The properties characteristic of electric charge

Literature: Bergmann-Schaefer, II, 1958, paras. 1...3
Pohl, Elektrizitätslehre, 1957, para. 16

Principle: A list of experiments by which electric charge may suitably be introduced.

In introductory courses on electricity, the electric charge can be defined in various ways; however, it is usually one of the first electric quantities used. It occurs in the experiments described here, which may therefore be used to bring out its characteristic properties.

Objects made of plastics, and also glass, hard rubber, and the like, tend to acquire an "electric charge" on being rubbed with dry wool, silk, fur, or against one another. This charge can be inferred from the fact that the charged bodies will attract or repel other objects. These experiments can be shown in the simple arrangement of Fig. 1. Plastics tend to become negatively charged on rubbing; positive charges can be obtained by rubbing glass vigorously with leather. The glass must be warmed up in a hot air current to reduce its high surface conductivity. The objects used should not carry any charge at the beginning of the experiment. They can be discharged by moving them rapidly through a non-luminous Bunsen flame.

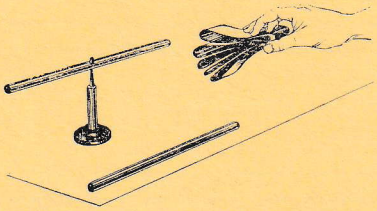

Fig. 1 Simple arrangement for demonstrating electric charge by attraction

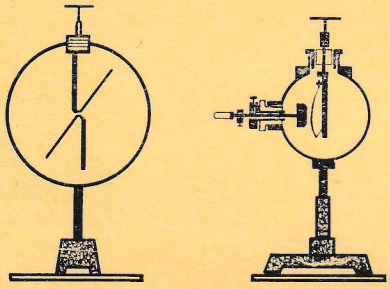

Fig. 2 Simple electroscope (on the left) and Wulf electroscope (on the right) for measuring charges

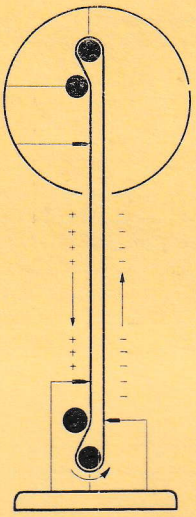

Fig. 3 Generation of charge with the van de Graaff generator

1. A plastic rod rubbed with a dry rubber belt will be attracted by the belt, but repelled by a second plastic rod rubbed in the same manner. Alternatively, a rubbed glass rod is attracted by a rubbed plastic rod. Two rubbed glass rods or plastic rods repel one another. Thus there exist two kinds of charge, which are called positive (glass) and negative (plastic), respectively.
2. After some time, the rubbed rods lose their charge. In the case of many substances, such as metals, this happens so quickly that the simple experiment of Fig. 1 cannot be performed with them at all. But metal objects can be mounted on substances which lose or conduct charge very slowly: these are called non-conductors or insulators. Such arrangements are used, for example, in the case of electroscopes, where mobile metal pointers are mounted on insulators. A charge on the insulated metal pointer causes it to be attracted towards the casing, i. e. the pointer is deflected. When a plastic rod is drawn across the metal plate attached to the electroscope, it will show a deflection, so it has become charged.

   The same method for charging metals is used in the case of "electrostatic" machines, such as the van de Graaff generator (see Fig. 3).

3. The electroscope facilitates the observations considerably and increases the number of possible experiments.
   a) When rubbed plastic, glass or the like is brought near the electroscope, it acquires an opposite charge.
   b) If the electroscope is charged with plastic, then, rubbed glass will reduce this charge, as glass induces a charge of opposite sign – in this case, a negative charge – on the electroscope.
   c) The charged electroscope retains its charge for a considerable period of time. A plastic rod brought into contact with the electroscope plate causes the charge to flow away very slowly, a glass rod lets it flow away much faster; wood, paper and so on will take it away even more rapidly. All metals discharge it at once. Charge can move very easily in metals, but not at all in insulators.
   d) The mobility of the charges in the metal pointer provides the reason for its deflection when a charged rod is brought near it. The charges which were originally distributed uniformly throughout the metal pointer separate. This induction effect repels charges of the same sign into the tip of the pointer, so that it makes a deflection (see Fig. 4).

