A New Electrostatics Toy for Demonstrations and Experiments

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***Abstract*—A new electrostatics toy, the Fun Fly Stick™ (about $30 from a variety of sources on-line) is entertaining in its intended use, but can be readily modified to make it a good, inexpensive, portable, safe substitute for other electrostatic generators for classroom use or for electrostatics demonstrations. This paper will describe the device, measurements of its charging characteristics using a computer interfaced charge sensor, simple modifications to improve its versatility, and a variety of experiments that can be carried out using it in conjunction with inexpensive materials.**

***Index Terms*—Electrostatics teaching, Van de Graaff Generator, Demonstrations.**

I. Introduction

THE FunFlyStick ™ produced by Unitech Toys. Inc. Foster City CA, is a small battery powered hand held Van de Graaff generator, designed to be used to levitate lightweight pieces of aluminized Mylar. Powered by two 1.5 volt AA cells, it consists of a plastic tube with the batteries mounted in one end. A motor drives a belt over two pulley spaced about 10 cm apart in the handle. At the end of the handle is a 20 cm cardboard tube that acquires charge from a metal collector at the end of the plastic tube. In use the operator presses a pushbutton switch, whose metal surround is connected to a metal collector at the motor end of the generator. As the motor turns, the cardboard tube acquires a positive charge. An aluminized Mylar™ flying toy draped over the cardboard acquires a positive charge and will lift off the tube. A person playing with the toy can then keep the flying toy suspended in the air. The FunFlyStick ™, instruction manual and set of flying toys costs about $30 and is available from a number of different suppliers. The low cost of the device makes it suitable for use in the classroom, and with a few modifications, it can serve as a replacement for larger and more expensive Van de Graaff generators, and be an object of investigation itself. This paper describes a series of experiments using the FunFlyStick ™ both in its original form and with modifications, in conjunction with a computer interfaced Charge Sensor made by Vernier Software (Vernier CRG-BTA www.vernier.com), and a variety of commonly available materials.

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II. Power Requirements

Although in my experiments I used the batteries to power the device, I considered modifying it to use an external DC power source. I measured the current with the motor operating as 1.44 amperes. Thus a 3.0 V external DC power supply with a 1.5 A current rating could drive the motor if one wished to make such a conversion.

III. Charge transfer rate with cardboard tube

A Faraday pail detector on a glass jar resting on a heavy-duty aluminum foil ground plane was connected to the Vernier Charge Sensor[1]. With the sensor set at the 100 nC range, the FunFlyStick was inserted into the Faraday pail and turned on. It took only a few seconds to acquire a positive charge of about 90 nC. Small sparks could be readily drawn from the cardboard tube. Wrapping the tube in aluminum foil to increase its surface conductivity allowed larger sparks to be drawn. The rapid charging suggested that a significant charge, in terms of a school laboratory, could be built up by increasing the capacitance of the device.

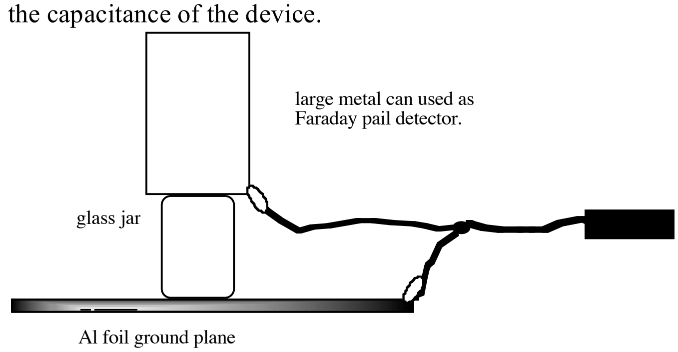

Fig 1. Charge sensor setup

IV. Iced tea can dome

Fortuitously, an empty Arizona Iced Tea™ can was found to have the pop-top opening of just the right size to slip over the end of the FunFlyStick ™ after the cardboard tube was removed. The can is slid on with the pop-top making contact with the collector electrode. The collector can, with a diameter of 7.5 cm compared to the 2.3 cm diameter of the cardboard tube, gave significantly larger sparks.

