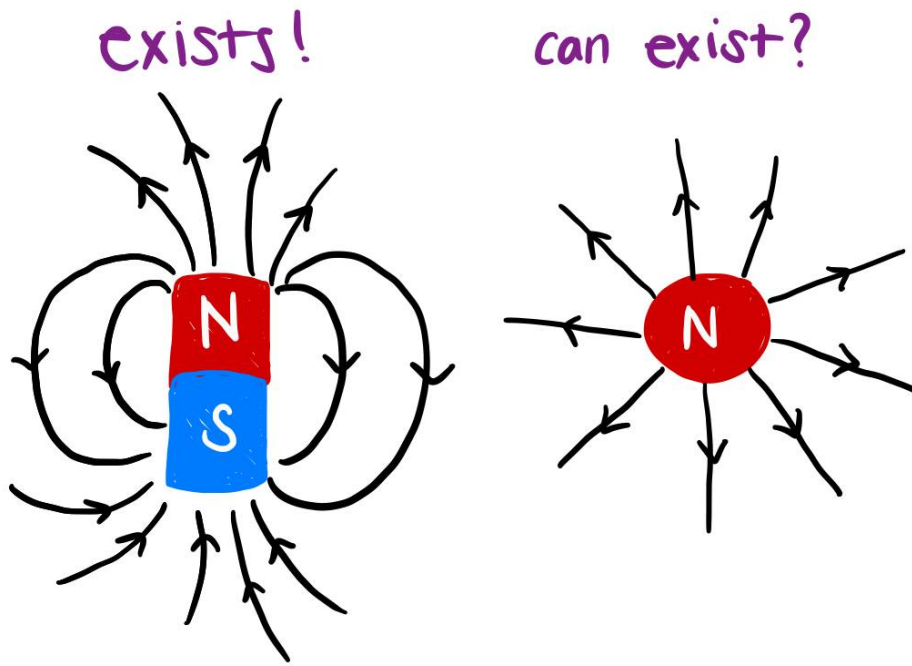


Weird Magnets... and How to Study Them?

Midori Yamada



When talking about magnets, most of us will probably think of colorful things that stick to the fridge. It was only through my studies and research that I found out they're connected to one of the greatest mysteries in science.

The magnet we know – a bar magnet – has two poles: a north pole and a south pole. When we break it in half, we won't get one half with a north pole and the other half with a south pole. Instead, each piece will create its own north and south poles, resulting in two new magnets. Scientists have wondered if it's possible to find a magnet with only one pole, just a north or just a south pole, which we call a magnetic monopole or a magnetic charge. Classical physics states that it is not possible to have an isolated magnet. But in the quantum world, it is possible. This was shown almost 100 years ago. Many scientists have tried to find magnetic monopoles, but to date, there is no known experiment that has shown the existence of magnetic monopoles.

But it was recently found that there are possibilities to create materials that contain objects that mathematically behave like magnetic monopoles. The idea is that in solid objects, there are many tiny particles, like atoms and electrons, very near to each other. All these particles jiggle, vibrate, or react together. When these particles move and interact in the right way, they can create a big "together movement", which is called collective excitation. Such

excitations can be described as if they were particles. Some of the excitations behave like magnetic monopoles, which can be felt by, for example, electrons or other collective excitations.

I am currently working on building theoretical models that create magnetic monopoles. One purpose is to provide a theoretical understanding of real compounds. The other is to see what new properties we can find from these new weird magnets. I use computer simulations to study these systems to make predictions. The numerical method I am using is very close to the experiments. The basic idea is that it keeps changing the system step by step, always trying to find the lowest-energy setup. Additionally, we try to incorporate thermal fluctuations by adding some randomness such that with a certain probability, it will choose the higher energy state. With this method, we can simulate a system at finite temperatures and see how the system becomes unstable or transitions into new phases.

Why I became a scientist.

For me, it's the mystery and excitement of discovering the unknown. Physics often goes against what we expect. When I started university, I realized how many phenomena seem contradictory or counterintuitive— things didn't work the way I thought they should. But then I realized: that's the magic. It's this thrill of being intrigued and wonder, how do these phenomena work, and the satisfaction when grasping the idea. We can predict something with math, and then — even if no one has seen it yet — it might turn out to be real.

That's how I feel about magnetic monopoles. Some scientists claim they cannot be found because they are too massive to create in particle accelerators or are too rare in the universe. Other scientists claim "one of the safest bets that one can make about physics not yet seen" on the existence of magnetic monopoles. I was drawn to physics because it's a field where the unknown is not a barrier but an invitation. Its reach—from abstract mathematical theories to real-world materials and technologies—means that even the strangest ideas can eventually shape our everyday lives.

For the concrete example of magnetic monopoles, their discovery could revolutionize how we understand and use magnetism. They might also lead to breakthroughs in data storage, as highly efficient and low-energy information carriers or quantum computing, by allowing new ways to control magnetic fields at the smallest scales. Just as the discovery of the electron transformed modern life, finding monopoles could open technologies we haven't even imagined yet, turning a once-theoretical idea into a practical impact.

If I could give advice to my 12-year-old self, it would be this: don't stress too much about figuring everything out right away. Your path won't be straight — mine wasn't. I had moments of doubt, and I wasn't sure if I belonged in science. But I kept following the things that made me curious. You don't need to find your "passion" in one moment. Just follow the sparks of interest, try different things, and keep learning. There are many doors and possibilities we cannot see at the point we are now, but which will open during the process of learning.

Whatever path you take, it will be hard. It's therefore important to surround yourself with people who encourage you to pursue your interests. Stay curious, ask questions, and don't be afraid of not knowing something. This is where science begins.

The grammar and language were checked using ChatGPT and Grammarly. The image was drawn by hand.

The author would like to thank Prof. Mark Vagins and the peer reviewer Ryota Matusda for giving me helpful advice to improve this essay.