INVESTIGATION INTO THE FACTORS AFFECTING THE STRENGTH OF ELECTROMAGNETS

Planning Experimental Procedures

There are three main factors which affect the strength of an electromagnet:

1. The size of the current.
2. The number of turns the coil has.
3. What the core is made of.

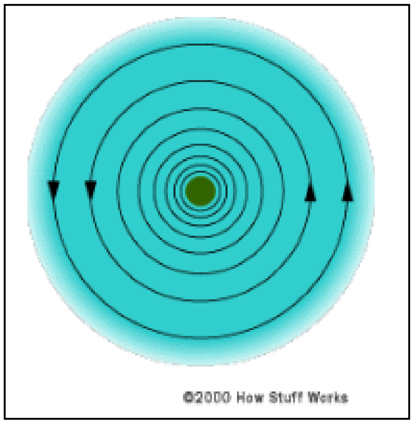
For this investigation, I intend to explore how the number of coils of insulated wire around an iron core effects the amount of paper clips attracted to the electromagnet. My prediction using results from the pilot study is that if I increase the number of coils the strength of the electromagnet will also increase (more paper clips will be attracted to the EM). However I have read that in theory, the strength of the EM will double as the number of coils are doubled (EM strength is directly proportional to the number of turns of coil).

I will use the following apparatus for this experiment: paper clips, soft iron core, insulated wire, voltmeter, ruler, wire stripper, crocodile clips and power pack. I have chosen this equipment because it suits the experiment I am doing and should also give me accurate results. The power pack will allow me to work with a safe voltage and to convert mains AC to DC.

First I will connect the voltmeter to the power pack. From the voltmeter I will attach two connecting wires to the crocodile clips. I will then cut a large length of insulated wire and wrap the desired number of coils tightly around the soft iron bar, this is my electromagnet (EM). Then I will remove 3cm of the plastic coating around the copper wire using a wire stripper. I will then connect the ends of the exposed wire to the crocodile clips. Then the power pack will be turned on and set at the correct voltage of 2V. Then I will hold the EM two centimetres above the container holding the paper clips. I will then remove the paperclips onto a blank sheet of paper and switch of the power supply. I will then count the number of paper clips picked up with the EM and record the results in table 1. I will then increase the number of coils and repeat the above procedure. The following diagram represents the apparatus set-up:

In the pilot study I found that the length of the copper wire at the start had to be 2m long. I also took some readings which gave a correct pattern of results, therefore I decided to use the same method of doing the actual experiment.

The magnetic field around a wire is circular and this field weakens as you move away from the wire as shown below. (Diagram 2)



The field is perpendicular to the wire and the field has a direction that depends on direction of the current flowing in the wire (Maxwell's screw rule). Because the magnetic field around a wire is circular and perpendicular to the wire, an easy way to amplify the wire's magnetic field is to coil the wire and make a solenoid. For example, if you wrap the copper wire around the iron bar 10 times, connect the wire to the battery and bring one end of the iron bar near to a compass, it will have a much larger effect on the compass. In fact, the iron bar behaves just like a bar magnet. This is because as the number of coils increase the magnetic field around the iron bar also increases. This is because each coil acts as a magnet and as the number of coils increase the strength of the magnet also increases. (See diagram 3 below)

To ensure a fair test the distance between the iron bar and the paper clips will be kept the same, in this case two centimetres. This will ensure accurate results because the distance will effect how many paper clips are attracted to the iron bar.

My readings will start from 10 number of turns up to 100 number of turns. Ten readings will be taken, as the number of turns will go up by 10 each time. It would be difficult to record readings outside this range because the iron bar is not long enough. However, this range should be large enough in order to give me an accurate set of results. Each reading will also be repeated three times to ensure there are no anomalous results.

Analysing Evidence

The experiment went according to plan and I also recorded some observations. As the number of coils were increased the copper wire became slightly hot. The voltage was also fixed at 0.92V.

I recorded the results in the table below:

	No. of paperclips picked up		
Number of coils	1st reading	2nd reading	3rd reading
10	7	6	4
20	13	22	16
30	30	30	33
40	34	40	36
50	53	65	54
60	60	76	75
70	80	89	85
80	89	102	97
90	99	104	102
100	100	105	111

