Physics: 3. Magnetism

***Please remember to photocopy 4 pages onto one sheet by going A3→A4 and using back to back on the photocopier***

Syllabus

OP45 Carry out simple experiments to show attraction and repulsion between magnets, and test a variety of materials for magnetism

**OP46** Plot the magnetic field of a bar magnet

**OP47** Demonstrate that the Earth has a magnetic field, and locate North and South.

**Questions to make you think**

1. Given three identical iron bars, two of which are magnetic, how would you identify the non-magnetic bar (no other equipment allowed)?
2. Given two identical iron bars, one of which is magnetic, how would you identify the non-magnetic bar (no other equipment allowed)?



To show attraction and repulsion between magnets

1. Hang a magnet from a wooden support.
2. Bring another magnet up close to it.
3. Notice that if you bring up a north pole it repels the north of the first magnet, but if you bring up the south-pole end it attracts the north-pole of the first magnet.

Conclusion:

Similar poles repel, opposite poles attract

To test a variety of materials for magnetism

To test a material for magnetism bring a magnet up to the material and see if the material becomes attracted to the magnet.

**To demonstrate that the Earth has a magnetic field, and locate North and South.**

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When we allow magnets to hang free, they come to rest with one end facing north and the other facing south.

We therefore label the north-facing end ‘the North Pole’, and the south-facing end ‘the South-Pole’.

‘pole’ means ‘end’.

**Uses of magnets**

* Fridge magnets
* In motors
* In speakers

**To visualise the magnetic field around a bar magnet**

**Method**

1. Place a bar magnet on a bench and place a page on top.
2. Gently sprinkle iron filings over the page.

**Result**

1. The filings with take the shape of the magnetic field.

**Tips:**

1. Cover the magnet in cling film first to prevent the filings accidently sticking to the magnet.
2. Spray paint over the patterm to make a permanent pattern.

**To *plot* the magnetic field of a bar magnet**

Equipment: Magnet, sheet of paper, compasses

Procedure:

1. Place the plotting compass beside the magnet and mark the position of the north end.
2. Move the position of the compass and repeat a number of times on both sides of the magnet.
3. Join the dots.

Result: a pattern is formed on the paper representing the magnetic field of the magnet.

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The lines joining the North and South poles are called **magnetic field lines**; they are most concentrated at the poles.

**Magnetic field lines are drawn going from north to south.**

**Did you know:**

**What is a compass made of?**

A compass contains a small, needle-like magnet balanced on a thin spindle which is free to move. Its north pole points north.

This means that what we call ‘The North Pole’ must actually be a south pole.

**Questions to make you think**

Given three identical iron bars, two of which are magnetic, how would you identify the non-magnetic bar (no other equipment allowed)?

**Exam Questions**

1. **** [2010 OL][2012][2012 OL]

The diagram shows the north pole of one magnet being brought up to the north pole of a freely suspended magnet.

1. What would you expect to happen to the freely suspended magnet?
2. What does this tell us about like poles?
3. [2007 OL]

The diagram shows a magnet freely suspended from a wooden stand.

|  |
| --- |
| RepelAttract |

****Complete the statements below using the correct word from the list on the right in each case.

* 1. When the north pole of another magnet is brought close to the north pole of the hanging magnet they will \_\_\_\_\_\_\_\_\_\_\_ each other.
	2. When the south pole of another magnet is brought close to the north pole of the hanging magnet they would \_\_\_\_\_\_\_\_\_\_\_\_\_ each other.



1. [2006 OL][2009 OL]

The diagram shows a bar magnet.

* 1. Draw the pattern made if iron filings or plotting compasses were placed around the bar magnet.
	2. Give one use of a magnet.
1. [2007]

The diagram shows the outline of a bar magnet.

* 1. Draw two *magnetic field lines* one on each side of the bar magnet.
	2. What are the *parts* labelled N and S in the diagram called?
1. 2011 [OL]

The diagram shows a bar magnet

1. What does the letter N on the magnet mean?



A student wanted to show the pattern of the magnetic field around a bar magnet.

