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University Physics II

Honors Project

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Electrostatic Motor

Introduction:

The principles of electrostatics are often hidden away in applications of everyday life. These principles are commonly used to purify food, create image sensors in digital cameras, make photocopies, and build motors.

The goal of this project was to research and implement the basic physics behind electrostatics to create a working motor.

Construction:

Two different motor designs were used in this project.

The first motor consisted of strips of aluminum foil attached to a plastic SOLO cup. The cup was placed upside down over a dowel rod. The dowel rod served as an axle for the rotating cup. The end of the dowel rod was sharpened to help decrease the amount of friction between the rotating cup and the dowel rod. Different amounts of aluminum foil were attached to the uniform plastic SOLO cups. This was done to determine the effects that varying amounts of aluminum foil would have on the number of revolutions per minute (RPM). Cups with 3, 4, and 6 strips of aluminum foil were used in the experiment.

The second design was constructed by placing a plastic bottle inside a 2-liter bottle. The 2-liter bottle served as a stator, the stationary part of the motor, and the smaller plastic bottle had strips of aluminum foil attached. The 2-liter bottle had two sheets of aluminum foil placed symmetrically on opposite sides of the outside bottle. These sheets served as conducting plates. Slits were cut on the sides of the bottle and part of the foil from the conducting plates was bent through the slits. This allowed charge to pass from the outside aluminum foil to the inside bottle. The plastic bottle on the inside of the stator was placed on a dowel rod, which served as an axle. Holes were drilled through the bottom of both bottles to allow the dowel rod to pass through. In order to decrease the amount of friction, a screw was placed through the cap of the inside bottle. The screw rested on top of the dowel rod and allowed the bottle to rotate with minimal friction. Different amounts of aluminum foil were placed on the rotating bottles. The bottles had 3, 4, and 6 strips of foil attached, respectively. Just like in the first design, the foil strips had equal width and height as well as uniform spacing. Again, this was done to help determine how foil affected RPM. (Chase)

Each motor design had its own base. The base for each model was constructed by drilling a small hole for the dowel rod in a block of wood. The dowel rod was then put in place and secured with putty. Copper wires with insulation were taped in place on the base. The fixed copper wires allowed an easy connection to the Van de Graaff generator using the alligator clips supplied in lab.

Physics:

The activities in lab earlier this semester physically showed how like charges repel each other while opposite charges attract (Stewart, Activity Guide). This is the underlying principle behind the electrostatic motor. The aluminum foil on the bottles and cups allowed charge to move around, but it is the force between like charges that caused the rotation. In addition, the strength of the electric force decreases with increasing distance. This is shown by part of Coulomb's Law, which states that the magnitude of electric force, F, is given by the following equation:

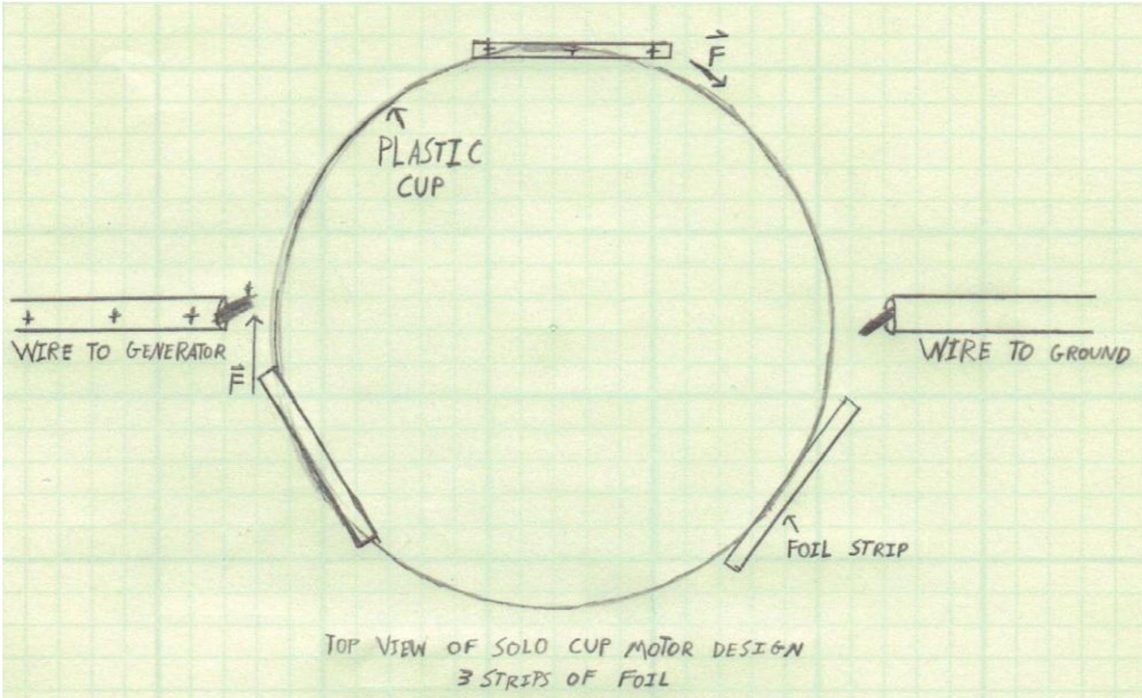
$$F = \left| \frac{kq_1q_2}{d^2} \right|$$

