Physics coursework

Investigating electromagnets

Aim: To investigate a variable that affects the strength and effectiveness of an electromagnet.

Introduction: In my following coursework, I will carry out an investigation on a variable, which affects the strength of an electromagnet. I tend to also create an accurate enough analysis, which will help me determine why the variable investigated, affected the strength of the electromagnet.

Background research:

An electromagnet is also known as a solenoid. An electromagnet usually consists of coils of wire wrapped around a magnetic core. The core could be Iron, nickel or cobalt, which are good electromagnets. Usually an electromagnet would consist of an iron core as this is the best at magnetising and proves readily available, because of these reasons I think the core, which I will use for the investigation would have to be an iron based core. Other cores that could be used prove ineffective as they become permanently magnetised so therefore are unuseful as they can only be used once.

Above we can see the magnetic field generated by a round wire carrying electricity (picture taken from encarta). This shows the way in which an electromagnet works.
If a solenoid is wound in the form of a helix, there will be a magnetic field. However, with the introduction of an iron core to go within the helix the strength of the field will be greatly increased. Microscopic domains in the core align themselves in the direction of the field thus increasing the strength of the field. When all the domains have aligned the core would have reached its saturation point.
Iron cores tend to have domains which are more jumbled up so when they are objected to a magnetic field or solenoid their domains become lined up but when the outside influence is removed the domains become jumbled up again.

Variables that affect the strength of an electromagnet:

Sources: physics matters (GCSE textbook), A-level textbooks, Microsoft Encarta 1999 and set knowledge

Current:

As the current is increased in a wire, the strength of the magnetic field becomes greater and therefore more effective. An A.C current would demagnetise the core while a D.C. current would magnetise a core. This is because the D.C. current is direct and therefore all the electrons are arranged in the same order creating a magnetic field. When the current is A.C, the electrons are free to move where they want so there is no magnetic field. When an electromagnet has a current induced in it, it becomes magnetised and the greater the current induced the greater the strength. This is because the microscopic domains within the nail receive a greater current and so the strength and actions of these domains are increased. In addition, if the solenoid receives greater current then the field it generates will be stronger. . On the power pack, which I will be, using there is an option to change the voltage, which could be altered to change current with the aid of an ammeter.

Number of coil's around a core:

A greater number of coils in the wire/solenoid around the core will increase the strength of the field produced by that electromagnet. This is because the amount of power given to the solenoid and core is increased so the core receives an increase in power, so the domains become aligned strongly, and more domains become aligned. In addition, with an increase in coils the coils cover a greater surface area of the core. This means the coil covers more domains and therefore more domains are influenced. Each turn has it's own field so more turns mean more fields. The greater amount of turns causes constructive interference, Which increases the size and strength of the magnetic field.

Type of wire:
The type of wire may also affect the strength of the electromagnet. If a wire is thicker then current can flow more easily and the current will increase so the strength of the electromagnet will increase. In addition, the length of wire may also affect the strength of the electromagnet because as the wire becomes longer there is a greater amount of resistance so current may decrease.

Preliminary work:
In my preliminary work, I carried out the method shown later in the investigation to help me decide what to investigate and what range to use. The problem with investigating current is that the power pack would reset at higher voltages above six for 10 coils. The problem with investigating the affect of different types of wire is that this variable would be too hard too measure. Investigating the affect of number of coils is feasible because the power pack does not reset and this variable could be easily measured through counting.

What I will investigate:
The variable that I will investigate will be the number of coils for the above reasons found in preliminary work. The range, which I decided to choose, from looking at, the preliminary work was from 10 to 100 coils.

Prediction:
I predict that with a greater number of coils around the nail that the strength of the electromagnetic field will increase. This is because when there are a greater number of coils around the nail then more of the microscopic domains in the nail are influenced to follow the same direction of the magnetic field produced by the solenoid and give the core a increase in it's magnetic strength. In addition, an increase in coils will increase the size of the solenoid. With a larger solenoid there is bound to be a greater magnetic field because of the greater current and size of the solenoid. In addition, if the size of the solenoid is greater then the solenoid will have greater power aligning more domains. Each turn has it's own magnetic field so more turns mean more fields. The greater amount of turns and fields in the solenoid causes constructive interference, Which increases the size and strength of the magnetic fields.

