Physics Sc1

Planning

Aim

To investigate the effect of current on the strength of an electromagnet field.

Previous Scientific Knowledge.

The passage of an electric current along a wire creates a magnetic field around the wire. The fields are in the shape of a series of concentric rings. The more coils used in the electromagnet, the stronger the magnet is. If there is one coil, and another is added, then the two coils have twice the strength of one. This is because the current going through the wire makes the soft-iron core is the factor that induces electromagnetism, as so when there is more current, there will be more wire or or a more magnetised core.

Magnets were formed when certain molten metals, (iron, nickel and cobalt,) cool . Normally when the atoms in a non magnetic crystallise, the atoms point in random directions. But because of the properties of the metals mentioned, these atoms line up into parts of the magnetic with similar directions called domains. This is because the earth has a magnetic field, and the atoms in the metal all follow these magnetic lines and form these domains. This is similar to what happens when an electromagnet is formed.

A permanent magnet will line itself up in the magnetic field of the Earth, so that one particular end of it points towards the Earth's magnetic north pole. This is called the north-seeking pole of the magnet and the other end is the south seeking pole.

The region around a magnet where a force is experienced is called the magnetic field of the magnet.

If a magnet is snapped in half, both halves will have north and south seeking poles, this can be explained by the Domain theory. This describes some metals as being full of domains, or tiny patches of magnetism. In unmagnetised steel these domains are jumbled up, so there is no overall magnetism.

In a magnet the domains are lined up so that at one end are the north seeking poles of domains, and at the other end are the south seeking poles:

Some metals, such as copper and aluminium cannot be magnetised. These non-magnetic metals have no domains to be lined up. However, an unmagnetised steel rod can be magnetised by stroking it with a permanent magnet, this pulls the domains into line:

When a magnet is broken, the new ends formed at the break will have one set of domain poles which are south seeking, and one set which are north seeking:

A magnet is said to be magnetically saturated when its molecular magnets all lie with their magnetic axis in the same direction. It isn't than possible to make the material into a stronger magnet.

The field pattern for an electromagnet (solenoid) is like that of a bar magnet. A current carrying coil of wire has a magnetic field around it and it can therefore attract magnetic materials, we will make use of this in our experiment.
The field around the solenoid causes the domains in the magnetic materials to line up in the same direction and so add to the magnetic effect. When the current is turned off the solenoid's fields stop, the ions domains return to the original random position and so the ion caused field also stops. This is the principle behind an electromagnet:

<u>Factors affecting the investigation.</u>

1. <u>Thickness of wire (diameter)</u>

It is important that this is kept constant because if the diameter of the wire coiled around the magnet changes, then a greater amount or less amount of current would flow through. Therefore the amount of current coming in contact with the magnet and strengthening the surrounding magnetic field would be varying.

If the diameter were larger more electrons would pass through since there would be less resistance and more space for electrons to pass through at one point, this would cause an increase in the current and therefore a stronger electromagnetic field.

To keep this constant I plan to keep the same wire coiled around the magnet throughout the experiment.

2. Type of wire

It is important that we use the same type of material throughout because different materials. eg. Copper and iron have different sized ions. The larger the ions the more collisions would occur and the lesser the current would be flowing through and as a result of this varying the strength of the electromagnetic field. Increasing the percentage of iron in the magnet, increases the strength of the magnet and so its permeability as ferromagnetic materials such as iron have large magnetic pereambility.

This will be kept constant by using the same wire coiled around the magnet throughout the experiment.

3. Length of Soft Iron

The longer the soft iron bar , the more domains there are which align with the direction of the magnetic field, therefore increasing the strength. Also increasing the cross-sectional area increases the number of domains which align in the direction of the magnetic field. We will not change the bar of soft iron in our electromagnet. This will be easy to keep constant.