V. Iced Tea Can Van de Graaff setup

A quick adaptation of the FunFlyStick ™ to a VDG generator was made by wrapping the handle in aluminum foil to contact the grounding ring on the switch, fastening the foil-wrapped handle to a large empty metal can (15 cm diameter by 17 cm height) with large rubber bands, and using a rubber band to hold the pushbutton compressed in the on position (Fig. 2). In this configuration, the FunFlyStick ™ functioned nicely as a small table-top VDG, generating small sparks and allowing small versions of traditional VDG experiments to be performed.

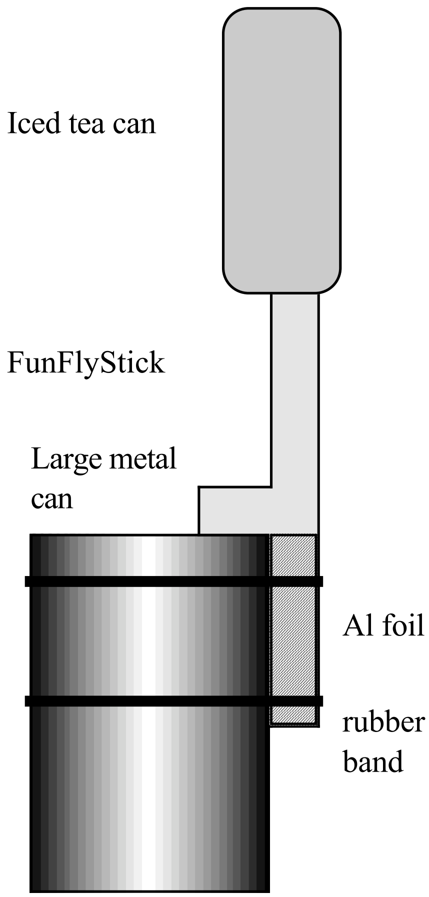

Fig. 2. Iced Tea Can Van De Graaff Generator

VI. Iced Tea Can VDG Maximum Charge

A procedure was now developed to measure the maximum charge on the iced tea can. The ITC-VDG was set up a distance away from the detector can connected to the charge sensor. In this arrangement, charging the VDG induced a charge in the detector can. The VDG reached a maximum charge limited by small spark discharges as shown on the computer sensor graph in Fig. 3. The graph indicated that the maximum charge was reached in about 30 seconds.

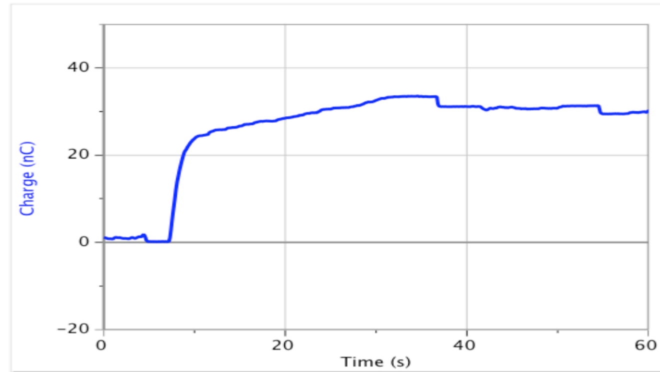

Fig. 3. Charge sensor vs. time monitoring for ITC-VDG

At this point the ITC-VDG was turned off and an identical insulated iced tea can was touched to the ITC-VDG terminal. The VDG was moved away from the charge sensor set up, and the insulated can, which now had half the charge on the ITC-VDG, was inserted into the faraday pail attached to the charge sensor. The resulting charge exceeded the range of the detector. The procedure was repeated, but this time, after obtaining half the charge on the insulated can, that charge was reduced in half again by sharing it with a second insulated can. Again, the test can at one quarter of the VDG charge was beyond the sensor range. Repeating the procedure of halving the charge repeatedly, gave a one eighth charge value of 45 nC. Additional halvings to 1/16 and 1/32 gave 24 nC and 10 nC respectively, as shown on the graph in fig. 4. This gave an estimated peak charge on the ITC-VDG of about 350 nC.