Fair test:
To ensure a fair test I will carry out the following precautions.

- Make sure that every time the core that I use will be iron to stop residual magnetism, which may affect the results.
- Use wire of same type to keep the same amount of resistance.
- Maintain the same voltage on the power pack.
- Measure the current not necessarily to keep a fair test rather than to reach a justified conclusion considering the changes in current.
- Use the same number of coils every time.
- Use the same equipment each time.

Above we can see an iron nail which is the core that will hopefully have no residual magnetism, which could affect the results. The wire wrapped around the core is the solenoid and it will mainly determine the strength of this electromagnet.

Safety:
All electric components should be handled carefully at all times, regardless of whether they are live or not. The iron nail and the core should be handled with great care because as electricity passes through them they become hotter, so electricity should always be turned off when not in use and only touch the nail wills it is unlikely to be hot.

Outline plan:
In my investigation, I will carry out a plan that will help me to investigate the affect of number of coils on the strength of an electromagnet. I propose to take down the extension of a Newton meter when the Newton meter pulls on the iron nail, this can happen because the hook of the Newton meter is attracted to magnets. The extension will give an indication of the strength of the electromagnetic feld.

Method:

I will change the variable of coils around a nail by starting with 10 coils and continue to wrap a further 10 coils the next time up until a 100.
I will keep the variable of voltage the same. The current may not be able to be kept the same because there is no method of maintaining current, but it will be measured to see how current may have affected the results. Two different people will count the number of coils on the nail to see if it has the correct number of coils. The wire will be kept the same throughout the investigation and the length will remain the same.

Apparatus:

Clamp: To keep nail wrapped in coils in place.

Clamp stand: to hold clamp in place.

Iron nail: To be wrapped in coils to pull down on the Newton meter.

Newton meter: To measure extension (and subsequently the strength of the electromagnetic field). Zero to10 Newton meters.

Wire/Coil: To act as the variable around the nail.

Power pack: To supply power to the coil and to control voltage. A.C/D.C function will be used to magnetise and demagnetise the nail. 0 to 12 volts

Crocodile clips and connected wires: To connect the coils to the power supply.

1. Set up apparatus as shown above but with the inclusion of an ammeter somewhere in the circuit. Wrap the desired amount of coils around the nail starting with 10 and attach crocodile clips to the ends of the coil.
2. Set the voltage on the power pack to 2 volts.
3. Put the Newton meter over the iron nail and let it make contact with the iron nail lift the New ton meter until it's no longer in contact with the nail.
4. Take down the result of the point at which the extension of the Newton meter had stopped.
5. Repeat this three times.
6. After three repetitions have been carried out for each experiment, and then add on another 10 coils to the nail. I.e. 10.20,30,40,50 and so on up until 100.

Accuracy of results

Three repetitions of the experiment for each certain number of turns on the nail will be carried out. Repetitions allow us to see whether some results are anomalous, and an average will give results that are more accurate because it takes into consideration what will happen the majority if the time for that certain experiment. An average of these three repetitions for each number of turns will be taken down to get more accurate and reliable results. I will plot a point 0,0 on my graph to show that there was no extension at this point and to make my line more accurate on my graph.

Proposed results table

The extension measures the strength of the electromagnetic field.

Number of coils	Extension 1	Extension2	Extension 3	Average extension
10				
20				
30				
40				

50				
60				
70				
80				
90				
100				

Observation

In my experiment, I had an ammeter placed in the circuit to see how current may relate t o the results, which I obtained. The different currents are displayed in the extra column that I decided to add on to my original proposed result table to show current. I had observed that in the experiment that current had increased and decreased at several points following no pattern.