where k is a constant, q_1 and q_2 are the charges of the particles, and d is the distance between the two particles. Because of Coulomb's Law, the wires and strips of foil were kept as close together as possible so as to produce maximum force, causing optimal rotation. (Stewart, Course Guide)

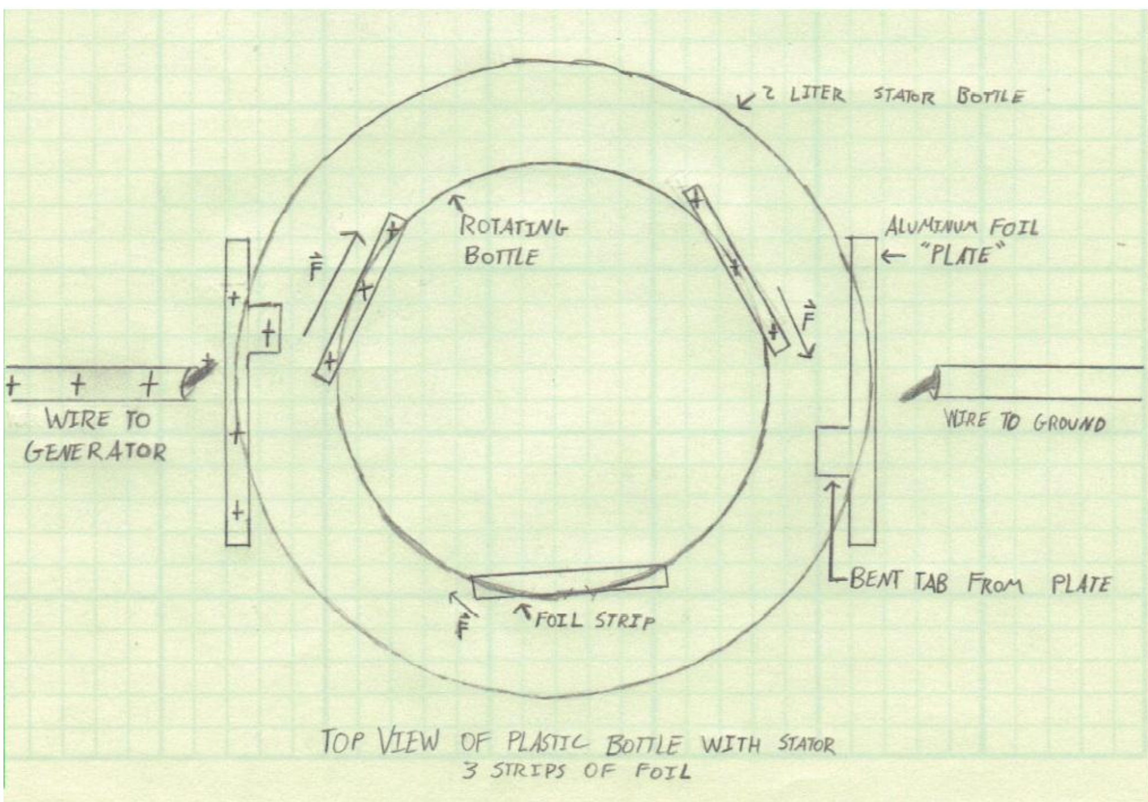
In the first motor design, the Van de Graaff generator supplied a charge through a wire. The wire was then placed very close to the SOLO cup. The charge in the wire ran onto one of the foil strips on the SOLO cup. This strip now had the same charge as the wire. Because the charge on the foil was the same as the charge in the wire, the force between the foil and the wire produced a torque, which, in turn, caused the cup to spin. There was another wire on the opposite side of the cup connected to a ground. The same principles take part in this wire. The grounded wire attracted the charged foil strip. The cup rotates causing the charged foil strip to pass by the wire connected to the ground. The charge from the foil is passed to the ground, thus giving the foil a neutral charge. The strip is not forced away by the grounded wire, but the cup continues to spin due to the forces experienced by other charged foil strips. As the neutral strip continued to spin, the wire connected to the Van de Graaff generator attracted it because it was neutral. The strip was charged again as it passed the wire connected to the ground. This cycle occurred with every foil strip on the cup.