1. Name a substance or a piece of equipment used in the laboratory to show the pattern of the magnetic field around a magnet.
2. Write the letter P below the pattern you would expect to get if you did this experiment.
3. [2008 OL]

Describe, with the help of a labelled diagram, how you could carry out an experiment to plot the magnetic field of a bar magnet.

Use the following headings: Labelled diagram, Equipment, Procedure, Result.

1. [2011]
2. What causes the iron filings to form the pattern around the magnet seen in the photograph?
3. How would you determine the position of the north pole of the magnet?



1. [2010]

The diagram shows a bar magnet with magnetic field lines on both sides.

1. Label the north pole (N) or the south pole (S) of the magnet in the diagram.
2. What information is given by the arrows on the magnetic field lines?
3. Describe, using a labelled diagram in the box provided, a simple experiment to show that like magnetic poles repel each other.
4. Name a material that is attracted by magnets.
5. How would you show that the Earth exerts magnetic forces?

**Exam Solutions**

1.
2. Repel / push away
3. (Like poles) repel
4. Repel
5. Attract
6. See diagram (one above and one below)
7. Fridge magnets / in motors / in speakers
8. 
9. See diagram (note that you must include the arrows going from N to S)
10. Poles
11. North pole
12. Plotting compass, magnetic filings
13. The first pattern is correct
14. Equipment: Magnet, sheet of paper, compasses

Procedure:

* Place the plotting compass beside the magnet and mark the position of the north end.
* Move the position of the compass and repeat a number of times on both sides of the magnet.
* Join the dots and include arrows indicating that the field lines are going from North to South.

Result: a pattern is formed on the paper representing the magnetic field of the magnet.

1. The magnetic field
2. ****suspend magnet - one end will point north
3. See diagram
4. They represent the direction in which a magnetic compass needle points/ the direction in which an isolated north pole would move if free to do so.
5. Bring a magnet towards a second magnet that is free to move (see diagram).

If two north poles or two south poles are brought close to each other they repel each other.

1. Iron/ steel/ cobalt/ nickel
2. The earths magnetism turns the needle of a magnetic compass/ freely suspended bar magnet’s north pole points north…

**Other Test Questions**

1. Complete the following in your answerbook: Like poles \_\_\_\_\_\_\_\_\_\_\_, unlike poles \_\_\_\_\_\_\_\_\_\_\_
2. List two uses of magnets.
3. What is a compass and how does it work?
4. What is a space around a magnet called?
5. Draw a diagram of a bar magnet and sketch some magnetic field lines around it.
6. Show by means of arrows the directions of the lines of force.

Teaching *Magnetism*

Syllabus

OP45 Carry out simple experiments to show attraction and repulsion between magnets, and test a variety of materials for magnetism

**OP46** Plot the magnetic field of a bar magnet

**OP47** Demonstrate that the Earth has a magnetic field, and locate North and South.

**Notes**

Magnets are one of the hardest items to keep track of in a science department.

1. Colleagues will lose them.
2. They will get them covered in iron filings; the best way to avoid this is to cover the magnet with cling-film at the beginning of the session.
3. They will lose the ‘keepers’ which go at the ends of pairs of magnets and as a result the magnets will lose their magnetic fields.
4. They will store them beside the plotting compasses and as a result the compasses will lose their magnetic fields or will have them altered such that they no longer line up north/south.

My suggestion is to allow each teacher to have their own set of magnets and plotting compasses and assume responsibility for those alone.

OP45: Carry out simple experiments to show attraction and repulsion between magnets, and test a variety of materials for magnetism

Allow students to play (‘investigate’) with two magnets per group.

I have one large box containing as many different types of metals as possible. Included also are ceramics, plastic, glass etc. Common examples of non-magnetic metals include copper (wire) and coins.

