Physicists circumvent centuries-old theory to cancel magnetic fields

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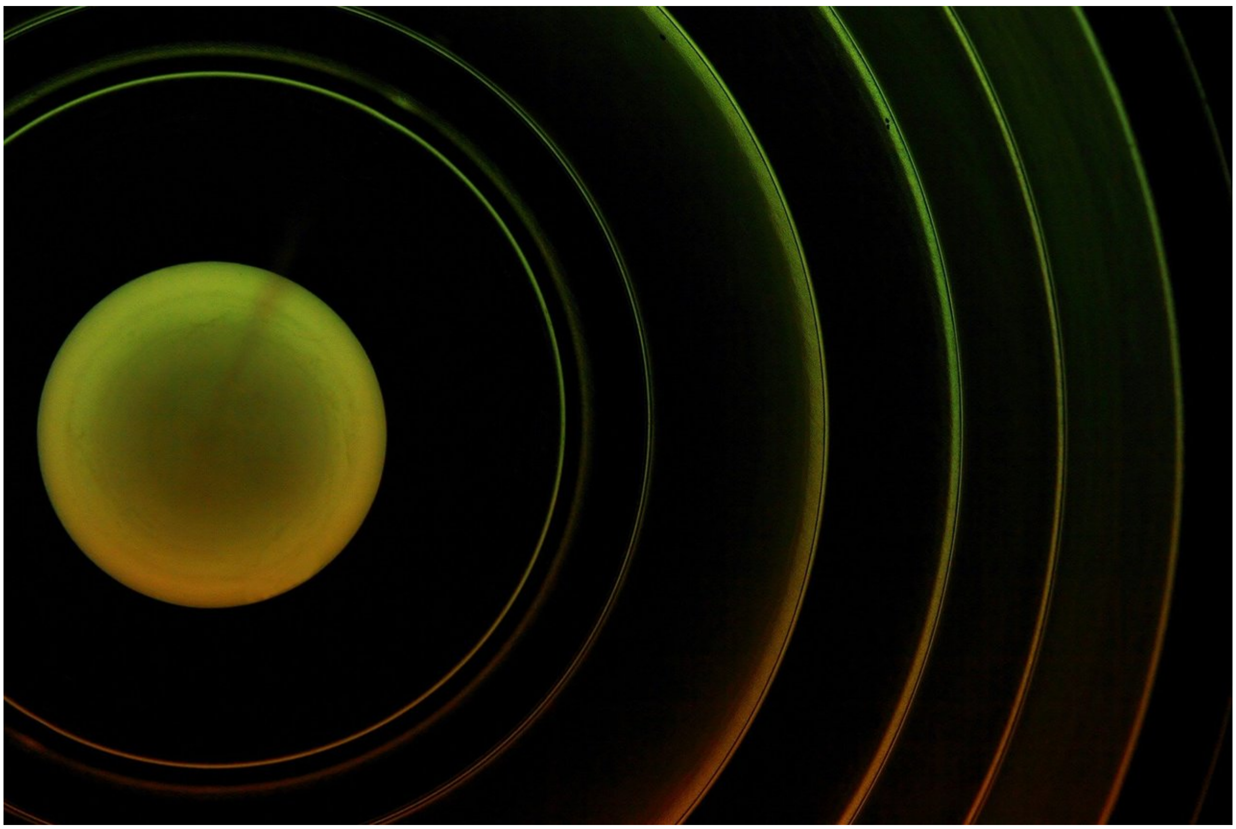

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A team of scientists including two physicists at the University of Sussex has found a way to circumvent a 178-year old theory which means they can effectively cancel magnetic fields at a distance. They are the first to be able to do so in a way which has practical benefits.

The work is hoped to have a wide variety of applications. For example, patients with neurological disorders such as Alzheimer's or Parkinson's might in future receive a more accurate diagnosis. With the ability to cancel out 'noisy' external magnetic fields, doctors using magnetic field scanners will be able to see more accurately what is happening in the brain.

The study "Tailoring magnetic fields in inaccessible regions" is published in *Physical Review Letters*. It is an international collaboration between Dr. Mark Bason and Jordi Prat-Camps at the University of Sussex, and Rosa Mach-Batlle and Nuria Del-Valle from the Universitat Autonoma de Barcelona and other institutions.

"Earnshaw's Theorem" from 1842 limits the ability to shape magnetic fields. The team were able to calculate an innovative way to circumvent this theory in order to effectively cancel other magnetic fields which can confuse readings in experiments.

In practical terms, they achieved this through creating a device comprised of a careful arrangement of electrical wires. This creates additional fields and so counteracts the effects of the unwanted magnetic field. Scientists have been struggling with this challenge for years but now the team has found a new strategy to deal with these problematic fields. While a similar effect has been achieved at much higher frequencies, this is the first time it has been achieved at low frequencies and static fields—such as biological frequencies—which will unlock a host of useful applications.

Other possible future applications for this work include:

- Quantum technology and quantum computing, in which 'noise'

from exterior magnetic fields can affect experimental readings
- Neuroimaging, in which a technique called 'transcranial magnetic stimulation' activates different areas of the brain through magnetic fields. Using the techniques in this paper, doctors might be able to more carefully address areas of the brain needing stimulation.
- Biomedicine, to better control and manipulate nanorobots and magnetic nanoparticles that are moved inside a body by means of external magnetic fields. Potential applications for this development include improved drug delivery and magnetic hyperthermia therapies.

Dr. Rosa Mach-Batlle, the lead author on the paper from the Universitat Autonoma de Barcelona, said: "Starting from the fundamental question of whether it was possible or not to create a magnetic source at a distance, we came up with a strategy for controlling magnetism remotely that we believe could have a significant impact in technologies relying on the magnetic field distribution in inaccessible regions, such as inside of a human body."

Dr. Mark Bason from the School of Mathematical and Physical Sciences at the University of Sussex said: "We've discovered a way to circumvent Earnshaw's theorem which many people didn't imagine was possible. As a physicist, that's pretty exciting. But it's not just a theoretical exercise as our research might lead to some really important applications: more accurate diagnosis for Motor Neurone Disease patients in future, for example, better understanding of dementia in the brain, or speeding the development of quantum technology."

More information: Rosa Mach-Batlle et al, Tailoring Magnetic Fields in Inaccessible Regions, *Physical Review Letters* (2020). DOI: 10.1103/PhysRevLett.125.177204

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