Likewise, the motor design with the stator bottle worked in a similar fashion. Charge was supplied to one of the plates which ran through onto the bottle on the inside portion of the model. Because the foil strip on the inside bottle was now charged with the same sign, a force was produced which caused rotation. As the foil strip was pushed away, the foil plate on the other side of the stator bottle pulled the strip towards it. Just like in the other model, once this strip came close to the foil plate it experienced a change in sign of its charge. Thus, the foil strip was pushed back towards the first aluminum plate. This process caused the torque needed for rotation by producing forces on all of the aluminum strips on the inside bottle. (Moore)

The figures below show a top view of the motors. For pictures of the motors, refer to **Appendix A**.



Cup Motor



Stator Motor

Procedure:

After the motors were constructed, each model was connected to a Van de Graaf Generator. The generator supplied a constant current to the wires on the base. The current from the wires caused the motors to rotate. The different designs for each model were tested individually. Tape was placed on the rotating objects so that each rotation could be identified with relative ease. A camera captured videos of the rotating bottles to allow observations of the precise number of revolutions each bottle or cup had.

Data and Results:

Data was taken for each rotating bottle and cup. The average RPM for each motor is displayed in **Table 1**.

SOLO Cup Motor	
Number of Foil Strips	**Number of RPM**
3	190
4	234
6	408
Motor with Stator	
Number of Foil Strips	**Number of RPM**
3	182
4	232
6	286

Table 1

It was observed that motors with 6 strips of aluminum foil performed better in terms of RPM than motors with 3 or 4 strips. Increasing the number of foil strips produced a force more often. When compared to a motor with only 3 strips, one with 6 strips would spin approximately twice as fast because a force was produced twice as often. The increased number of strips caused more force interactions resulting in higher RPM. The SOLO Cup design suggests that when more strips of foil were attached to the cup, the resultant RPM was better. This is also supported by the design with the stator. However, placing 6 foil strips on the SOLO cup had a bigger effect on RPM than placing the same number of strips of the plastic bottle. In terms of RPM, the SOLO cups performed better than the bottles. Since the cups are lighter than the bottles, they are able to rotate at the same speed using a smaller force. Also, the rotating cups had less friction than the rotating bottles. Another factor that would decrease RPM for the bottle motor would be the aluminum foil on the outside of the stator. This would cause charge to be lost because of the uneven surface and the crumples on the foil. Because of this lost charge, a smaller force would be produced on the inside causing slower rotation.

Conclusion:

The experiment successfully displayed the physics of electrostatic motors. The working motors physically showed the principles of repelling like charges and attractive opposite charges. By testing different motor designs with varying amounts of aluminum foil on each motor, an observation relating the amounts of foil to RPM could be made. The experiment determined which motors produced an optimal force from repelling like charges. From the motors it was determined that more strips of aluminum foil resulted in a larger number of RPM. Thus, the amount of foil on the motor is directly related to the force produced from the repelling and attracting charges. In terms of efficiency, the SOLO cup motor design proved to be the best.

References

Chase, John. "Build an Electrostatic Motor." Instructables. 23 Aug. 2006. 15 Feb. 2009 <http://www.instructables.com>.

Moore, Arthur D. Electrostatics and Its Applications. New York: Wiley-Interscience, 1973.

Stewart, John and Gay Stewart. Spring 2009 University Physics II-Activity Guide. Fayetteville: John and Gay Stewart, 16 Dec 2008.

