Compass WIP

Keywords: 2017, Compass, Magnet, Magnetic Attraction, Magnetic Field, Magnetic Repulsion, Magnetics, Magnetism, Physics

Meta Description

Understand how compasses work - and when they will malfunction! A great way to learn about magnetism, magnetic materials and the Earth's magnetic field.

Learning Objectives

Understanding how a compass works.

Understanding the earth has a magnetic field which can be used for navigation.

Observe magnetic field lines and describe the patterns observed.

Key Terms

Bar Magnet
A bar shaped metal object which has North and South magnetic poles and an associated magnetic field around it.

Compass
An instrument used for navigation. It has an arrow which, in general, orients itself to always point North.

Earth's Magnetic Field
The Earth has a weak magnetic field all round it. It is as if there is a bar magnet in the core of the Earth.

Induced Magnet
While a magnetic material is in the field of a permanent magnet, it becomes a temporary magnet with its own North and South poles.

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Magnetic Field
The area around a magnet where magnetic materials experience a magnetic force. The field is oriented from the North pole of the magnet to the South pole.

Magnetic Field Strength
A way of quantifying the intensity of a given magnetic field. The greater the strength, the more intense the field. Measured in A/m.

Magnetic Force
A force exerted by a magnet on another magnet or on a magnetic material. Magnets always attract magnetic materials, but they can attract or repel other magnets.

Magnetic Material
A material which can be magnetised by a magnet (eg. iron).

Permanent Magnet
An object which retains its magnetic field.

Method

Step 1
Turn the glass upside down.

Step 2
Place the skewer on the bottom of the glass, making sure that one end of the skewer overhangs the edge of the glass. Tape the skewer to the glass.

Step 3
If the magnet does not have its North and South poles clearly marked, place a small piece of tape on one end as a marker, so you can tell the ends apart.

Step 4
Tie one end of the string around the middle of the magnet and tie the other end to the end of the skewer. The magnet should a suspended from the skewer. Ensure that there is enough space for your to write beneath the magnet. This is your compass.

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Step 5
Place the compass on a sheet of graph paper. Make sure that the magnet and the glass are both within the area of the paper.

Step 6
Use the pencil to draw around the the glass, marking its position.

Step 7
Turn the glass so that the magnet is close to the edge of the paper. Keep the glass on its marking.

Step 8
Draw an arrow pointing in the direction of the skewer. To do so, make a small mark at the base of the glass, directly below the skewer. Then make another mark beneath the end of the skewer. Join the two marks to finish the arrow.

Step 9
Once the bar magnet stops moving, draw an arrow on the paper showing its direction.

Step 10
Keeping the paper in the same position, rotate the glass so that the skewer faces a different direction. Ensure the glass remains on its marking.

Step 11
Repeat steps 8 – 10 until you have four or five pairs of arrows.

Step 12
What do you notice about the direction of the magnet?

Step 13
Untie the magnet from the string. Place the magnet beneath the plain paper and slowly pour some iron filings over the top of the sheet. Observe what happens.

Alternative Method

- Instead of a barbecue skewer, a wooden chopstick can be used.

Precautions

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1. Wash hands thoroughly after handling the iron filings. Do not inhale or ingest the filings.
2. The skewer has a pointed end, so handle with care. Keep your face away from the point when marking the directions. A small piece of polystyrene or sponge could be used to cover the point, especially if working with children of a young age.

Narrative

Imagine you're out hiking in the hills. You have a map and you know the direction you have to walk in. However, it's a rainy, misty day and you can't really see where you're going. What do you need to use to make sure you're walking in the right direction?*(Answer: Compass)*

We use compasses to know where North, South, East and West are located. A compass has a little magnet which always turns to face the same direction; it always makes the compass arrow point North. Why does this happen?

Every magnet has a North pole and a South pole. Opposite poles attract – so a North pole would attract South pole. It's kind of like how peanut butter and jam*just go together*, even though one is salty and the other is sweet. Similar poles, on the other hand, repel each other. Kind of like how you might think twice before adding extra salt to a packet of crisps – the result would probably be disgusting.

The centre of the Earth acts like a giant magnet, with a magnetic South pole up at the top, in the *place*we call the North pole. So, the North of the compass magnet is attracted to the Earth's*magnetic* South pole. The compass will always point towards the place we call the*geographic*North Pole, which is where the Earth's*magnetic*South pole is at.*(An image may help since this concept may be confusing) License: Public Domain Dedication. No copyright.*

Questions

Why does the magnet always face the same direction?
It aligns with the Earth's magnetic field.

Why was the glass rotated?
To show that no matter the original direction of the magnet, it will always align.

Why do the glass, skewer or paper not attract the magnet?
They are not magnetic materials.

Why do the iron filings form 'lines'?
They align with the magnetic field lines.

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Why is iron attracted to the magnet?
Iron is a ferromagnetic material.

Why is iron not attracted to one pole and repelled by the other?
Magnetism is induced in an iron filing such that it is attracted to the nearest pole.

What do you think would happen if we placed the compass near to a very strong magnet or large piece of iron?
Compass would interact with these materials.

What would happen to compasses if the Earth's magnetic field were to flip?
Compasses would just have to be re-labelled.