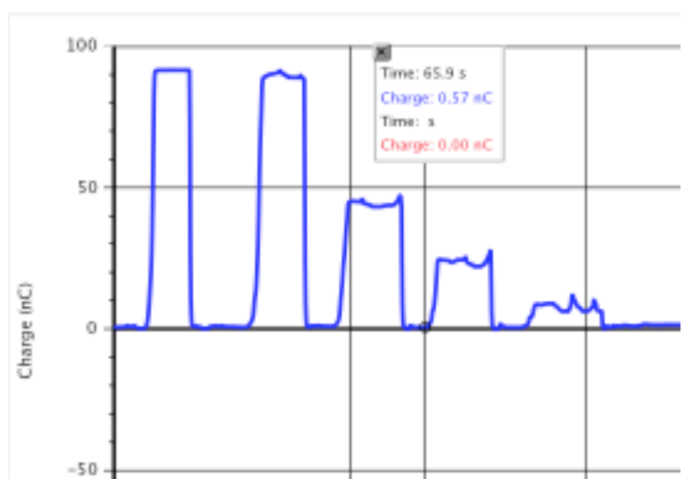

Fig. 4. Charge sensor readings for ½, ¼, 1/8, 1/16, and 1/32 of ITC-VDG maximum charge.

VII. Iced Tea Can VDG Maximum Charge

A spark gap made from two brass spherical drawer knobs with 3.1 cm diameter was used to estimate the maximum voltage of the ITC-VDG. One sphere was attached to the iced tea can, and the second was attached to the grounded base (Fig. 5). The charge sensor was placed nearby to monitor the charge state, and the sphere gap was adjusted until the VDG reached its maximum charge before the spark occurred as shown in the graph in fig. 6.

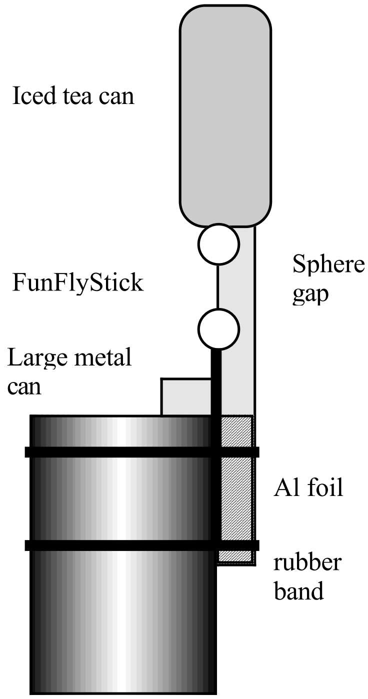

Fig. 5. Iced Tea Can VDG set up for voltage estimate.

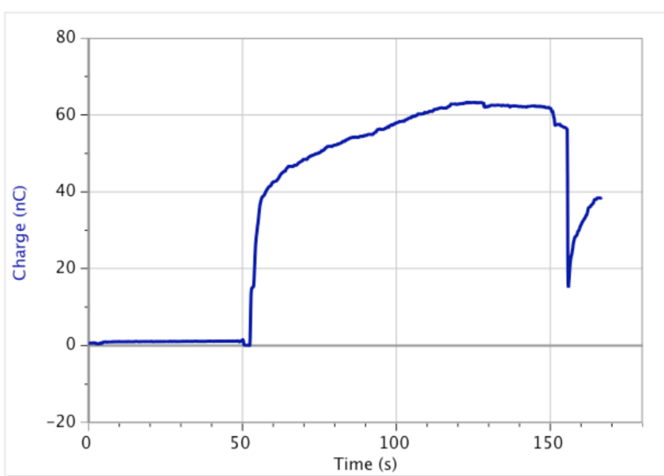

Fig. 6. Sensor graph monitoring charge and spark on ITC-VDG.

