Stories of Science: Finding our way to levitating frogs

The story of magnetism

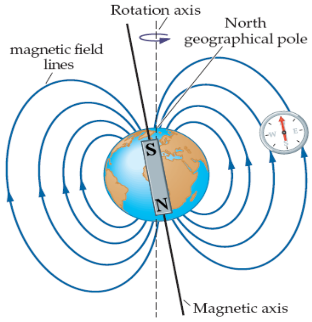
Our story begins with a spot of mining. Magnetic materials were not invented but have always existed in natural forms such as the elements Iron, Nickel and Cobalt. Magnetic materials were initially mined from the ground with the most common naturally occurring magnetic material being magnetite (a combination of Iron and Oxygen in the combination Fe_3O_4). When mining magnetite, miners would have noticed that two pieces of magnetite would be attracted to one another when placed in one orientation, whilst they would repel when one of the pieces was flipped around. For a long time in human history, though, magnets had no significant practical use.

Finding our way

Prior to 1000BC, finding your way across land or sea required using the position of the sun or stars in the sky, but these methods require good weather conditions. A revolution occurred in China, when people took pieces of magnetite and floated them on water so they were free to move. They realised that no matter what time of day or the weather conditions, the piece of magnetite would move in the water to point northwards. The first compass needle had been invented and the end that pointed northwards was called the 'north pole' of the magnet.

Seeking an explanation

In the 15th century, William Gilbert was the first person to explain why compasses all pointed north. His experiments showed that the Earth has its own magnetic field, with the magnetic poles being located close to the geographical north and south pole. His explanation then meant that the north pole of a compass needle must point towards the south pole of the earth's magnetic field for them to be attracted to one another. This meant that the magnetic poles of the earth must be the opposite way around to the geographic poles. The geographic north pole hosts the south pole of the earth's magnetic field (as shown in the diagram).



The interaction between a compass and the earth's magnetic field.

Electricity points in a new direction

Compasses also lead to the next revolution in our understanding of magnetism.
Hans Christian Ørsted was giving a lecture in 1820 when he noticed that the needle of a compass was deflected from pointing north when he turned on an electric current. Prior to this, people had only ever seen magnets move due to the presence of other magnetic fields. Realising this, Ørsted concluded that the electric current must be producing a magnetic field of its own, and that the compass was interacting with this. This realisation has paved the way for scientists to create giant magnetic fields using coils of current-carrying wire, these devices are called electromagnets.

The maths of it all

Whilst lots of experiments had shown the properties of magnets, the underlying laws (the formulae and mathematical rules) had not been discovered. Scientists use maths as an additional language with which to describe physical processes. It is a language that is understood by scientists all over the world, no matter what languages they speak. So, rather than simply saying "an electric current creates a magnetic field", James Clerk Maxwell wrote a series of four mathematical equations to show how electricity and magnetism are linked together. His description showed that electricity and magnetism are parts of a larger force called electromagnetism and his equations showed that light itself is a manifestation of electromagnetism.

Floating frogs

A baby frog floating inside a magnetic

Certain materials can become magnetic when the material is placed within a strong enough magnetic field; this is seen when a paperclip becomes magnetic when placed close to a bar magnet. Water is a billion times less magnetic than a paperclip, but with a strong enough magnetic field, we can cause water to behave as a magnet too. The physicist Andre Geim (see also: Science Story of Graphene) realised that, because living things are made up of so much water, it might be possible to make a small frog become magnetic and then repel it with a magnetic field so that it seemed to be floating. Andre Geim used the electric current within an electromagnet to create a huge magnetic field that caused the water molecules within a frog to behave like a magnet. He did this in such a way that the magnetic north pole of the frog was lined up with the north pole of the electromagnet. This meant that the frog was repelled and seemed to float in mid-air. The magnetic force between the frog and the electromagnet was so big that it counterbalanced the weight of the frog, allowing it to float freely. It has taken almost 500 years to understand magnetism, but there is every chance that we could make large enough magnetic fields to levitate humans!

Comprehension and Reflection Questions

1. Can you explain the observations of the miners in the first paragraph?

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2. Why should we not use the word "invented" when talking about the concept of magnetism?

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3. What are the different ways in which a magnetic field is created?

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4. Describe how to make a simple compass.

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5. What is the advantage of using mathematics and equations to describe processes?

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6. Why isn't water magnetic all the time? What makes water behave like as a magnet?

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Extension Activities

Ideas for things to do next:

Think about the composition of the different parts of our bodies (e.g. organs, skin, bones etc.). Describe what you think it would feel like to be levitated within a gigantic magnetic field, giving reasons for your ideas.

Further Reading

Ideas for things to read next:

Berry, M V and Geim, A K, 1997, 'Of flying frogs and levitrons' Eur.J.Phys 18, 307-313. (https://www.ru.nl/publish/pages/682806/frog-ejp.pdf)

https://michaelberryphysics.wordpress.com/ignobel/

http://www.ucl.ac.uk/EarthSci/people/lidunka/GEOL2014/Geophysics9%20-Magnetism/Useful%20papers/Magnetism.htm