When there were more coils on the nail the extension did tend to increase but in a few occasions, it did stop extending the Newton meter at short distances. These anomalous results may have been the result of the holder of the Newton meter holding the Newton meter in a certain way not allowing getting near optimal results. This may have been because as the Newton meter was moved the surface area contact between the hook and the iron nail might have been decreased. So the electromagnetic influence of the nail on the hook could have been decreased, also if the Newton meter was pulled really quickly then the full extension achievable may not have happened due to the rapid movement.

When there were a greater number of turns on the electromagnet, I observed that the electromagnet would become quite hot and subsequently the power pack would reset, this meant we had to take our results as quickly as possible before the power pack would reset.

As far as I could tell, there was no residual magnetism on the electromagnet.

Actual results table

The table below has units for extension (strength of field) measured in Newton meters in columns 2,3,4and five. The current is measured in amperes. All the below results are for a voltage of two. Only the number of turns was purposely changed.

Number of coils	Extension 1 Newton meters (Nm)	Extension2 Nm	Extension 3 Nm	Average extension Nm	Current Amperes (A)
10	0.3	0.5	0.4	0.40	6.8
20	0.8	0.7	0.9	0.80	7.2
30	1.3	1.1	1.1	1.16	7.4
40	1.6	1.7	1.6	1.63	7.2
50	2.0	2.1	1.9	2.03	7.4
60	2.2	2.3	2.3	2.26	7.5
70	2.6	2.4	2.5	2.50	7.7
80	2.7	3.0	2.6	2.76	7.9
90	2.7	2.9	2.9	2.83	7.7
100	2.9	3.0	3.0	2.96	7.8

Analysis

From my graph and results table, we can see the general trend that as the number of turns go up, so does the extension of the Newton meter. By looking at the results table we can see that extension goes up but in no set difference, although there is a extension there is no way of knowing exactly how much the extension will be. The extension of the Newton meter gives an indication of the strength of the electromagnetic field.

Also as there are more turns on the iron nail then there are more coils to take effect on the microscopic domains within the iron nail, this would have accounted for a lot of the strength within the electromagnetic field.
My explanation for the change in gradient from steep to flat is that when there were it will be.
By looking at the graph, we can see there are two lines, one is a straight line and the other is a curved line, which follow the general trend of the results. From the straight line we can see that my prediction is proved true which is as the number of turns go up so will the extension of the Newton meter.
However, by looking at the curved line that is a more accurate representation of my results we can see that the curved line initially starts almost straight and is steep. However, as it reaches70/80 coils the curved line begins to bend and become more straight an in line with the horizontal axis. Essentially the line starts with a steeper gradient but as the line progresses, that line becomes more horizontal. The reason for the general trend of the line showing that, as there are more turns there is a greater extension is that the strength of the electromagnetic field increases. The scientific explanation for this is, as mentioned in my background research is that as there are more turns of the wire on the electromagnet the magnetic field increases in strength which I think is down to several factors.
Each turn of the wire has it's own small electromagnetic field, so when there are more turns of the wire each with it's own field (solenoid) then the strength of each individual field will form a collective of small electromagnetic fields. All these fields will cause constructive interference amounting to one large and strong electromagnetic field. Few turns on the coil some of the microscopic domains within the iron core would have been influenced to follow the direction of the magnetic field. Neighbouring microscopic domains would have also been affected from current and charge carried over in the core, as they were not being used. However, as there were more coils the iron core would have had a lot of its domains affected by the coil already. This is the point were the iron core is saturated and so there weren't many domains left to be affected by the number of turns leading to a little increase in the strength of the electromagnetic field.
My original prediction had come true because as we can see from the graph as the number of turns went up so did the strength of the electromagnetic field. One thing that I didn't expect was that when the number of turns increased that the amount that the strength of the electromagnetic field increased by had decreased due to the saturation of the iron core. Although my prediction was proved true by all obtained results we can see that the turns and extension are not proportional and the gradient decreases.
I am pretty sure that if I continued taking more results by obtaining extra results that when the number of turns of the wire had increased that the strength of the electromagnetic field would have only increased by small unmeasurable amounts which could not be measured by my equipment available.
My continued curve of best fit which follows the general trend of all the results, shows generally that if there were more results obtained then the results would show very small increases in the extension of the Newton meter if the number of coils was increased. This is because the strength of the field would only increase because of the addition of another small magnetic field and not because the domains were aligned because they would have already been used up, so an increase in this way would only account for little of the increase.
As we can see from the result table, the current had generally increased with more turns although there were a few anomalous results. This shows us that when there were more coils there was more current meaning that the solenoid had received an increase in power, which probably accounted for some of the increase in electromagnetic strength.
My explanation for this is each little, turn of the wire around the core has it's own electromagnetic field (X). As there is an increase in the number of coils there are more electromagnetic fields (X). With more electromagnetic fields, the strength of the overall electromagnetic field is increased because the strength of each little electromagnetic field produced by each turn is all added (X+X) together to produce the greater electromagnetic field which has a greater strength as shown by the graph. This is one of the scientific reasons for an increase in the strength of the electromagnetic field and subsequently extension of the Newton meter.
Another scientific explanation for the increase in strength of the electromagnetic field with an increase in number of turns is that as there are more coils there are a greater number of microscopic domains being influenced to align in the same direction. I think there are several reasons for the microscopic domains being influenced to align a lot or less. The first one being when a core that can be affected by a field (in this case iron) is placed in a field the microscopic domains within that core are aligned with the field, this action increases the strength of the electromagnetic field. Therefore, as an iron core is placed within a field the microscopic domains would follow the trend of the field. The other reason for the domains being aligned is when the coils are wrapped directly around the iron coil these turns around the core affect the microscopic domains directly as there field of a turn affects the domains within the iron core. By looking at the two above variables for the saturation of the domains, we can

