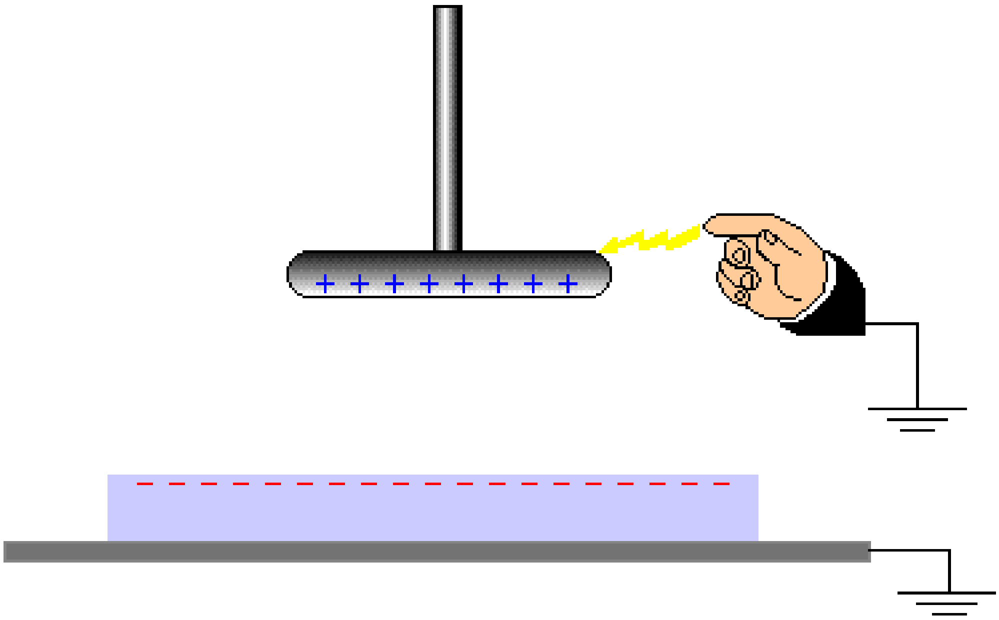
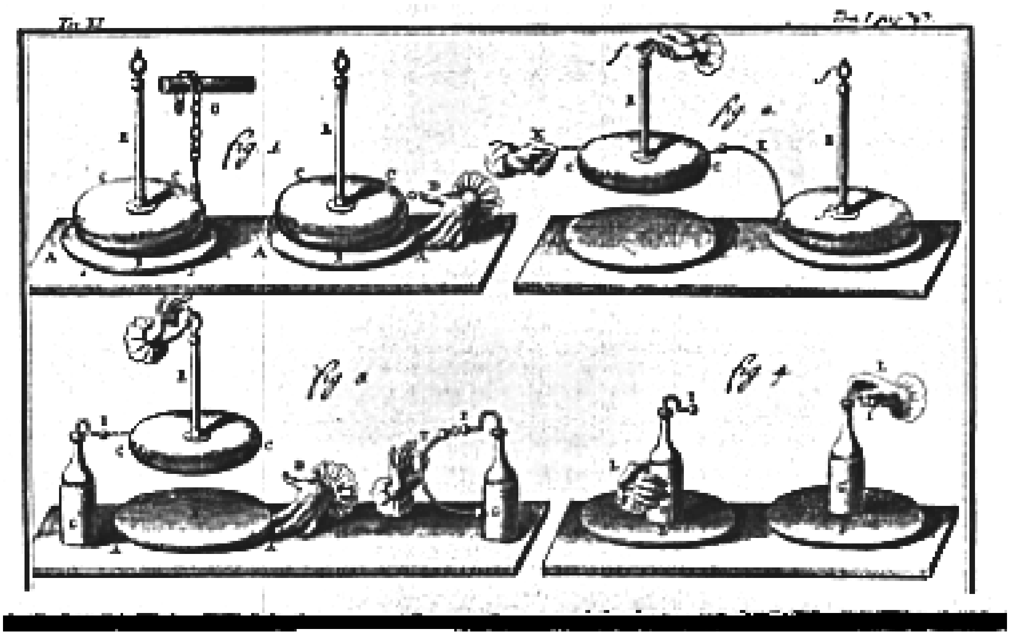
Electrophorus and Accessories

