PHYSICS COURSEWORK

BY

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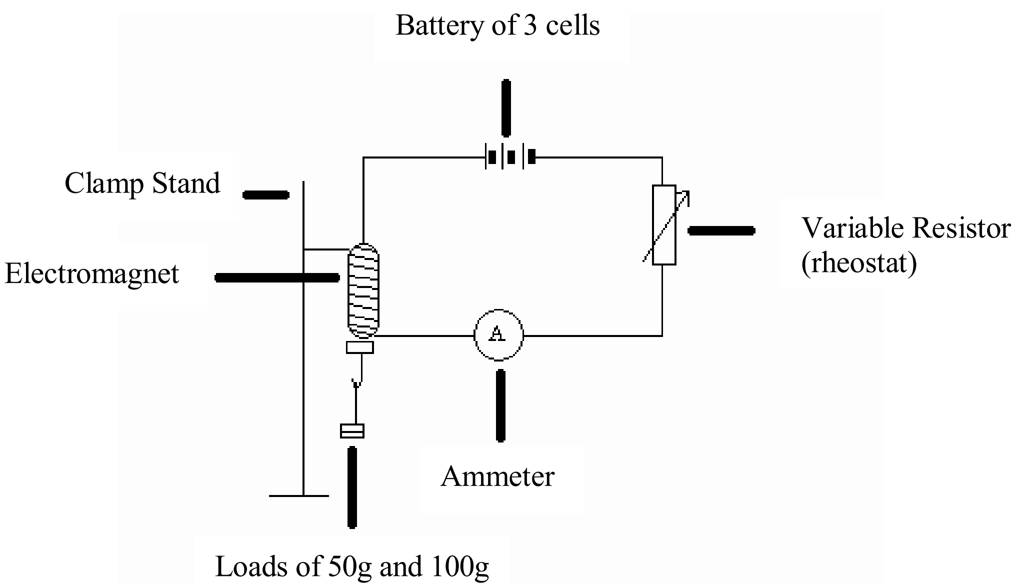
Investigate the relationship between electromagnet strength and amount of current flowing through the wire.

1. PLAN:

Diagram:



The Experiment:

I set up the equipment as shown in the diagram above. I put the variable resistor in the circuit to vary the current flow. I put the ammeter in the circuit to measure current flow at certain points. I then added an electromagnet to show that when electricity flows through a wire wrapped around a magnetically soft iron core, a magnetic field is created. I also added the electromagnet because we needed it to investigate the relationship between

electromagnet strength and the amount of current flowing through the wire. Moreover, I added a battery consisting of 3 cells to provide electrical energy to the circuit. Furthermore, I added a load to the electromagnet to provide a measurement of magnetic strength of the electromagnet. Finally, I needed the clamp stand to hold the electromagnet and to balance the load. I also kept all the equipment the same throughout the whole experiment to maximise efficiency.

In this experiment there were 2 variables; the independent variable (the current) and the dependant variable (the mass to pick up). However, to keep this test as fair as possible, I tried to minimise the effect of the variables on the experiment. Firstly, I tried to measure the readings from the ammeter as accurately as possible (to the nearest 0.01 or 0.02 amps). Then, I tried to measure the load as accurately as possible. However, this will not be fair as there is a huge error range because I only used 50g and 100g weights. This means that a measurement of weight can only be to an accuracy of 50g. This is highly inaccurate and so made the test unfair.

There were many safety aspects while carrying out this experiment. I had to take many precautions to ensure that I did not get hurt, nothing got damaged and the experiment remained a fair test. In order to avoid being electrocuted, I had to check that all the wires and components were correctly coated and safe to use before I began the experiment. Then, I had to check that all the liquid (especially water) was as far away as possible from me to avoid short-circuiting and potentially causing a fire, or again, electrocution. Next, I had to ensure that the electromagnet would not melt, giving unreliable readings, so I performed a preliminary, secondary experiment in which I tested the range of current the electromagnet could withstand (from 0.1A at most resistance to 3.4A at least

resistance). The electromagnet was not damaged, nor any other component over this range, so I used the range of 0A-3.4A for my experiment. Furthermore, I had to make sure no battery cell was faulty or broken. I tested this by putting each battery cell in the circuit at the same time and making sure that the circuit was complete with the correct current flowing through it. Finally, but perhaps more importantly, I had to make sure that I did not get hurt while putting weights on to the electromagnet. This may sound obvious, however, when I added weights beyond the point that the electromagnet could hold them, they fell with some speed and force (especially when the load exceeded 1 kg). As a result, I had to guarantee that nothing in the vicinity of the experiment could be damaged (especially the apparatus and my hands!).

Now, I will explain my method of measurement. The idea behind the experiment is very simple; to add masses of 50g and 100g to an electromagnet at a certain current (in Amps) and record the mass that the electromagnet could hold and then to draw a graph of mass against current and analyse its shape. To keep the experiment as fair as possible, I measured the current every 0.2A from a range of 0A-3.4A (giving 18 readings). However, as the variable resistor was very sensitive, I may have had a measurement error in the range of ±0.05A. However, to maximise the reliability of this experiment, I performed the experiment 3 times and then used the average of my result s to plot my graph. This minimised the error range. Furthermore, the hook that held the weights to the electromagnet weighed 23g. In order to maximise efficiency, I used the mass of the hook as a weight measurement, too. Each load of 50g or 100g also had the mass of the hook added to it, to maximise reliability of the results.