obviously see as my results state that if there are more turns then there are more domains influenced to align with the field. This is because when there is a stronger electromagnetic field due to the addition of the individual electromagnetic fields then more microscopic domains are influenced to follow the general trend of the electromagnetic field because of a stronger electromagnetic field affecting the core and it's domains. Also, when there are more turns of the wire around the iron core containing the domains there are more wires directly affecting the domains with there own individual electromagnetic field which aligns the domains. When all the microscopic domains are aligned, they would have reached their saturation point where no more domains could be aligned. The saturation would also explain why there was a decrease in the amount that the Newton meter had extended. As there was a greater saturation the amount that the Newton meter had increased with its extension had decreased a lot showing that the alignment of microscopic domains contributed greatly to the strength of the electromagnetic field, because the increases were very small after the saturation points. The only reason for the actual increase in the extension at the saturation points would be the addition of extra coils (X+X).

Evaluation

I think that the test I carried out was a fair one because the results that I obtained could have been backed up by scientific explanation. My measurements were made as accurate as possible by carrying out all the things as mentioned in fair test and by producing replications of the same experiment.
All my results fitted the pattern in my graph to an extent that I could say that all my results were justified and accurate.
I would carry out an experiment on the nail when there were no coils wrapped around it to see if the nail starts with residual magnetism so can be taken into account in my analysis.
If I had more time to carry out experiment, I would have investigated a greater number of coils to see what the further affect would have been. In addition, with time permitting I would have carried out a greater number of repetitions.
I feel quite surely that the results that I got were accurate enough for me to form an accurate conclusion. My averages show this as they all follow a general trend that is stated in my analysis. However, there are a few anomalous results e.g. column extension 2, number of turns, 90 where the extension in fact decreases from 3 Newton meters to 2.9. These results could be down to several factors such as the inaccuracy of equipment or human error, but these results only slightly affect the average so the conclusion remains valid.
I also would have used a method in which I could hold the Newton meter in the same place and slowly lift it at a constant rate; this could have been done with a robotic arm.
In addition, I would have used a very accurate Newton meter with an easier to read digital display.
Another method would be to have used an electronic scale and see by how much a magnet affixed to the scale would be attracted to an electromagnet hanging over it, with increasing number of turns around the core. The negative readings on the scale could be used to see by how much the nail attracts itself to the electromagnet. This method would require a very sensitive scale (0.001g) because the nail will be very minutely attracted away from the scale.