Thomas B. Jones
Professor of Electrical Engineering
University of Rochester



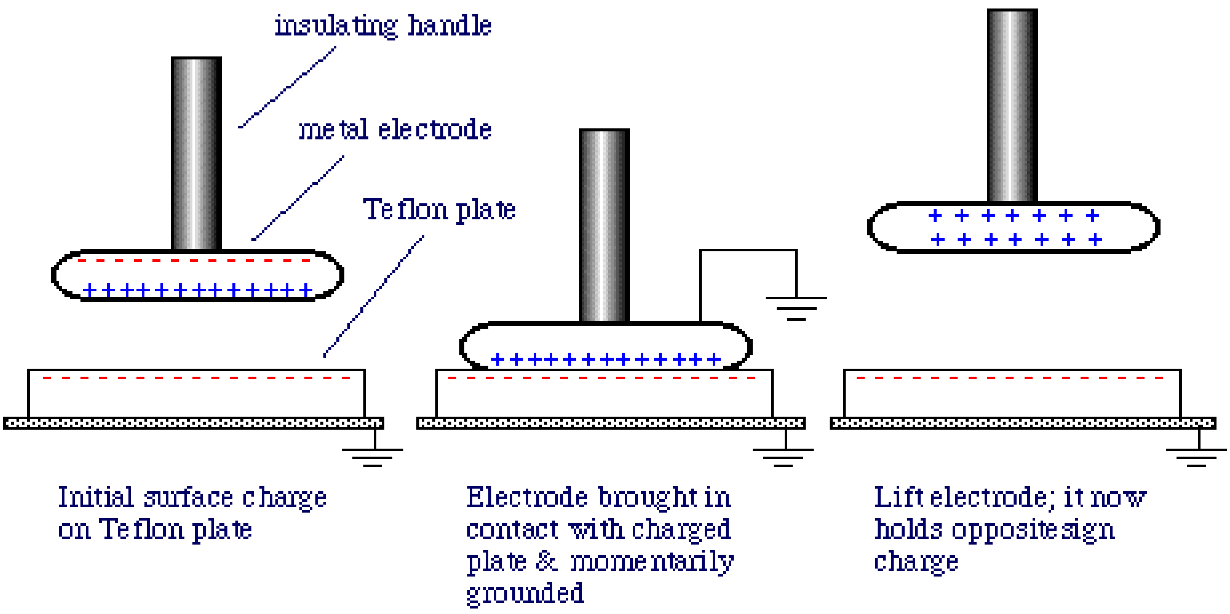
Johannes Wilcke invented and then Alessandro Volta perfected the electrophorus over two hundred years ago. This device was quickly adopted by scientists throughout the world because it filled the need for a reliable and easy-to-use source of charge and voltage for experimental researches in electrostatics [Dibner, 1957]. Many old natural philosophy texts contain lithographs of the electrophorus.



A hand-held electrophorus can produce significant amounts of charge conveniently and repeatedly. It is operated by first frictionally charging a flat insulating plate called a "cake". In Volta's day, the cake was made of shellac/resin mixtures or a carnauba wax film deposited on glass. Nowadays, excellent substitutes are available. Teflon^{TM}, though a bit expensive, is a good choice because it is an excellent insulator, charges readily, and is easy to clean and maintain. The electrophorus is ideal for generating energetic capacitive sparks required for vapor ignition demonstrations.

The basic operational steps for the electrophorus are depicted in the sequence of diagrams below. Note that the electrode, though making intimate contact with the tribocharged plate, actually charges by induction. No charge is removed from the charged cake and, in principle, the electrode can be charged any number of time by repeating the steps depicted. Click here to view a neat animation of the electrophorus charging process. Ainslie describes interesting experiments with an electrophorus that was charged in the Springtime and then its charge monitored throughout the summer [Ainslie, 1982]. The apparent disappearance of the charge during humid weather and its reappearance in the Fall must be attributed to changes in the humidity.

