An investigation into how the strength of an electromagnet is affected by varying the current

Introduction

I am investigating whether, and if so, how an electromagnet is affected by varying the current. An electromagnet is a magnet created by winding a wire around a soft iron c-core and running a current through the wire. Current is measured in Amperes (A).

Variables available

Voltage
Current
·N0 of coils around the c-core
Size of the c-cores (thickness/length)
Type/size of the wire coiled around the c-core

I chose to use current as my variable. I decided this because I have access to accurate equipment to measure the current, when I change it. The other available variables will be kept constant throughout the experiments.

Aim

I aim to find how varying the current in an electrical circuit affects the strength of an electromagnet.

Background Scientific Knowledge

My c-cores that I will be using will be ferromagnetic, meaning that it quickly becomes demagnetised when the current is switched off and that it is very good at increasing the strength of the magnetic field produced by the current in the wire. To become magnetic in the first place, the electrons in the c-core (the one with the wires around) will have to align themselves. This happens when they group together in domains. The majority of these domains are usually only partly aligned. When every electron in every domain is aligned, then the magnet has reached its potential and is described as "saturated." I also know that if there are more coils around the core, the electromagnet is stronger. Also the type of wire
Will affect the electromagnet's strength. I will use the Internet or an encyclopaedia to help me. I also know that Hans Christian Oersted (Ä) and Michael Faraday (Å) both found that magnetic fields and an electrical current were directly related to each other (a current can create a magnetic field).

Prediction

I predict that as the current increases, the strength of the electromagnet will also increase. Furthermore, I predict that when current doubles, the strength of the electromagnet will also double.

I can see that if there is more current running through the coils:
Power = Voltage * Current (P=VI) (* means times)
This shows that if the current increases, so does the power, thus increasing the strength of the electromagnetic field. This means that as the electromagnetic field is stronger, a larger force is required to pull the metal from the electromagnet.
Using my background knowledge, I know that magnetic effects are produced by a

moving electrical charge (current). This tells me that the current will cause the c-core to have a magnetic field.

Safety

I will need to use goggles in my experiment, because I will be pulling c-cores apart, and when they come apart, there will be a danger of one hitting me in the face. Common sense dictates that the variable resistor could become hot, so it will not be touched, apart from when the resistance is required to change.

Preliminary experiments

I tested my plan by doing a preliminary experiment. I checked whether I had too many coils and how easy it was to keep the voltage constant. I found that the electromagnet was too strong (I couldn't pull the c-cores apart easily enough) with 20 coils, so I decided to use 10 coils. I tested my plan with 10 coils and it worked out much better, because I could pull the c-cores apart a lot more easily, so I could take more accurate results. I also found that, to keep the test fair, I would need to keep the voltage constant, so I decided to include a voltmeter into my circuit plan. I found that anything less than 10 coils was too weak to get results which could be measured accurately. Also, it was not very accurate when I pulled the c-cores apart, horizontally, due to friction on the desktop that I was using to put the equipment on. Here are the results from the preliminary experiment:

Current results (N)

1 amp04.5

2 amps23

3 amps48.5

4 amps>100

5 amps -

6 amps -

Plan

This is my plan after having consulted my preliminary experiments:

1)I will set up the apparatus as shown in the diagram below.

2)Set the current at the right amount of amps.

3)Use newtonmeter to pull c-core from magnetised c-core (slowly).

4)Record the force (N) and minus the weight of the c-core.

5)Repeat 2-4.

Equipment list

1 Power Pack

1 Ammeter

2 Soft Iron Cores in a C-shape

Wires

1 Voltmeter

1 Variable Resistor

Newtonmeters (0-1,0-10,0-50N)

I am going to test how many Newtons it takes to pull the metal away from the electromagnet, with different currents. I will have to subtract the force due to gravity that the C-core has. This is because I will be pulling the c-core, from the

electromagnet, vertically. It will give me the true reading of how many Newtons it actually took to pull the objects apart.

Fair tests

I will make it a fair test by keeping everything the same, apart from my variable (current). To change the current, I will need to change the resistance, which, in turn, will change the voltage (V=IR), so I will need to include a voltmeter into the circuit to make sure that the voltage can be monitored and will be easy to correct.

So, the things that I am keeping constant are:

-Alignment of c-cores (same surface area of the ends of the c-core touching the magnetised c-core ends),

-Voltage (0.5V),

-Type of wire and its length,

-Type of metal core,

-Same c-cores each time,

-Number and tightness of coils,

I will use the ammeter to check that I am doing the test with the correct current. I will use the voltmeter so that when the voltage changes, due to resist ance, I can correct it on the power pack. I will use 6 different levels of current (1,2,3,4,5 and 6 amps) and I will repeat each experiment once
and the take an average to help make a fair test with reliable results. This
will give me a good range of results, which can be plotted on a graph, so they will be easy to analyse.

