

Basic electrostatics experiments with the electrometer amplifier

Objects of the experiment

- Investigating charge separation when two friction rods are hit together
- Detecting charge separation when a friction rod is rubbed with a friction foil
- Investigating the polarity of charged friction rods after they have been rubbed with various friction foils

Principles

Charges can be separated through hitting or rubbing two materials together.

This experiment shows that one of the materials carries positive charges, and the other material negative charges. It demonstrates also that the absolute values of the charges are equal.

If the charges of both materials are measured at the same time they cancel each other out. The sign of the charge of the material does not depend on the material alone, but also on the properties of the other material.

To determine the charge separated, e.g. by hitting two materials, the electrometer amplifier is used. This device is an impedance converter with an extremely high-ohm voltage input ($10^{13} \Omega$) and a low-voltage output (1Ω).

By means of capacitive connection of the amplifier's input and using a Faraday's cup to collect charges, this device allows to measure extremely small charges. Thus charges found in experiments of contact and friction electricity can be conducted with a high degree of reliability.



Fig. 1: Experimental setup with power supply 450 V (see also Fig. 2)

Apparatus

1 Electrometer amplifier	532 14
with	
1 Plug-in power supply 12 V AC	562 791
or with	
1 Power supply, 450 V, 230 V	522 27
1 Pair cables 100 cm, red/blue	501 46
1 Connecting rod	532 16
1 Multimeter LDanalog 20.....	531 120
1 Faraday's cup	546 12
1 Clamping plug.....	590 011
1 Capacitor, 1 nF, STE 2/19	578 25
1 Capacitor, 10 nF, STE 2/19	578 10
1 Pair of friction rods PVC and acrylic	541 00
1 Leather	541 21
1 Polyethylene friction foils	200 70 750
1 Induction plate	542 51
1 Pair cables 100 cm, red/blue	501 46
1 Connecting Lead 50 cm Black	500 424
 <i>additionally recommended is a non-smoking flame, e.g.:</i>	
1 Butane gas burner	666 711
1 Butane cartridge, 190 g	666 712

Setup

The experimental setup with power supply, 450 V and plug-in power supply 12 V AC is shown in Fig. 1 and Fig. 2, respectively.

Further hints of how to measure the charge with the electrometer amplifier can be found in the instruction sheet 532 14.

Carrying out the experiment

Remark:

Before carrying out the experiment discharge the friction rods and the Faraday's cup in order to obtain exact experiment results.

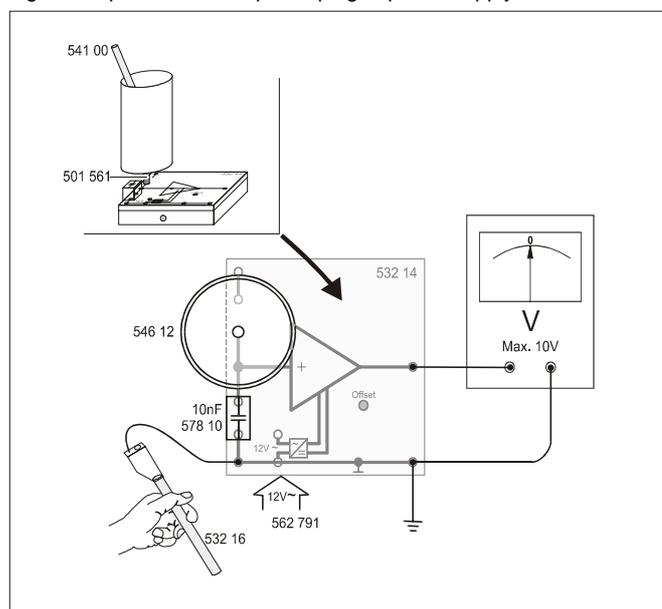
Further hints:

For discharging the friction rods it is recommend quickly move them longitudinally through the non-luminous flame of the cartridge burner several times.

The Faraday's cup is discharged by touching it with the connecting rod until the multimeter displays a voltage of $U = 0$ V.

- Hit the discharged friction rods together several times. Then hold them apart in your hands.
- Hold the PVC rod in the Faraday's cup so that about a quarter of its length is inside the cup and observe the deflection of the multimeter pointer.
- Do the same with the acrylic rod.
- Then hold the two rods in the Faraday's cup simultaneously and observe the deflection of multimeter pointer again.

Fig. 2: Experimental setup with plug-in power supply.



The induction plate can be used to demonstrate the transfer of charge from a friction rod to the Faraday's cup, e.g. by touching the friction rod with the induction plate and holding the induction plate into the Faraday's cup the charges can be transferred and measured.

Measuring example

Table. 1: Measured polarity of charges after hitting the PVC and acrylic friction rods

Friction rod in the Faraday's cup	Polarity of the charge
PVC	-
Acrylic	+
PVC and acrylic	0

Evaluation and results

When two friction rods are hit together, charge separation takes place.

In the course of charge separation electrons are transferred from one friction rod (e.g. acrylic) to the other (e.g. PVC).

The friction rod which has lost electrons (acrylic) carries a positive charge after the process of friction.

The friction rod which has acquired electrons (PVC) carries a negative charge.

The polarities of the charged friction rods are always of opposite signs.

The magnitudes of the charges are equal.

Further experiments

Instead of hitting the friction rods to separate the charges a friction rod can be rubbed with various materials to generate charge separation.

a) Detecting charge separation when a friction rod is rubbed with a leather

- Rub the discharged acrylic rod with the leather, hold it in the Faraday's cup so that about a quarter of its length is inside the cup, and observe the deflection of the multimeter pointer.
- Remove the acrylic rod.
- If necessary, discharge the Faraday's cup, hold the leather over the opening of the cup, and observe the deflection of the multimeter pointer.
- Remove the leather.

Table. 2: Polarity of the friction rod and the friction material after charge separation.

Friction rod	Polarity of the friction rod	Friction material	Polarity of the friction material
Acrylic	-	Leather	+

b) Investigating the polarity of charged friction rods after they have been rubbed with various friction materials

- One after another rub the PVC and the acrylic rod with leather and paper. Each time hold the respective rod in the Faraday's cup so that about a quarter of its length is inside the cup.
- Observe the deflections of the multimeter pointer, each time taking down the polarity of the charged friction rods.

Table. 3: Polarity of friction rods after being rubbed with various friction foils.

Friction rod	Friction material	Polarity of the friction rod
Acrylic	Polyethylene	+
PVC	Polyethylene	-
Acrylic	Leather	-
PVC	Leather	-
Acrylic	Paper	+
PVC	Paper	-

The results of Table 2 and Table 3 can be summarized as follows:

When a friction rod is rubbed with a friction foil, charge separation takes place.

In the course of charge separation electrons are transferred from one body (friction rod or friction foil) to the other.

The body which has lost electrons (friction rod or friction foil) carries a positive charge after the process of friction.

The body which has acquired electrons (friction rod or friction foil) carries a negative charge.

The polarities of the charges on the friction rod and the associated friction foil are always of opposite signs.

The polarity of the charges carried by a friction rod after being rubbed depends on the materials the friction rod and the friction foil are made from.

The different materials can be arranged in a triboelectric series according to the electron affinity.

For proximate materials in the triboelectric series, like PVC and Polyethylene, additives like colorants might even change the expected polarity.