The energy for each capacitive spark drawn from the electrophorus is actually supplied by the action of lifting the electrode off the cake. This statement can be confirmed by investigating the strength of the sparks as a function of the height to which the electrode is lifted. Layton makes this point and further demonstrates with a small fluorescent tube the dependence of the electrostatic potential on the position of the electrode [Layton, 1991]. Lifting the electrode higher gives stronger sparks [Lapp, 1992].



CLICK HERE to view an **interactive, animated** version of this demonstration that reveals the movement of charge as the steps of the demonstration are followed. Please be patient while the Java script loads!

The electrophorus works most reliably if the charged insulating plate rests atop a grounded plane, such as a metal sheet, foil, or conductive plastic. [See Bakken Museum booklet, pp. 78-80.] The ground plane limits the potential as the electrode is first lifted from the plate, thus preventing a premature brush discharge. In dry weather, powerful 3/4" (2 cm) sparks can be drawn easily from a 6" (15 cm) diameter, polished, nick-free aluminum electrode. Estimating the potential of the electrode at V = ~50 kV and the capacitance at C = ~20 pF, we get

$$Q = CV = \sim 1 \text{ microCoulomb}$$

for the charge and

$$U_e = CV^2/2 = \sim 30 \text{ milliJoules}$$

for the capacitive energy. This energy value easily exceeds the minimum ignition energy (MIE) of most flammable vapors.

Click here to learn about a new type of electrophorus invented by S. Kamachi.

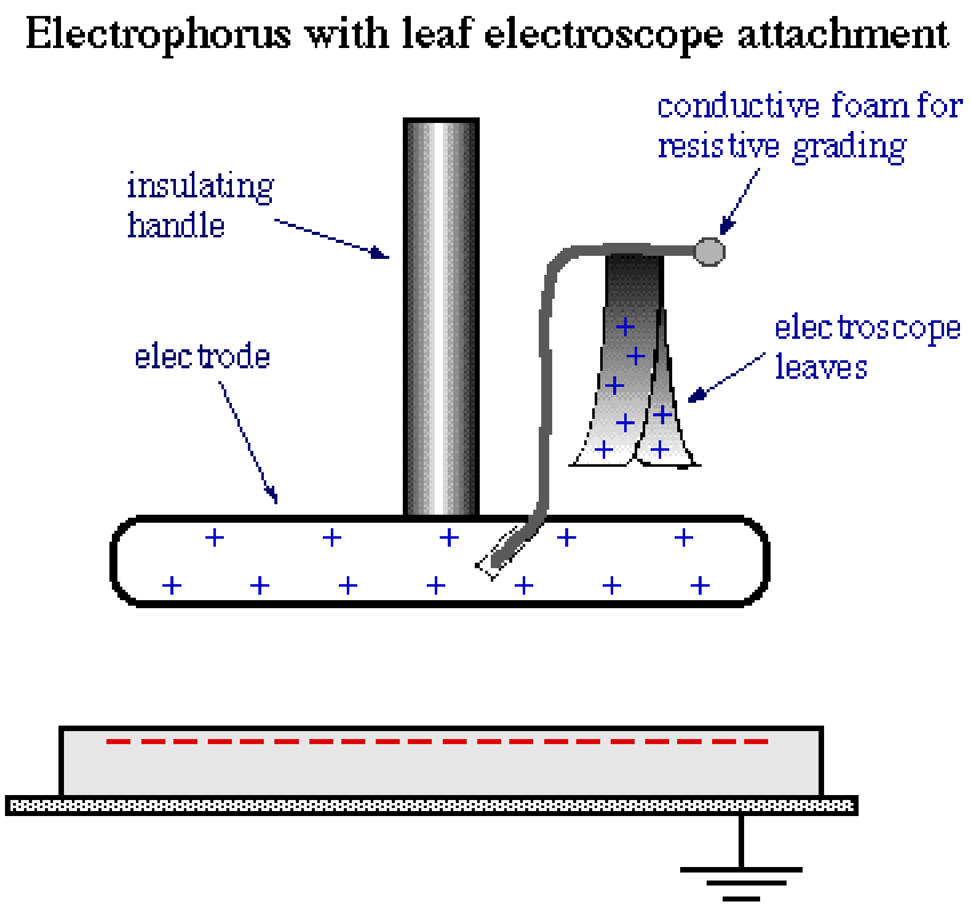
The Exploratorium located in San Francisco has a web page describing construction of a simple electrophorus out of aluminum pie plates and other inexpensive materials. Young scientists should check out this page. In addition, the library references at the bottom of this page are filled with interesting information about the electrophorus and other electrostatics demonstrations. One example is the cylindrical electrophorus [Ainslie, 1980].

