EMF Investigation

Planning

Aim and hypotheses

According to Fleming's Rule, electricity is generated when movement occurs in the magnetic field. Alternatively, switching direction of the magnetic field also works. Alternating current is a good way of alternating the field direction. The electricity generated, of in the other words, the electromotive force, is measured in volts. By varying different parts of the apparatus, the EMF output could also vary. The aim of this investigation is to establish a connection between the factors and the output.

Possible factors that could be altered in a general apparatus are:

* Frequency of field alternation

* No of coil of wire in the magnetic field

* Strength of magnetic field, varied by

* - size of electromagnet

* - current used to establish and maintain the magnetism of the electromagnet

* - no of coil used to magnetize the electromagnet

* Moving the wire in the magnetic field

A preliminary experiment, with the same apparatus used, is done earlier on and some useful information was acquired from it.

As it was mentioned that alter the direction of the field generates electricity, and it was found out in the preliminary experiment that the more frequent that the field is altered, the quicker would electricity be generated, so by looking at different frequency, perhaps a pattern indicating the relation.

In an experiment involving generating movement by electromagnet, the more wire coiled through the motor, the faster the movement would be. So in reverse, if more coil of wire is passed through the field, more electricity should be consequentially generated.

Strength of electromagnet is also one of the three factors in the Left-Hand rule. Thus if the strength of the magnetic field is increased, more electricity should be generated. In the same way, more movement of the wire in the field should generate more EMF. The proof of this has also been acquired through the preliminary experiment. However, it was found out that the result in moving the wire in the field is too insignificant to record, so this factor could be undoubtedly omitted. Also no of coil used to magnetize the electromagnet contributes towards the strength of the magnet, it provides more area of magnetic field in the wire that magnetize the metal electromagnet.

From the list, I choose to investigate into the effect of varying the frequency of the power alternating and strength of the electromagnet. Using a signal generator and varying the current passing through the electromagnet respectively could do this. The voltages that the power pack can supply are 0, 2, 4, 6, 8, 10 and 12 V. The maximum amps that it can go up to is 0.30A, so the exact current measurement has to neglected until the actual experiment itself, then it could be properly recorded and presented. As a criterion, the other factors have to be kept constant in order to make this a fair test. Here are the variations:

10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 Hz

0.025 - 0.30 Amps

Ideally, all results should be repeated, and the average should be taken to obt ain more accurate results.

When carrying out the experiment, make sure that the factors are controlled strictly. Make sure that the current is the same, if necessary. Make sure that 240 coils of wire are being used. Make sure that the electromagnets are connected to each other firmly, if not, push them into each other. Make sure that frequency stays the same all the way through the experiment, and that there is only one loop of coil in the field at all the time.

Planning

Apparatus and Methods

Equipment list

* Green wire, stripped at both ends

* Connector wires

* Ammeter

* AC power supply

* 2 horse shoe metal

* 120/ 240 coil of wire, magnetizing the horse shoe metal

* Oscilloscope

* Power lines

* Signal generator

Methods

* Connect the circuit up as shown in the diagram.

* Before any power is turned on, make sure the circuit is safe to use and is connected correctly.

* Turn the power on. Adjust the voltage so that the current reading is correct.

* Make sure that the control factors are the same.

* Read the voltage reading on the oscilloscope.

* Record the results.

* Repeat the experiment necessarily, varying the factors as needed.

Safety precaution

* Dealing with electricity is dangerous. Take attentive cautions.

* The horseshoe metal, when the power is passed onto them, could be dangerous as they rush into each other. Put them together before the power is turned on to prevent accidents.

Prediction

As the frequency of the AC current increases, more electricity should be generated. According to the trial experiment, the quicker the direction of the magnetic field alternates, more electricity is generated. So if the frequency of the change in direction is higher, more EMF should be generated.

