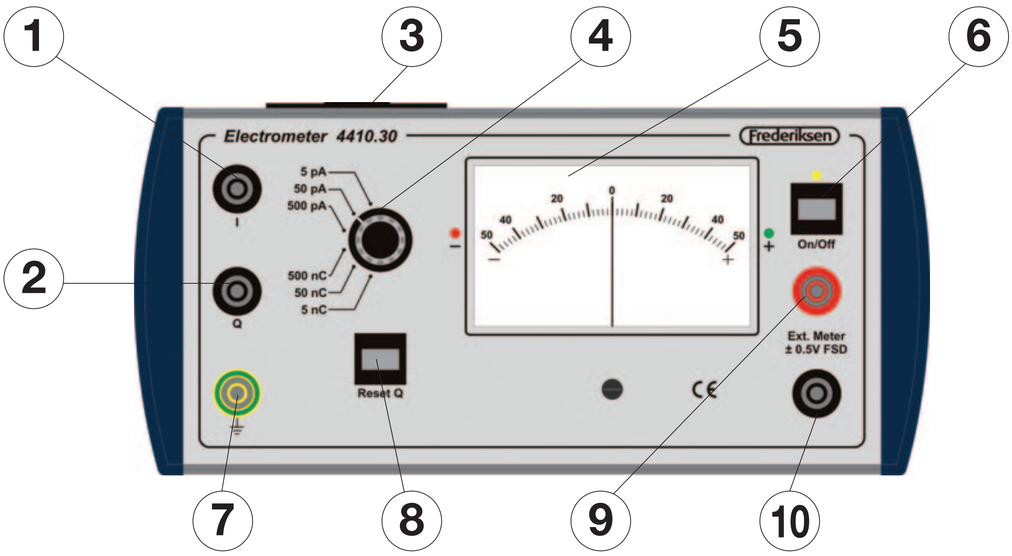
# Manual for electrometer no. 4410.30

17.12.10 Ae 4410.30




**Note:**
The purpose of this apparatus is to measure very small electrical currents and charges. It is therefore very sensitive to disturbances that you normally would neglect completely. Please read the section "Application hints"

## DESCRIPTION OF THE APPARATUS

The electrometer has on its left side input connectors for current (1) and charge (2). The reading is shown on a zero centered analogue instrument (5). The scale goes from "-50" to "50" and is read in connection with the setting of the switch (4). If for instance the switch is set to 500 nC, the meter will read from -500 nC to 500 nC.

During charge measurements the apparatus can be zeroed with the switch (8).

An output is provided between the sockets (9) and (10) for data logging or a demonstration meter. The voltage varies between -500 mV and 500 mV, corresponding to meter readings between "-50" and "50".

The yellow/green socket (7) to the left as well as the black socket (10) to the right are connected to chassis ground.
The apparatus is driven by a 9 V battery, placed in the holder (3).

### Current measurements

The input *I* is used with the switch settings 5 pA, 50 pA and 500 pA for measuring small currents.

The current goes through a 1 GΩ resistor.
This results in a voltage drop in the three measuring ranges of respectively 5 mV, 50 mV and 500 mV.
The current input is not protected against an overvoltage larger than 1 kV (corresponding to a current of 1 μA or 1,000,000 pA).

### Charge measurements

The input *Q* is used with the switch settings 5 nC, 50 nC and 500 nC for measuring charge.
The charge measurement can be zeroed by pressing *Reset Q*.

Charge is transferred to an internal 1 μF capacitor. This results in a voltage in the three measuring ranges of respectively 5 mV, 50 mV and 500 mV. In connection with typical electrostatic experiments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(with voltages in the kilovolts range), this voltage can be considered to be 0 V.

In other words, when measuring for instance the charge of a metal sphere, the measuring process can be viewed as a discharge of the sphere while concurrently keeping track of the amount of charge that leaves the sphere.

The charge input withstands a lasting voltage up to 70 V (corresponding to a charge of 70 µC or 70,000 nC).

During electrostatic experiments where charge is transferred to the input by a ball or the like, there is no risk of damaging the apparatus – only if the input is connected directly to a high voltage supply, bad things will happen.

## APPLICATION HINTS

### Grounding

In all experiment with static electricity or tiny currents it is an advantage to have a well-defined zero for all voltages. Normally you chose "earth" as this zero point.