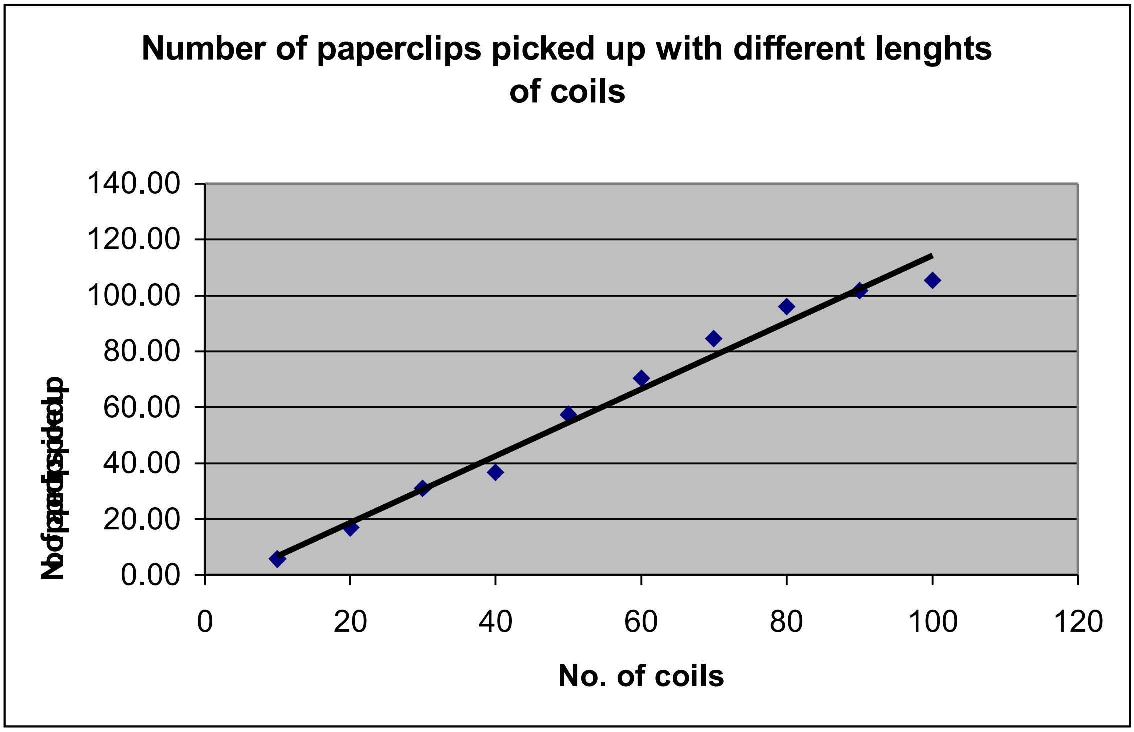
Table 1

A further table was drawn in order to show the average results.

	No. of paperclips picked up
Number of coils	Average
10	5.67
20	17.00
30	31.00
40	36.67
50	57.33
60	70.33
70	84.67
80	96.00
90	101.67
100	105.33

Table 2

These results were plotted onto a graph, which is shown on the following page.



From my results it is evident that as the number of coils increase so does the number of paper clips picked up. This is what I expected to happen as shown by my prediction.

With ten coils the EM was quite weak, e.g. it only attracted approximately 6 clips. When I doubled the number of coils the number of paperclips attracted was 17. I had expected the number of paperclips to double to 12 as I predicted . When I doubled the number of coils from 20 to 40 the number of paperclips attracted increased from 17 to 36. This almost agrees with my prediction. This is also true for 50 coils and 100 coils. My graph shows almost linear relationship between the number of coils of the solenoid and the strength of the EM.

Scientific reason for this is that each turn of wire acts like a single magnet and produces a magnetic field (see diagram 1). As the number of turns increased so did the strength of the magnetic field. The fields combine to give stronger magnetism, hence more paperclips are attracted to the EM.)

Evaluating Evidence

The graph shows that as the number of coils increase so does the number of paper clips picked up. The two factors are proportional to each other because the graph shows a linear relationship. The experiment shows that the electromagnetic field of the solenoid increases as the number of coils are increased. Therefore, more paper clips are picked up.

As the graph is a straight line the gradient can be worked out by dividing the vertical height by the horizontal height:

$70 \div 60 = 1.17$

With this figure it is possible to work out the number of paper clips picked up by multiplying the number of coils by 1.17.

The experiment was successful as it produced accurate results to back up my prediction. My prediction turned out to be correct because the number of paper clips picked up did increase when the number of coils increased. The number of coils increase the strength of the magnetic field because when the wire is coiled it helps to amplify the magnetic field. Scientific reason for this is mentioned under the analysis of evidence.

From the graph the readings for 90 and 100 coils do not seem the fit the linear relationship. This could be due to the heating effect produced by the current which will lessen the strength of the EM; hence the number of paperclips attracted will decrease. The reading for 40 coils also did not fit the pattern and is most likely to be an anomalous result. There are several reasons for this: the voltage may not have been consistent; the distance from the EM to the paperclips also acts as a source of error.

If I were to repeat this investigation I would use slightly different apparatus in order to gain even more accurate results. I would use a wooden stand and clamp the electromagnet at a fixed distance from the tray of paperclips. This would improve the accuracy of the results and perhaps I would have more confidence in my prediction. I would also use different types of wire that can conduct electricity, e.g. nichrome or aluminium. Then I could compare those results with the results gained in this experiment. If possible I would try and investigate readings beyond 100 coils or I would increase the number of coils in steps of 5.

Also, a different shape of iron core could be used, e.g. u-shaped. “In this case the strength of the electromagnet is more powerful than a straight one for obvious reason that both poles can be used to attract and lift iron objects; but it is actually much more than twice as powerful as a single pole.” If the experiment was done using a u-shaped electromagnet it would give comparable and much more accurate results.

In order to get extra information on the topic I would investigate the other two factors which affect the strength of an electromagnet. I would use varying amounts of currents or I could use a different core for the electromagnet.