4. Number Of Coils

To keep this constant, I will use the same number of turns coiled around the bar at each reading. To make sure the coils do not unwind, I will use insulation tape at each end of the bar, a little bit of the wire will be kept bare so it can be connected to the circuit. I performed some preliminary tests to see how the number of coils affects the strength of the magnet. I know that an increase in the number of coils will increase the strength of the electromagnet just like the current through the wire. If the coils are coiled towards end, then one end will be more powerful than the other, and affect the results. I will try to keep the shape of the coils uniform. I will keep the number of coils constant throughout the experiment.

Prediction

I predict that the as the current increases through the wire the strength of the electromagnet increases. I predict this because in ferromagnetic materials, such as iron, the electons of each atom produce a resultant magnetic field because they are moving charges and moving charges form electric current. Therefore when the current is increased more domains align in the direction of the solenoid field, increasing the overall magnetic effect .ie. Increasing the strength. I believe that when I do the experiment, proportionally as the current increases, the strength will increase. " I have made this prediction because as you increase the current, you will induce more domains to line up- and if its proportional, you would then double your current which would therefore double the domains (force). If you were to cut a magnet in half, it doesn¡¦t destroy it, in actual fact two magnets are created.

This is because the current going through the wire makes the soft-iron core is the factor that induces electromagnetism, as so when there is more current, there will be more

electromagnetism. This is the same with the number of coils, eg with the electromagnet, the more power is returned. The return and investment are not directly proportional.
The quantity that I am intending to investigate in my experiment is the strength of the electromagnet. The factors that affect the strength of an electromagnet are: The temperature, current, length of the core, diameter, the thickness of the wire used for the coils, how tightly the coils of wire are wrapped around, the material and also the number of turns on the electromagnet. I am only going to vary current in the experiment, all the other factors I will keep constant. I have chosen to vary current because, the more turns there are, the more powerful the magnet becomes and therefore the more domains there are. The thicker the diameter is, the more domains there are in the middle and therefore the stronger the electromagnet becomes. The higher the temperature is, the easier it is for the domains to be able to turn and line up. If you use a thinner wire it will cause more resistance in the experiment. All of these factors will change the strength of the electromagnet.

I decided to do current, as the others were more difficult to do. I believe that when I do the experiment, proportionally as the current increases, the strength will increase.

<u>Method</u>

1) A 2.5 m electrical wire will be coiled around a soft-iron core 100 times.

2) Crocodile clips will be connected to yellow connecting wires at each end.

3) These together with the ammeter will be connected up to the power supply as shown in the circuit diagram.

4) A plastic beaker with a piece of metal attached to it will be hung of the magnet.

5) Sand will be poured into the beaker until the beaker falls from the magnet.

6) The weight of the beaker and sand will be taken.

6) The power will be turned off. This will allow the magnet to cool.

I will vary only the current in this experiment. All other factors will be kept constant. I will measure the amount of sand at 0.3 Amp intervalsand vary the current from 0A to 2.7A . I will repeat each experiment three times for accuracy.

Preliminary Work

A number of preliminary experiments were carried out to ensure that we had a good range of readings and to identify any problems in the apparatus. These were the problems that occurred:

- The beaker unbalancing.

If sand was poured into the plastic cup too fast it would unbalance the cup and therefore fall. Also if the sand was not poured in evenly in the beaker it would build up on one side of the cup and unbalance it. To solve this problem we made sure that the cup was evenly balanced when we started the experiment. Also as we added the sand we poured it in slowly and made sure it was evenly spread in the beaker.

- The electromagnet overheating.

If the electromagnet is left on at high voltages for a long period of time our results will be affected and unfair. To solve this problem we will turn off the electricity for 3 minutes after every test to allow the magnet to cool down.

- Voltage

We began by applying a voltage of 6V, this produced a current range of 0A to 2.4A. This could give us 10 readings increasing at o.2A intervals. However because there is a small interval between the current readings this will lead to unclear results which do not show a decisive pattern.

6 Volts	Current (A)	Mass (g)
	0.2A	4g
	0.4A	5g
	0.6A	9g
	0.8A	11.5g

We decided to increase the range of current readings by increasing the voltage to 9V. This gave us a current range of 0A to 2.7A. This would give us 8 readings increasing in 0.3A intervals.