Brief Explanation

Magnets have a magnetic field about them, which exerts a magnetic force on magnetic materials (like iron) which enter the field. The magnetic field travels from the North pole of the magnet to the the South pole. When two magnets are placed near each other, opposite poles attract and similar poles repel.

The Earth also produces its own magnetic field. The effect is as if there is a large but weak magnet in the core of the Earth. When left hanging freely, a magnet will align with the Earth's magnetic field. The North pole of the magnet points towards the Earth's North pole. This is because the North of the magnet is attracted to the Earth's Magnetic South pole, found at the geographic North pole. This concept is used in compasses.

When a compass is placed near to a large quantity of magnetic material (eg iron or steel), the magnet in the compass induces magnetism within this material. The magnet and the material become attracted to each other. The magnet ceases to align with the Earth's magnetic field since the attraction is much weaker than that between the magnet and the magnetic material.

Detailed Explanation

The magnetic field is the area around a magnetic material where a magnetic force can be experienced. Magnetic materials include iron, cobalt, steel, nickel and some rare earth metals.

Different magnetic materials have different magnetic properties. The magnetic flux density, B, at any point in a magnetic field is the number of lines of magnetic force per unit area. The high concentration of lines at the ends of the magnet mean the density is higher there than at the sides of the magnet. The magnetic field strength, H (A/m), of a material is related to ? (?T) by the equation:

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$$H \qquad ?= ?_o?_r \qquad [1]$$

Where $?_o$ is the permeability of of free space (constant value of 4?.10-7and $?_r$ is the relative permeability of the material).

The Earth has a weak magnetic field. The South pole of the Earth's magnetic field is found near to geographic North, while the North pole is found near to geographic South. The poles are not exactly aligned with the geographical poles – there is an angle of variation between them. Approximately once every 100, 000 years, the Earth's magnetic field flips. It is believed that the Earth is nearing such a flip. If this were to occur, then compasses would have to be re-labelled.

Permanent magnets (like the one used in this experiment) can induce magnetism in magnetic materials like steel or iron. When the material is moved into the field of the magnet, induced magnetism converts the material to a temporary magnet. The induced field is such that material is attracted to the magnet. So if an iron bar is placed near the North pole of a magnet, a South pole will be induced in the end of the bar nearest the magnet and a North will be induced at the other end of the bar, which is further from the magnet. Thus, the magnetic material is attracted to the permanent magnet. When the material is moved away from the magnet's field, it becomes demagnetized. This induced magnetism occurs at an atomic level within the atoms of the material.

Applications and Research

Applications
Compasses have been used for centuries for navigation and orientation. These magnetic devices indicate the cardinal directions: North, South, East and West by aligning with the Earth's magnetic field. They are used by hikers, diversand adventurers. Sophisticated compasses are found in sailing boatsand aircraft.

Research
Permanent magnets used in computers, mobile phones, headphones, speakers, certain motors and MRI machines are made from rare earth metals. These rare materials are mainly sourced in China. Research in Europehas been focused on mining these elements, finding substitutes and in particular, finding environmentally friendly ways to recycle these magnets from devices which have been thrown away. Recycling oriented research is focused on extracting the materials from old devices and processing them so new magnets can be made.

Investigation

- Carry out the experiment very close to the front of a fridge. What do you notice? (The fridge door acts as a large and relatively powerful temporary magnet which will attract the bar magnet. The magnet will cease to align with the Earth's field).

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- When using iron filings to observe the field lines, place a second magnet under the paper, close to the first and then pour the filings over the top of the paper. Observe how the field lines of each of the magnets interact.



Subject

Physics

Education

Primary
Secondary

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Time Required

~30 minutes
Preparation: 10 minutes
Conducting: 20 minutes
Clean Up: 5 minutes

Cost

10 – 25 €

Recommended Age

6 – 9
10 – 12

Number of People

1 participant

Supervision

Required

Location

Indoors
Festivals
Laboratory

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Materials

1 wooden barbecue skewer

1 sheet plain paper

Drinking glass

Iron Filings

Graph paper

Pencil

Small bar magnet (preferably with the North and South poles marked)

String

Tape

Contributors

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Sources

Complete Physics, Stephen Pople, Pg 216, 222(Book)

Sixth Form College Physics, A. C Xuereb, Pg 213 – 214 (Book)

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Compass, China, 220 BCE

Compasses & Navigation, Errors

European Rare Earth Magnet Recycling Network

Introduction to Magnetism and Induced Currents

Magnetic field, field strength, and flux density

Make Your Own Compass – SICK Science

Navigation by the Numbers: How to Use a Compass

Rare-earth Magnet

Science Project: How does a compass work

Time for a New Compass? Earth's Magnetic Field may be Slowly Flipping

Additional Content

10 Awesome Magnetic Tricks! (Beginner)

How Magnets Work(Beginner)

Monster Magnet (Beginner)

How It's Made Magnets(Intermediate)

Japan's Maglev Train Breaks World Speed Record with 600 km/h Test Run(Intermediate)

Using a Compass(Intermediate)

2012: Magnetic Pole Reversal Happens All the (Geologic) Time(Advanced)

Researchers discover first sensor of Earth's Magnetic Field in an Animal(Advanced)

Time for a New Compass? Earth's Magnetic Field may be Slowly Flipping (Advanced)

Cite this Experiment

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