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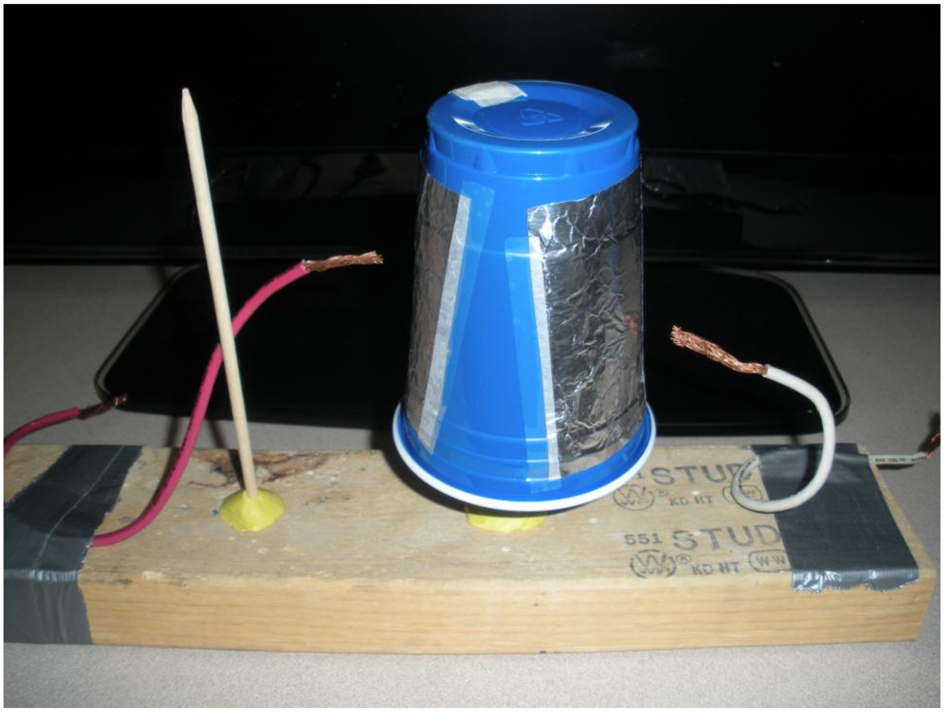
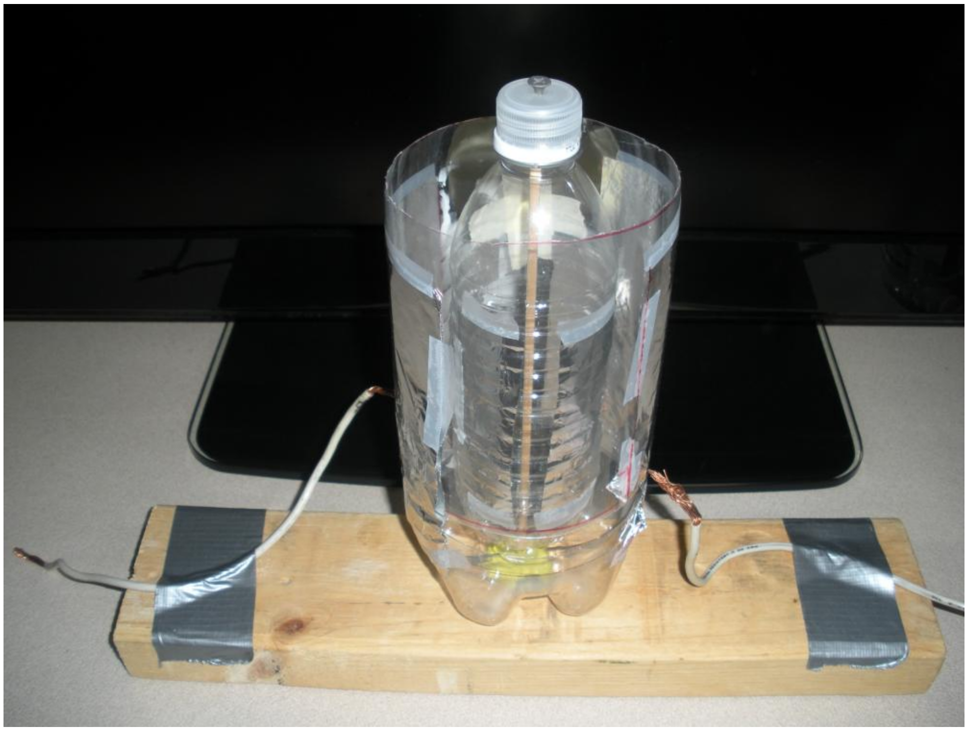
Appendix A



Cup Motor - Side View

Cup Motor – Top View



Stator Motor – Side View

Stator Motor – Top View