9 Volts	Current (A)	Mass (g)
	0.3A	2.5g
	0.6A	10g
	0.9A	16g

Results Table

Voltage:9V

Current (Amps)	1st reading (g)	2nd reading (g)	3rd reading (g)	Average (g)
0	0.0	0.0	0.0	0.0
0.29	39.4	35.5	41.8	38.9
0.62	74.8	76.2	78.1	76.3
0.91	102.3	101.7	106.6	103.5
1.21	121.1	124.3	128.5	124.6
1.50	143.4	146.9	147.9	146.0
1.82	179.4	183.4	184.3	182.4
2.10	200.7	204.2	201.5	202.1
2.39	218.5	222.1	224.4	221.6
2.69	235.9	238.5	237.9	237.4

Analysis

When we look at the graph we can see that as the current increases the strength of the magnet increases. This is shown by the approximate straight line produced.i.e. indicating proportionality between the rate at which the strength of the magnet increases in relation to the current.

The shape of the graph indicates the increase of current, 0.3A-0.9A, resulting in the jumbled domains in the magnet beginning to line up i.e. at one end are the north seeking poles of domains and at the other end are the south seeking poles. The gradually increasing curve from 0.3A-0.9A indicates that the low currents were beginning to be strong enough to make the domains line up. Perhaps only making the outer domains of the magnet line up, as the field lines around the coil do not start off strong enough to affect the middle domains in the magnet, which remain de-magnetised.

As the current increases, the strength of the field lines increase resulting in more domains lining up in the magnet, thus increasing the strength of the magnetic field. This in turn causes more domains to line up which in turn add to the strength of the field lines. Therefore this resulting in a greater weight being attracted by the magnet, as an increasing amount of domains are being lined up and this is shown by the approximate straight line.

Towards the end of the graph the electromagnet is running out of domains to line up in the magnet and as shown on the predicted graph the magnet should reach saturation, the point at which all the domains are lined up and the magnet has reached its maximum strength i.e. fully magnetised. However, we did not approach a point where the curve began to reach a horizontal. Perhaps this was because the current readings were not large enough to sufficiently strengthen the electromagnetic field lines and line up all the domains of the magnet.

The results do support the original prediction that as the current in increased the strength of the magnet increases. The rate of increase of the strength of the magnet begins to increase slowly on the actual graph, as suggested earlier this may be because it is harder to get the domains moving initially than it is to keep them moving, The results do increase proportionally to each other as predicted i.e. an approximate straight line was produced.

Evaluation

I think that the procedure used was quite successful after carrying out a series of preliminary experiments to try and identify and eliminate as many sources of errors as possible. All the independent variables, with the exception of current, were kept constant throughout the procedure. The following variables were all very easily kept constant by keeping them the same throughout the experimental procedure:

- Voltage in the circuit
- Number of coils of wire around the electromagnet.
- Type of material acting as the core e.g. iron, steel.

I think that the experiment was done successfully as all the repeats were similar, and we did not have any anomalous points, as shown on the graph. These could have been the result of human error in noting the readings of current or the weight of the cup, however this is unlikely as two sets of repeats were carried out

The reliability of the results could have been improved by;

- A more accurate ammeter could have been used which measured to 2 decimal places instead of one.

- A wider range of current readings and a stronger electromagnet could be used to ensure that saturation was achieved, this would improve the reliability of the results and support the original prediction more accurately.

To ensure that the point of saturation is reached I would like to repeat the investigation perhaps with more coils around the electromagnet. This would increase the current and in turn strengthen the electromagnet's field pattern, resulting in more domains being lined up and saturation occurring earlier.

I would also investigate using different ferromagnetic materials acting as the core, I know that the softer the metal is the easier it is for the domains to be lined up. The electrons of each atom in a metal produce a resultant magnetic field because they are moving charges and moving charges form electric currents. These resultant magnetic fields would vary depending on the type of metal and so it is important I experiment with different metals acting as a core. Saturation could also be achieved earlier by increasing the strength of the electromagnet.