Beakman's Motor

Comments from Spring 2000

Fields and Waves I

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Speeds: Here is the list of speeds attained (official)

Top Third: 160, 134, 112, 84, 81, 76, 75, 69, 68, 68, 67
Middle Third: 63, 61, 57, 54, 50, 50, 47, 44, 42, 42, 40
Bottom Third: 38, 35, 30, 29, 25, 24, 21

General Comments: There are some general comments and ideas that apply to any report.

1. Read the instructions thoroughly. A couple of groups noted that their work would have been easier if they had read the instructions first. I also answered a lot of questions that were addressed in the write up.
2. Include all materials that have been asked for and the grade sheet. Many groups did not include the grade sheet, which was provided to make it easy to identify what points were awarded for each section. Also, even though we signed off for the two speed tests on specific sheets in the write up, these sheets were not included with the report. Anything we have you get signed has a purpose, so please include it.
3. Present your material simply and clearly. Do not make it difficult to find information. It should be possible to identify the main ideas and results in your report in about 5 minutes. Some reports took almost 30 minutes to read. 30x30 is 900 minutes or 15 hours, which is why I have trouble getting them back to you in a timely manner. Circuit component values should be clearly listed on circuit diagrams and in tables. Use bulleted lists whenever you can.
4. The input impedance of an oscilloscope is not 50 ohms. This is the kind of mistake that actually should embarrass an electrical engineer.

Intro: Most people had at least 3 goals listed. Most of the goals were not very specific, but the full 3 points was given anyway.

Design: This section should address how the motor works and should provide sufficient information for some other student with a comparable background to build the same motor. Many groups did not describe their designs completely, but many gave excellent information, usually in the form of a figure. Almost no one addressed the issue of phasing in their design. Everyone noted that half of the enamel should be removed on one end of the axle, but did not indicate which half. The original Beakman's design also shows the magnet and the coil not lining up. That is because they chose to remove the half of the enamel on the side of the axle, rather than on the bottom. There is a simple test to see where the enamel should be removed. Hold the coil gently when it is not rotating and try to feel where the force is the greatest. The axle should be making the best contact at this angle. The discussion of forces and angles is best done using the $\vec{J} \times \vec{B}$ model rather than the fuzzier description based on the repulsion of similar magnetic poles.

Almost everyone mentioned the number of turns in their various designs, but no one had a concrete reason for the number of turns that they found to be optimum. I am still waiting for someone to give me a quantitative argument for the best number of turns.

Several people talked about the importance of fixing the paperclips securely (both electrically and mechanically) to the battery. The most elegant solution to this problem was to use a plastic clamp. (Check out the pictures of motors found in the announcements page.)

Analysis: There were many deficiencies in this section which should provide a model and analysis sufficient to make sense of the data.

1. The wrong formula was almost always used to find the inductance of the coil. The best place to find this formula is in the University of Missouri-Rolla website at http://www.emclab.umr.edu/. Many people also used the length of the wire instead of the length of the coil. The simple solenoid formula that most people used overestimates the inductance by a lot. Thus, it still can be used to show that the inductance has little or no affect on the motor unless the speed gets to be really, really high. For example, all resistances in the circuit add up to less than 1 ohm. Therefore, for a motor turning at less than 200Hz, $wL << R$ as long as $L << \frac{1}{2p\,200} \approx 800mH$. Since $L_{coil} \approx N^2 R m_o \left[\ln\left(\frac{8R}{a}\right) - 2 \right]$, the inductance of a 7 turn coil with a radius of 1cm and a bundle radius a = 1mm, is about $1.5mH$, it is pretty reasonable to neglect inductance.
2. The emf was rarely calculated correctly. The emf is produced by the rotation of the coil in the field of the permanent magnet. Crude data on the field magnitude was provided on the project webpage. Typical values are about 500 Gauss which is 0.05 Tesla. The EMF through a 1cm radius coil is $emf = -\frac{d\Lambda}{dt} = -\frac{d}{dt}\left(BpR^2 \cos wt\right) = wBpR^2 \sin wt$ which has a magnitude of about 20mV even at 200Hz. Since this is much less than 1.5 volts, we can neglect it. The most common mistake made was to use the difference between 1.5 volts and the voltage across the coil when it was conducting current as the emf. The drop in voltage observed is due to the resistance of the coil and paperclips, not the emf. One way to be sure that this voltage difference is not due to emf is to check the voltage when the coil is not moving.
3. Almost no one took the circuit diagram and predicted the voltage that should be observed across the coil when it is connected. Since this is a very obvious observable, it makes sense to calculate it.

Basic Motor Performance: Some groups did not include the signature sheet for this test.

Implementation: Almost all groups had useful information to share about their difficulties in making their designs work.

Final Motor Performance: Again, signature sheets were not included. I think that we should have encouraged you all to keep the number of significant digits you reported in your frequency down to no more than 3. That was our fault.

Performance Verification and Discussion: Almost all the groups that achieved speeds above 40Hz did the proper verification using the DC power supply. In retrospect, the motors were working well enough this time that this procedure was probably not necessary. In the future, I will be leaving it up to the TA or instructor to decide whether this extra procedure is necessary. On the plus side, it did give some additional information about the motor. For example, many groups found that the speed did not change monotonically with voltage, as one would expect. This is a concrete observation to make about the data. The most significant observations that can be made have to do with the observed waveform. Everyone should have noted the voltage levels and the times that the voltage was high and low. Then these and other observations should have been discussed. There was some discussion about how smooth the signals were when the coil was carrying current, but little else. Other observations had to do with how dirty the axle contacts got, the change in the shape of he coil when it rotates, etc. Collecting a list of all such observations and then discussing the ones you can is what the discussion section should be all about.

Personal Responsibility: The group tasks were rarely broken down the way they should be. For example, one member of each group should have the responsibility to read the entire write up and all suggested supplemental reading and then summarize everything useful, especially the list of specific items to be included in the report. I did think that most groups had some kind of reasonable approach to dividing up the work, but a more specific breakdown should be developed.

Creativity: There were some very creative ideas in the reports and designs. However, I did not expect anyone to write a section on their creativity. I expected to find evidence of creativity in the report and note it in the appropriate spot on the grade sheet.

Appendix: I was glad to see that very few groups copied every reference they found and attached them to the report. That only makes me tired carrying around so much paper. Rather, some good choices were made to include certain critical information on such topics and the specifications for batteries.