Analysis

(GRAPHS NOT AVAILABLE). My results are good. They are what I basically expected (strength of electromagnet increased as the current increased. My graphs have shown this, and they each show a good curve of results. I have included a graph of my results, a graph of my found pattern results and a graph to compare these two curves.

My results don't fit my prediction. This may have been due to the fact that my prediction wasn't researched thorough. I may have one or two anomalous results. For example, the first result seems to be very low, and there is a big difference between both of my results at 4A. I will be able to discover which are the anomalous results when I come to find a pattern in my results. However, I still believe that my results are very good and that it will be easy to find a pattern from them.

After having consulted my results, I have been able to find a pattern:

This doesn't show any pattern at all, but if I were able to manipulate my results slightly, it shows a distinct pattern:

Current real results pattern results

1amp 1.55 3

2amps 8.3 8

3amps 14.9 15

4amps 22.9 24

5amps 36.4 35

6amps 47.9 48
My true results aren't that much different than the ones that I found to fit a pattern, apart from the first reading, which was much too low (anomalous result). The explanation for this anomalous result is shown in the "Evaluation." The pattern can be showed as below:
Using this pattern, I was able to find a formula:
F=I2+2I (where F= Force required to split c-cores (N), and I= Current (A))
I can show that the formula F=I2+2I works, using my manipulated (pattern) results:
1amp 12+2*1=3 (correct)
2amps 22+2*2=8 (correct)
3amps 32+2*3=15 (correct)
4amps 42+2*4=24 (correct)
5amps 52+2*5=35 (correct)
6amps 62+2*6=48 (correct)
Conclusion
I have found that increasing the current of the circuit does directly affect the strength of the electromagnet, although it is not directly proportional. My results were quite accurate, but they are still very good (allowing for human error). I found that my prediction was correct to a certain extent, because I did predict a direct relationship between the increasing strength of the electromagnet and the increasing current. However, my prediction to a degree of accuracy was incorrect. A possible explanation to why the power of the electromagnet is increased by the current increasing could be the equation that I mentioned in my prediction (P=VI). It shows how changing the current directly affects the power of the circuit, if everything else is kept constant (e.g. voltage). However, I still cannot give an explanation as to why there is a pattern like the one that I found. I still managed to find a general equation for my results (F=I2+2I). All of my results support my conclusion, except my 1A
reading, because it was just over half as much as it should be to fit the pattern. Therefore, my conclusion should be correct for every test that
involves varying the current to affect the strength of an electromagnet, if everything else was kept constant. In my case, my experiment followed each of those mentioned factors.
I think that my most useful graph was the one, which compared my set of data and the data that I created from my general formula. This is because it showed me which of my results were slightly wrong, to see if I had any anomalous results.
Evaluation
Overall I consider my experiments to be very successful, as the results were clear enough for me to analyse and interpret to find an equation and a pattern. It completed its intended purpose, so I am pleased about my findings. The experiments were adequate to prove my theory, because every result, except one, fitted my pattern within reason.

I think that my test was perfectly fair, because everything was done in exactly the same way, except for the variable, which I chose to test. However, not all of my results were 100% accurate, which could have been due to:
-Human error of reading the newtonmeters/Voltmeter/Ammeter,
-Changing temperature of the variable resistor,
-Lack of accuracy of the newtonmeters,
-Loose connections (e.g. coiled wire attachment to crocodile clips),
-Bad alignment of the c-cores.
I think that the most significant of the above was that I couldn't write my results to any decimal places after it got past 10N, due to an inaccurate meter, which affected my results. If I did some further experiments, I would not be surprised if I got more-or-less the same results. However, I could expect a different anomalous result. This is only providing that I do my further experiments using the same equipment that I used for my original experiment; otherwise the results could be greatly affected. The only thing that I would rather change is to have a digital voltmeter instead, as it would be easier to read than an analogue meter. This means that I would be less likely to make a mistake. Also, I would have liked extra time, so that I could take an average of 3 results, which would make the average more accurate.
If I had extended time, I could investigate the experiments further, and get more accurate results. I would like to have done more experiments with a higher current. This would mean that I could investigate the saturation theory, and whether beyond a certain point, it does not matter how much you increase the current, the electromagnet will not get stronger. Also, I could mathematically prove my theory about the current directly affecting the electromagnets strength, due to its increase in power. I could measure the gradients of the graph to find the exact increase in strength between each measurement. It would also be useful and interesting to see whether
the heat of the variable resistor affected the results. My anomalous result could have been due to the variable resistor being cold, during the first experiment, when all of the equipment was cold.
I would also like some extra time to do some proper research into the findings of the first people to test this investigation. It would also be interesting and useful to discover what they found.
Acknowledgements
Encarta '98
The Cambridge Encyclopedia
Amperes theory web page for engineers