Spotting patterns is an important skill in science and sufficient time should be provided to allow the students to come with these themselves.

They should note down any observations that they make, and try to generalise.

While students will always enjoy playing with magnets, be sure to point out that they will be asked to report to the class at the end.

One possible option is have three or four of them in a group discussing it with each other, and one of them gets nominated to report to speak for the group at the end.

For instance they might note that:

1. They stick together when close by
2. Sometimes magnets attract each other, sometimes they repel (unlikely to use these terms).
3. Magnets attract some materials but not others.
4. The only materials that they were attracted to magnets were metals.
5. They stick to ~~anything~~ most metals.
6. It was not possible to distinguish why it was attracted to these particular metals.
7. The magnets are quite hard to pull apart when they are side by side.
8. The metals seem to be more attracted to the poles than to the middle.
9. The magnetism goes through other objects (like a pencil case or table).
10. When one nail was hanging at the end, it in turn became a magnet and attracted other nails.
11. When the first nail was removed from the magnet, the second nail quickly lost its magnetism.

Alternatively you could mention some of these topics in advance and ask the students to investigate.

Don’t mention anything about North or South poles yet.

Introduce the term ‘magnetic’:

**A metal which is attracted to a magnet it is said to be ‘magnetic’**.

**OP46: Plot the magnetic field of a bar magnet**

There are 12 sets of small magnetic compasses; these are used to plot the magnetic fields.

Note that students should know that the lines joining the North and South poles are called **magnetic field lines**; they are most concentrated at the poles.

**Activity:** visualising the magnetic field lines

For each group use a salt cellar containing iron filings.

Cover the magnet in cling-film and place a transparent acetate over the magnet. Then sprinkle on the filings. See the note below on Physics and Art to create a more permanent display.

**Syllabus: Demonstrate that the Earth has a magnetic field, and locate North and South.**

* It’s best done outside.
* I think it’s one of the most amazing/mysterious activities in all of science.
* I find this effect is only noticeable if I tape two magnets together with their North-poles alongside each other (hence the requirement to tape them up).
* Rather than using a finicky paper-stirrup I use a special knot with the cord itself so that the magnet lies horizontally in it. It’s too difficult to explain it here; I’ll stick a photo of it here if some-body asks me.
* I rarely get this to work inside in the lab but you’re trying it you will need a wooden retort stand and the set-up needs to be kept as far away as possible from mains electricity (not easy to do in a science lab). This is due to the magnetic affect associated with mains electricity.

**Introduce terms ‘North Pole’ and ‘South Pole’.**

When we allow the magnets to hang free, they ‘always’ come to rest with one end facing north and the other south.

We therefore label the north-facing end ‘the North Pole’, and the south-facing end ‘the South-Pole’.

‘pole’ means ‘end’.

See the note on the Earth’s magnetic field for a more detailed outline.

# Activities:

# Electromagnets

Tips for using these have been included in the **Energy** chapter (under *energy conversions*).

#### Physics and Art – making permanent magnetic field patterns

Make iron filings patterns of magnetic fields then spray the patterns with matt black car paint (outdoors) - which gives a pretty good impression of the field patterns - white on black when the filings are shaken or brushed away.

Or try black paper and white spray paint.

Use a digital camera and print out the pictures.

A messier alternative:

1. Thoroughly wax the paper before hand (rub on candle or use wax pellets from the chemists and iron).
2. Allow the paper to cool.
3. Sprinkle on the filings with magnet underneath in the usual way, (but do the whole thing on a heat proof mat).
4. Take a bunsen burner and waft it above/on the paper (slightly stronger than a safety flame).
5. Wax melts...goes shiny.
6. Leave paper to cool - iron filings are "stuck on".
7. Kids love it!
8. Be careful that the paper doesn’t go on fire if heated too vigorously at the edges (mind you it does help give that authentic 17th century effect!).