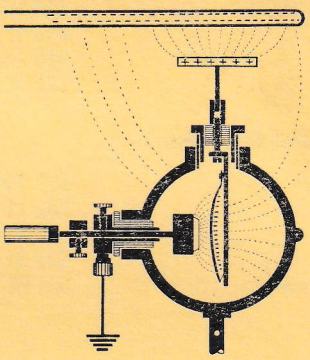

Fig. 4 Schematic representation of the electrostatic induction in the Wulf electroscope when a charged rod is brought near

   e) The electroscope does not deflect if the dry rubber belt and the plastic rod that was rubbed with it are brought near the electroscope together. When brought near it separately, however, each produces a deflection of approximately the same size for both.
   f) A rubbed plastic rod placed near the electroscope causes it to deflect. The deflection can be reduced by bringing a rubbed glass rod near the electroscope, because it carries a charge of opposite sign.

In the experiments listed so far, electric charge manifested itself by setting up forces between the bodies carrying the charges. A further experiment will establish its close relation to yet another electric quantity, electric current. When

an electrically charged metal object is discharged through a metal wire, a transient current flows through this latter. It can be indicated by a sensitive current-measuring instrument. The time integral of the current can be measured by a ballistic method (see DC 537.721.8;b). It is a measure of the electric charge that was on the metal object; the relation between this charge Q and the current I is defined by the formula

$$Q = \int I\,dt \quad \text{and} \quad I = dQ/dt\,.$$

These experiments establish the following characteristic properties of electric charge:

1. Charges on objects act on charges on other objects through forces which are set up by them between these objects.
2. There exist two kinds of charge, positive charge and negative charge. Their effects can be superimposed on one another.
3. The mobility of charges is high in metals and zero in insulators.
4. Moved charges, or charges that flow away from a charged body, constitute an electric current.

Formerly charge was defined by Coulomb's law (see DC 537.211;b), and electrical quantities were expressed in terms of mechanical ones. Nowadays charge is defined by $Q = \int I\,dt$ and the current I is introduced as a fundamental electric quantity. Accordingly, the unit of electric charge that has nowadays come to be adopted is 1 As (ampere second) = 1 C (coulomb).

Apparatus required for the experiment:
(in order of assembly)

1. For the experiment of Fig. 1

	Cat. No.
1 Glass tube, 25 cm long	541 01
1 Glass tube with cap, 25 cm long	541 02
1 Leather, for the separation of charges by friction	541 21
Amalgam (Kienmayer's)	541 24
1 Plastic rod (Mipolam), 25 cm long	541 04
1 Plastic rod with cap, 25 cm long	541 05
1 Stand for the magnetic needle	513 51
1 Spare rubber belt	from 541 70 or ET-No. 558
1 Air fan, 220 V A. C. or 110 V A. C.	545 20/21

2. Additional items required for the other experiments

1 Simple electroscope	540 09
1 Wulf electroscope	546 01
1 Projection attachment	546 02
1 Lamp-house with E 14 socket	450 60
1 Single-lens condenser	460 17
1 Lamp, 6 V, 30 W	450 51
1 Transformer, 6 V, 30 W	562 76
1 Van de Graaff generator	541 70

3. For ballistic measurement of current

1 School mirror galvanometer	532 10
1 Sensitivity regulator	532 11
or	
1 Measuring amplifier	532 01
1 Demonstration multirange meter	531 86

Useful hints:

1. The equipment and its use are described in the relevant Directions for Use.
2. To avoid surface conductivity the rods should be warmed up with the fan. This is particularly important for the glass rod.
3. The glass rod should be rubbed with leather on which some finely pulverized amalgam has been dusted. A thin greyblack coat suffices. Rub vigorously till leather and glass rod begin to get hot.
4. The plastic rod can easily be charged by rubbing it with dry textiles.
5. To remove any charge on the rods just draw them through the non-luminous flame of a Bunsen burner.

Assembly:

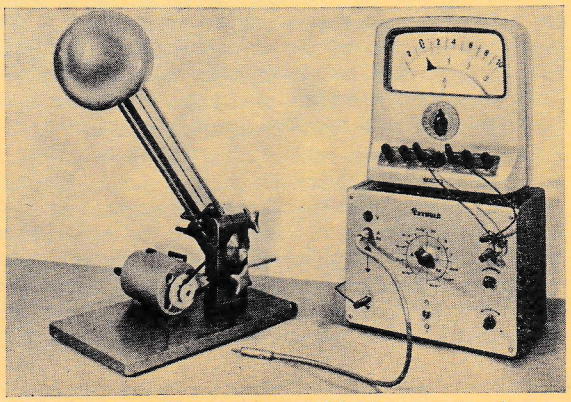

Fig. 5 Arrangement with measuring amplifier for measuring the current-time-integral obtained on discharging the sphere of the van de Graaff generator