Finally, I shall give my hypothesis. I predict that the graph of mass against current will be an S-shaped curve. I

think this because at the start of the experiment, the magnetic domains in the piece of magnetically soft iron will be randomly arranged, with only a few arranged in the correct way, creating a flat, small gradient to the graph. This means that the electromagnetic field will be very weak, enabling the electromagnet to pick up small loads of mass. However, as the current increases, more and more domains will be lined up, increasing the mass that the electromagnet will be able to lift, and causing the gradient of the graph to initially increase each time a new mass is put on and then to decrease as the majority of the domains are lined up, thus creating a curve. However, at a certain point, the domains will all be lined up. At this point, the electromagnet cannot carry any more mass, no matter how much more current I put through the solenoid as it is completely magnetised. This will form an S-shaped curve.

However, if I do not reach the part of the graph where the points level off (if there is not enough current to line most of the domains up), then I will only plot the first part of the S-shape, corresponding to an x^2 graph (a parabola of a quadratic equation).

As a summary, I believe that as the current increases, more mass will be picked up by the electromagnet, forming an S-shaped curve.

2. EXPERIMENT:

Results Table:

Current (A)	Mass (g) Experiment 1	Mass (g) Experiment 2	Mass (g) Experiment 3	Average Mass (g)
0	0	0	0	0
0.2	0	0	0	0
0.4	0	0	23	7.7
0.6	23	23	123	56.3
0.8	73	73	173	106.3
1	123	123	223	156.3
1.2	223	173	273	223.0
1.4	273	273	323	289.7
1.6	373	373	373	373.0
1.8	423	423	473	439.7
2	523	473	523	506.3
2.2	623	573	573	589.7
2.4	673	673	673	673.0
2.6	723	723	773	739.7
2.8	823	823	873	839.7
3	1023	1023	1023	1023.0
3.2	1373	1373	1373	1373.0
3.4	1373	1373	1373	1373.0

In this results table there may be errors due to the presence of anomalous results. In order to get the best results, I have estimated that in my measurements of current there was, on average, an error of 0.05A either side of each measurement. There was also an average error of 50g in my measurements of mass as I only used 50g and 100g weights. Hence, there is an error of 50g either side of my mass measurement. I plotted these error bars on my graph, to make it fairer.

3. ANALYSIS:

I have observed the following by plotting my graph. The graph is the parabola of an x^2 graph (a quadratic equation). This is exactly what I expected from my hypothesis. However, I also predicted that the full graph would be an S-shaped curve. The graph showing my results only shows the first part of the S-shaped curve because the current was not high enough to line up all the magnetic domains up to completely magnetise the magnetically soft iron core. For this to happen a much higher current than 3.4A used in this experiment would be required.

The graph had an equation of:

$$Y = 109.82x^2 + 27.128x + 5.4561$$

This confirms that the line was a parabola of a quadratic equation (of formation ax^2+bx+c) where a=109.82, b=27.128 and c=5.4561 (the y-intercept).

To further justify that this line was the best correlation to the data, it had an R^2 value of:

$$R^2 = 0.9849$$

As a perfect correlation is when $R^2=1$, I only had an error of 0.0151. This indicates that the regression line is almost perfect. This in turn confirms that the line is a parabola, proving my hypothesis to be correct.

I only had 3 minor outliers:

(2.4,673) , (2.8,839.7) , (3.2,1373)

These anomalies are naturally occurring variations. I can tell this because all of them occur within the last 5 values and in the rest of the graph there are no anomalous values.

The reason for this is that, as more domains line up in the iron core, the more range there is for an error, magnifying the error potential, and causing these values to become less aligned and more irregular. I believe that if I would have continued recording the results up to the area where the graph becomes S-shaped, then there would be even more anomalies.

4. EVALUATION:

I believe that this experiment was effective, as I have taken into account all the factors that prevented it from being an unreliable experiment, making it as fair as possible. The above statement is supported by the fact that my values have very small variations showing that each of my 3 experiments were performed under almost identical conditions. Also, further evidence of the experiment being effective was that there were only 3 outliers in my 18 results. This shows a very small proportion of anomalous results.

However, the fairness of the experiment is outweighed by its inefficiency. The experiment may have been made unfair by 3 main factors; the equipment I used, the number of measurements of current and mass (and whether I repeated them enough times) and the error in my measurements of mass.

The first factor that may have made my results unfair was the fact that I used normal laboratory equipment that was not of maximum efficiency. This may have affected my results.

The second factor, which may have affected the outcome of the experiment, was the number of measurements of current and mass. I measured current at intervals of 0.2A. To improve my results table and graph, it may have been better to measure the current at intervals of 0.1A as this creates a smaller range for errors to take place, keeping the results more equal and evening out any bad results. However, I consider that I repeated the experiment enough times, as an average of 3 times is very fair. However, if I would have repeated it some more times (e.g. 5 times) then it may have given me a smaller error range, as the big errors may have evened out by the number of times I repeated the experiment.

The third factor, which may have affected my results, was the error in my measurements of mass. The masses I used (excluding the mass of the hook, attached to the electromagnet to hold the masses) were either 100g masses or 50g masses. This meant that the error in measurement was 50g. This made the test unfair, creating possible anomalous results. However, I tried to keep the graph as fair as possible by creating error bars on the graph to account for this factor.

Finally, I could make a few improvements to this experiment, to make it even fairer. Firstly, I could perhaps record my current every 0.1A rather than 0.2A as this helps to make the experiment fairer with a smaller error range.

I could also repeat the experiment 5 or 6 times to iron out any outliers and keep the results as compact as possible, with an almost perfect correlation for the graph.

Lastly, instead of using masses of 50g, I could use masses of 10g. This would help to reduce the size of the error bars shown on my graph.