# Geographic North Pole versus Magnetic South Pole

Geographic North Pole is fixed (it has to be - Santa Claus lives there!), but the Magnetic South Pole actually moves slowly.

Sometimes it actually ‘flips’ completely; South becomes North and North becomes South.

This takes thousands of years.

This could be a problem if – like many species of bird – you rely on the magnetic field for navigation.

Apparently they have a mineral called magnetite in their brain which responds to the Earth’s magnetic field.

It is thought that dolphins and sharks may also have this ability.

**See below for a more detailed outline.**

**Points for discussion**

* Einstein first realized the wonders of the science world at the age of four when his dad gave him a magnet to play with.
* Use a broken magnet to show that a new North and South pole are created whenever a magnet is ‘halved’.
* Given a bar-magnet and another similar-looking non magnetic metal, how could you tell which one was magnetic?

# Hint: the magnetic field is most concentrated at the poles.

* If you get a chance purchase a 3-d magnetic field apparatus. It is composed of a cylindrical magnet contained within a second plastic tube; alternatively you can see videos of these on YouTube with instructions on how to make them.
* Magnets were associated with sex: the French word *aimant* means either magnet or lover. Magnets could lure lovers or keep a spouse faithful. Even now someone with a magnetic personality can ‘pull’.
* Edmond Halley (he of the comet) began what became a systematic study of compass variation, and quickly calculated that the Earth was one huge ball of magnetism, and proposed that its interior might not only be hollow, but even populated – an idea that seeped into romance, satire and (long afterwards) science fiction.
* Making a magnet: Take a large nail and stroke it in one direction about ten times. To de-magnetise it hit it with a hammer or heat it with a Bunsen.
* Why is it that some materials are magnetic and others are not?

# The Earth’s Magnetic Field

The origin of the Earth’s magnetic field is still unknown, although the consensus appears to be that it is probably caused by electric currents circulating in the molten outer part of the iron-rich core of the planet, which is at a temperature of at least 2200 °C. Either way, the situation today is that it acts as though there is a bar magnet in the centre of the Earth, with its *South end* up beside our *Geographic North Pole*.

This is why the north pole of our magnets point there (a little confusing, isn’t it?).

However the magnetic North Pole is not directly in line with the geographic North Pole, and the difference gets bigger as you travel further north (or south) of the equator (see diagram).

This difference is known as *magnetic variation*, and once the angle is known, the Earth’s magnetic field can be used for accurate navigation.

But this arrangement is not immutable over geologic timescales.

Every 500,000 years or so the system “flips”, and the magnetic field undergoes complete reversal; the north magnetic pole becomes the south and vice versa.

The last time this happened was about three quarters of a million years ago, so one might infer that a flip is overdue.

Some scientists have been bold enough to predict that it will occur suddenly somewhere around 2,000 years from now.

It’s much more likely however that the flip, while ‘sudden’ on a geologic timescale, would actually be much more gradual, taking perhaps 1,000 years or more.

This view is supported by the fact that no major species extinctions have been associated with the last magnetic field reversal 750,000 years ago.

What would happen if the molten iron inside the Earth were to cease to slosh around completely?

For starters there would be no magnetic field. And the consequences of this?

Without the protection of the magnetic field life on Earth, including life for all human beings, would be greatly subject to greatly enhanced and very harmful cosmic radiation; satellites would be nudged from orbit; the climatic consequences could well be dramatic.

**The Earth’s magnetic field can be used for accurate navigation, both by man and animal.**

Bird Migration

Many migratory birds such as swallows have a mineral in their brains known as *magnetite*, which helps them navigate as they travel across the oceans.

It has also been shown recently that sharks are sensitive to magnetic fields. Scientists put a number of hammerhead sharks into a pool which they surrounded with copper wire. When they turned on the current through the wire there was a noticeable change in behaviour of the sharks.

A study recently found that even cows in a field tend to align themselves along the magnetic North-South axis. This was first noticed when sharp-eyed observers were looking at images of the countryside using GoogleEarth.