RETURN TO TOP OF THIS PAGE

Electroscope accessory

A simple leaf electroscope attachment, shown in the figure below, makes it very easy to reveal some of the important charging and charge redistribution phenomena of the electrophorus. This accessory is especially handy because it works even on warm, humid days when large, impressive sparks can not be coaxed out of the electrophorus. Refer to the electroscope page for details on how to make this convenient accessory.

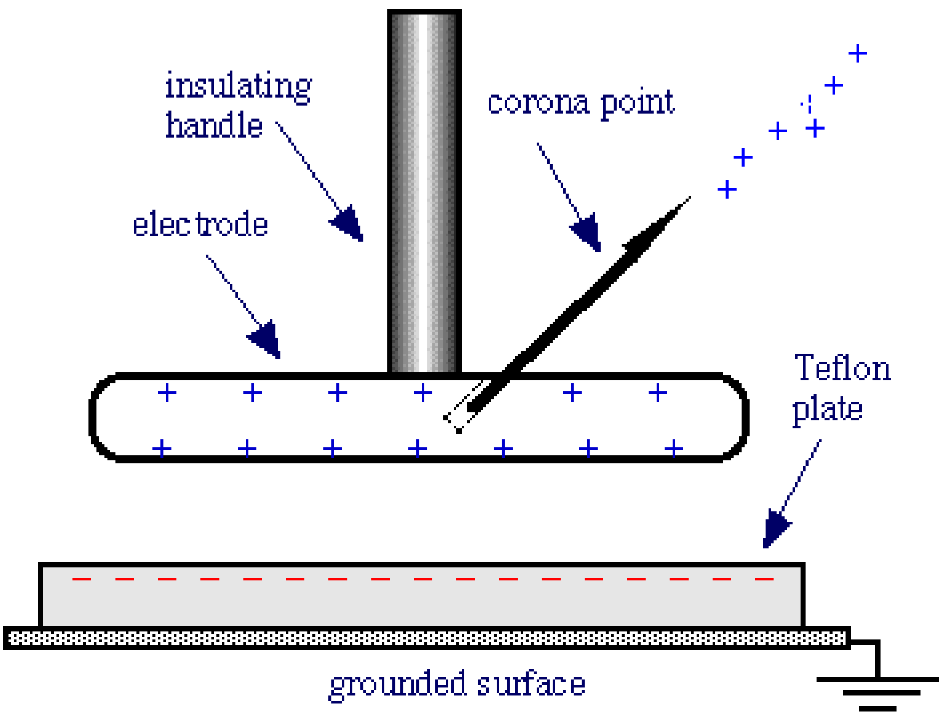
The electroscope is operated in the same way as before, but now the electroscope reveals information about the charge and its distribution on the electrode. In particular, it should be noted that, as the electrophorus is lifted up, its charge does not change. The leaves of the electroscope spread apart because the **constant** charge on the electrode redistributes itself, with about half of the charge moving to the top surface. Another thing to notice is that the leaves, which spread to a wide angle when the electrode is first lifted, slowly come back together with time, indicating the leakage of electric charge, presumably due to corona discharge from the edges of the leaves.



