "band of data points" associated with measurement time rather than scan speed?*
A. This requires further experimental investigation. Empirically, bands of data points are typically observed at short measurement times (and sometimes at long, 20 ms, times), suggesting relevance to the system's decoherence time. Execute a DOE varying both measurement time and scan rate across several voltage segments; generally, bands are observed at shorter measurements [3]

4) Common Pitfalls & Mitigations

Q7. *What are typical fabrication pitfalls, and how can they be prevented?*
A.

- Do not take shortcuts, reuse old devices, or rework partially built devices.
- Converge quickly to a best known method (see Refs. [5, 6]).
- Start with batch fabrication (5–10 devices per cycle) to learn fast.
- Treat each production step as critical, e.g., Kapton adhesion to the phosphor bronze beam is as important as the quality of the central notch.

Q8. *What are typical measurement pitfalls, and how can they be prevented?*
A.

- Avoid attempting to capture the full -10 V to +10 V range at high detail initially; focus on limited higher voltage segments relevant to your objective.

- Anticipate changes in the PWP layer thickness during measurements, which may force range adjustments (e.g., from 0-500 nA to 400-500 nA). Practice these scenarios in advance.

References

[1] Zenodo site, https://zenodo.org

[2] Read Me file, https://molecular-conductor-basics.nl/Home/

[3] Measuring the measurement problem - arXiv, https://arxiv.org/abs/2510.01945

[4] Replicating the MCB PWP file, https://molecular-conductor-basics.nl/Home/

[5] Solid Works drawings, https://grabcad.com/library/mcb_setup-1

[6] Detailing the natural creation... - arXiv, https://arxiv.org/abs/2106.07735

[7] A Pivoting... - arXiv, https://arxiv.org/abs/2105.07051