And as the current is increased through the unmagnetized-magnet, more electricity is generated. This is because the electric domains inside the magnet become magnetized. This is not a cumulative effect, so more energy is needed to magnetize more domains. The more domains magnetized, the stronger the electromagnet will become.

Planning

Background Knowledge

Electromagnet is often a piece of metal in a coil of wire. When the wire has no current flowing through, the magnet is just a regular piece of metal that possesses no magnetic ability. However when the current is passed through, the metal becomes magnetized. This is because the wire is magnetized; thus the metal adjacent to it becomes magnetized also. As the wire has no obvious poles for being a magnet, the direction of the field is determined by the Right Hand Rule that determines the direction of the field by looking at the direction of the current. If the current is flowing vertically upwards, the field is anti-clockwise, and respectively if the current is flowing downwards, the field id going clockwise. If one closes his right hand, the thumb is the direction of the current, and the fingers indicate the direction of the field, going around in a circle. So this magnetic field magnetizes the metal and the metal becomes a magnet. This starts off with electricity, so the magnet is hence called electromagnet.

How is electromagnet used to generate electricity? The answer has to come initially from the rule of motor - the Left Hand Rule, or Fleming Rule, that explains why the motors work, and how would they work. If one holds up his left hand in the 'gun' position, and bend the middle finger 90 degrees inwards,

The First finger shows the direction of the Field.

The seCond finger shows the direction of the Current.

The ThuMb shows the direction of the Movement.

So if the current and field are the inputs and the movement is the output, this process should be reversible. If the movement is put in and the field stays constant, current, or electricity, should be generated. Moving a wire in a magnetic field could do this. If the wire is connected to a galvanometer or a device that detects electricity, small electrical reading should be picked up. However this process is not efficient, as much of the energy input is lost, for example in form of heat, so this process is not popular at all in reality. Another possibility is that the direction of the magnetic field could be altered and this should create similar effect with more efficiency. This way, the power supply that maintains the magnetism of the magnet has to be switched on and off rapidly in order to make the current generated worthwhile. Using alternating current of AC power supply normally does it, as it changes direction every so often. Domestic electricity alternates at 50Hz, which means 50 times per second. This process, when compared to the latter, is much more efficient, as not as much energy is lost during the conversion, and the device needed to flicker the current is not as sophisticated as the one needed to move the wire around the field, and it is more easily done.

Evaluation

This experiment has worked well and has finally produced sufficient results that a meaningful conclusion could be deduced from it. The results are more realistically accurate as they have been modified by the Root-Mean-Square Rule, so they are more reliable than if the readings are taken straight from the oscilloscope.

However, the methods used were not in such way that gives the most reliable results. In fact, assistant equipment such as rheostat could be employed for this case to make the variation of current more accurate. The coils were not done in exactly the same way, so the length of the coils inside the magnetic field is not precisely the same in all cases. A mechanical device could be utilized instead of doing it by hand. A doughnut shape magnet could be used instead to prevent the diversion of flux on the corners.

The results, however, are not strictly and totally accurate, as the circuit itself is not 100% efficient. The Transformer Rule only work assuming that the efficiency is 100%, but in fact, there are so many possibilities that energy could be lost. The resistance inside the wires drains up some of the energy, as well as the Eddie-current that occurs inside the magnet itself. Some flux of the magnetic field can also be lost through the magnet's shape - on the corners, for instance. From this, a high expectation cannot be made from such inefficient system because there is no solution to gain total efficiency.

If further investigations are to be carried out, the field of increase in efficiency of a transformer circuit is much of an interest. Different types of magnetic substance could be used to decrease the eddie-current, as well as different shapes, and different ways to decrease the resistance inside the circuit.