The sphere spacing of about 2.4 cm was compared with the tables in A. D. Moore's *Electrostatics* [2] to obtain a maximum voltage of about 60 kV. From the voltage and charge, the capacitance of the ITC -VDG can be estimated as 6 pF. The online demonstration book at the University of Wisconsin [3] gives the capacitance of VDG's at about 1.1 pF/cm of radius, making the iced tea can VDG equivalent to about a 12 cm diameter Van De Graaf generator. As such it can be used to carry out many of the usual demonstration experiments done with larger generators. It is sufficiently robust to charge a modest size Leyden jar in a minute or so to an energy sufficient to deliver a good shock.

VIII. Dipole Generator Configuration

Because the ITC-VDG is battery powered, there is no need for one terminal to be at ground potential. Thus the FunFlyStick™ can be set up to have both a negative and a positive terminal by fastening a second iced tea can to the handle end of the FunFlyStick™ after wrapping the handle in aluminum foil to make contact with the switch surround. The apparatus can now be supported on an insulating stand by the motor housing as shown in fig. 7. With this arrangement, a pair of small film can Leyden jars can be easily be charged oppositely, and the field pattern around the dipole generator can be explored using an electrostatic compass made from oppositely charged pieces of Scotch™ Magic™ tape.

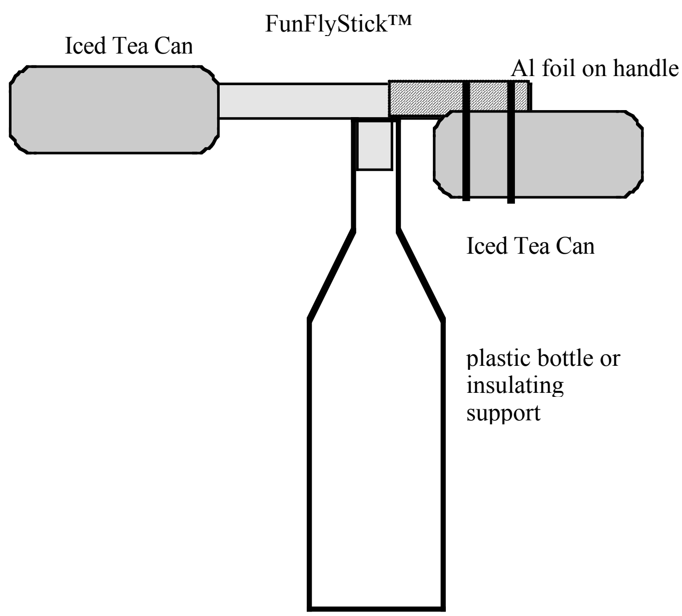

Fig. 7. FunFlyStick™ set up as dipole Van de Graaff generator.

IX. Conclusion

For a classroom on a low budget, the modified FunFlyStick™ is an inexpensive and versatile charging device. For a teacher with a larger budget, a set of ITC-VDG's could provide each laboratory group with a generator to use for more extensive electrostatic investigations. In conjunction with a computer interfaced charge sensor, quantitative investigations can be pursued as well as the usual qualitative electrostatic experiments.

References

[1] R. A. Morse, "Electrostatics with Computer-Interfaced Charge Sensors," *The Physics Teacher*, vol. 44, no. 8, pp. 498-502, Nov. 2006
[2] A. D. Moore, *Electrostatics.* Garden City, NY: Doubleday, 1968. p. 203.
[3] http://sprott.physics.Wisc.edu/demobook/chapter14.HTM