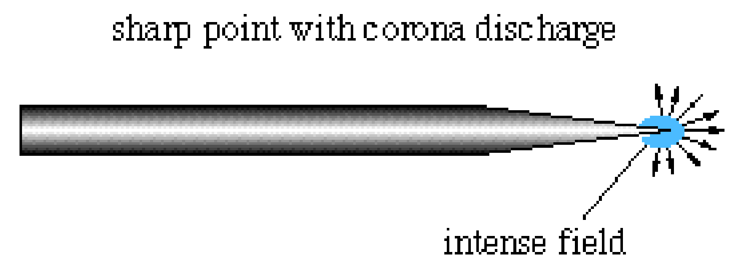
Corona discharge accessory

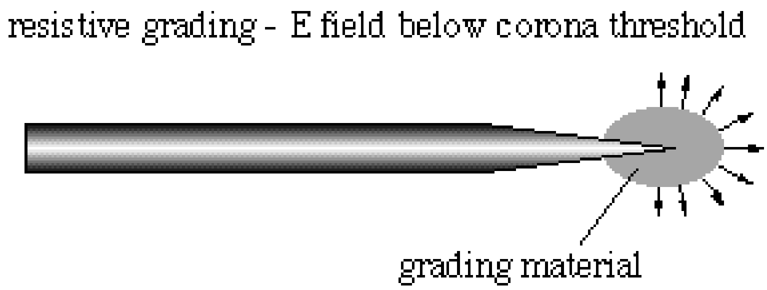
Another simple accessory is a corona discharge point that can be attached to the electrophorus. The attachment is a metal rod of diameter 1/16" or greater with one end sharpened to a point. When the charged electrode is lifted, the electric field at the sharpened tip exceeds the corona limit and a local discharge starts, dissipating the charge on the electrophorus. If one listens closely as the electrode is lifted, a soft, varied-pitch buzzing noise lasting just a few seconds may be heard. This is the corona, and it stops after the voltage has been reduced below the corona threshold. Passive corona discharge points are used widely in manufacturing to dissipate unwanted static charge.

Corona discharge point attachment for electrophorus



The corona discharge can be largely suppressed by covering the sharpened point with a small piece of antistatic plastic foam of the type used for packaging ESD-sensitive electronic components. The figure below shows how this scheme -- *called resistive grading* -- works to reduce or stop corona discharges.





Library references

D.S. Ainslie, "Inversion of electrostatic charges in a cylindrical electrophorus", Physics Teacher, vol. 18, No. 7, October, 1980, p. 530.

D.S. Ainslie, "Can an electrophorus lose its charge and then recharge itself?", Physics Teacher, vol. 20, No. 4, April, 1982, p. 254.

Bakken Library and Museum, Sparks and Shocks, Kendall/Hunt Publishing Co., Dubuque, IA, 1996, pp. 53-55.

B. Dibner, Early Electrical Machines, pub. #14, Burndy Library, Norwalk, CT, 1957, p. 50-53.

R.A. Ford, Homemade Lightning: creative experiments in electricity (2nd ed.), TAB Books (McGraw-Hill), New York 1996, chapter 10.

O.D. Jefimenko, "Long-lasting electrization and electrets," in Electrostatics and its Applications (A.D. Moore, ed.), Wiley-Interscience, New York, 1973, pp. 117-118.

D.R. Lapp, "Letters," Physics Teacher, November, 1992, p. 454.

W. Layton, "A different light on an old electrostatic demonstration," Physics Teacher, Vol. 29, No. 1, January, 1991, p. 50-51.

K.L. Ostlund and M.A. Dispezio, "Static electricity dynamically explored," Science Scope, February, 1996, pp. 12-16.

RETURN TO TOP OF THIS PAGE

ELECTROSTATICS DEMO MAIN PAGE | JOURNAL OF ELECTROSTATICS | T. B. JONES'S WEB PAGE

Please send email if you have comments or questions about either the electrophorus or about this page.