Analysis

After altering the strength of the magnetic field and the number of coils inside the field, it is found out the effect that they have on the EMF output is significant. The best-fit lines of the graphs are in linear fashion, suggesting that the effect is directly proportional to what has been changed. The reason that the EMF output after altering the strength of the field has increased is because of the little magnetic domains inside the magnet itself. They are magnetized as current is passed through it. Not all of them are magnetized at once, as it is not cumulative, needing energy to maintain the magnetism. The more current passed in, the more domains would be magnetized, making it stronger and stronger. However there should be a certain point where there are no more domains to be magnetized, and the strength would stay constant after the critical point. And the reason why increasing the amount of coils inside the magnetic field works is because it provides more sites for energy transfer between the magnetic field and the electrons inside the wire, making electricity generation much quicker. Unlike the strength factor, there seems to be no limit of how many coils would make the maximum output.

However there is a theory linking these factors together. It is called 'Transformer Rule'. It says:

Primary Voltage = Primary turns of coils

Secondary Voltage Secondary turns of coils

This formula shows that the changes are directly proportional to each other. However the voltage in this case is not so accurate, as AC current needs to go through a conversion process in order to make it more accurate. This is called 'Root-Mean-Square'. The formula for this is:

RMS = EMF

2(2

This formula can be used to obtain the proper value of voltage. Then the comparison could be made using the Transformer Rule. If a mathematical prediction were to be made, it would have to follow this equation:

Induced EMF = Voltage input * No. of coil in magnetic field

No. of coils magnetizing the electromagnet

Looking at the frequency variation, the result turns out to be in lin ear fashion. However, frequency 0Hz, which looks as if it was going to cross the y-axis, generating the electricity, theoretically should not behave in such way. When the frequency is 0Hz, it means the field is not altering at all. It should not generate electricity, so the missing content between frequency 0Hz to 10Hz is the question of what actually happens. If this fact is to be omitted, then it could be concluded that as frequency is increased, more EMF is generated, given that the current stays the same at all frequency. This is because the field alternates more frequently, so electricity is generated more quickly, too, as well as the quantity of EMF induced.

A magnetic field can be pictured as consisting of lines of magnetic flux. As the magnet is stronger, there is more flux lines. The flux linking the coils is changing, in both the number and movement. The EMF induced is greatest when the 'flux linkages' are changing the fastest. The rule can therefore be simply stated as the induced EMF is proportion al to the rate of change of magnetic flux linking the coil. In the other words, the more flux (stronger the magnet), the more links (more coils) and the faster speed (bigger change, in frequency, for example), the greater the EMF. This is called Faraday's Law. An EMF is induced, whether or not current flows - current will flow if the circuit is complete.

After a study, it has been revealed that the circuit used contains so many built-in errors that cannot be helped. These factors are:

* Eddie current inside the magnet itself;

* Flux being lost on the corners of the magnet; and

* Resistance of the wire.

This is the only valid explanation for the difference from the obtained results and the calculated results. The formula is accurate given that the efficiency of the circuit is 100%, but in this case, it is not.

Nevertheless, all that were predicted happened in the experiment. Some gives unprecedented results, but they all turn out with patterns within them. They seem to be accurate to a certain extent, as they all fit in their own patterns, despite the peculiar turnout of the frequency graph.

Mathematical Prediction

Strength of Magnetic field

Voltage input Coil in Magnetic Coil magnetizing EMF induced inV

in V Field electromagnet calculated configured obtained configured

2 1 240 0.008 0.024 0.060 0.021

4 1 240 0.017 0.047 0.120 0.042

6 1 240 0.025 0.071 0.180 0.064

8 1 240 0.033 0.094 0.240 0.085

10 1 240 0.042 0.118 0.300 0.106

12 1 240 0.050 0.141 0.360 0.127

Coils inside magnetic field

Voltage input Coil in Magnetic Coil magnetizing EMF induced inV

in V Field electromagnet calculated configured obtained configured

4 1 240 0.017 0.047 0.178 0.063

4 2 240 0.033 0.094 0.358 0.127

4 3 240 0.050 0.141 0.538 0.190

4 4 240 0.067 0.189 0.715 0.253

4 5 240 0.083 0.236 0 .895 0.316