A correctly installed, grounded mains socket provides this zero potential. When you are using for instance our 6kV supply 3660.50 or the 500V supply 3655.60/65 with the appropriate power cord, the ground connection is available as the yellow/green socket on the back. This should be connected to the electrometer chassis – either the yellow/green socket to the left or the black socket to the right.

If you work on a table with a metal frame, you may with advantage ground connect this also (eventually by means of an alligator clip).

If you also ground a 4410.02 insulated rod or a terminal like 4350.10 you have an un-insulated ground to discharge diverse metal balls as well as the experimenter.

### Removing static charges

If you want to experiment with electric charges by means of for instance a 4415.00 metal plated ball on rod, the experiment may be disturbed by small charges on the rod.

If a radioactive alpha source with a Perspex handle is used with the 4410.35 ionization chamber you may again observe that the apparatus reacts to charges on the handle.

Likewise charges may be created on the plastic insulation of the sockets of the apparatus when a cord is pulled out. Such charges may seep in to the $I$ input and show itself as a current that only very slowly falls towards zero – and that may be strong enough to throw the instrument off scale.

In the last case the problem is usually remedied by moistening a cotton swab with 96 % ethanol and inserting it into the socket. After removing it again and the liquid has evaporated, the dial should go to rest at zero.

To remove charges on insulated rods, you may also use 96 % ethanol. You should be aware that there is a risk that Perspex may get frosted or even crackle by contact with ethanol. It should be mentioned that our 4415.00 metal plated ball on rod uses a Perspex rod – but we have in fact never observed problems with the use of ethanol in connection with our work with the apparatus.

## EXPERIMENTS

The accessories mentioned are not part of 4410.13 but may be ordered separately.

### The ionization chamber

The ionization chamber (4410.35) consists of a center electrode and a surrounding grid electrode. The center electrode is put into the $I$ input such that the connector to the grid electrode is positioned to the left of the cabinet. Connect the grid electrode to a normal low voltage supply (for instance 3630.00) which has its other pole connected to the electrometer's ground (black socket to the right – or eventually yellow/green socket to the right). The measuring range should be 5 or eventually 50 nA. Check that the socked has not been charged. While turning up the voltage to something like 10 V, you will observe a momentary current as the grid is charged – but this should vanish fast, making the current approximately zero.

Prepare an alpha source (like our 37 kBq Am-241 source) so the handle is not charged, and move it close to the ionization chamber. When it gets close enough, you will observe a current running between the electrodes – the air has been partially ionized.

Likewise, you can place a burning match near the ionization chamber and gently blow the flame in the direction of the chamber. The free ions from the flame are enough to carry a measurable current.

### A small signal diode as a photo detector

A solar cell is in fact just a diode with a special appearance. An ordinary small signal diode in a glass housing (as for instance 1N4148) has in fact the same photoelectrical properties – the light sensitive area is just substantially smaller, giving rise to photocurrents in the picoampere range.

Set the range switch at 500 pA and connect the diode between the $I$ input and zero (⏚) with a couple of leads and alligator clips.

Shield the diode from direct illumination. The current should be below 50 pA under these conditions.
Now, let light from a flashlight or the like hit the diode and observe that the photo current rises significantly.
(Please note that this is an example of an experiment, where hum from the mains can give weird results – the diode may rectify the induced noise voltage, resulting in a overloaded input circuitry. Try to move the experiment to another position in the room.)

**Examples of electrostatic induction**

Prepare two 4415.00 metal plated ball on rod so they have no electric charges on the rods.

Use two 4410.02 insulated rod; one connected to a current limited, grounded high voltage supply and the other connected to zero (⏚). Connect also the negative pole of the power supply to zero.

Adjust the voltage to approximately 1.5 kV.

> **Note:** Use **only** a high voltage supply with an output current limiter (like our 3660.50) that ensures it is not dangerous to touch the equipment.

Place a 4425.00 faraday cup in the $Q$ input of the electrometer. Select the 5 nC range and press *Reset Q*.

Charge one of the metalized balls and position it inside the faraday cup – without touching it. The charge on the ball draws a charge of approximately same size but opposite sign up into the metal of the cup. As the cup and the input were initially uncharged, this must leave an equally large charge inside the input, with the same sign as the charge on the ball.

Lift the ball out of the cup – the meter returns to zero.

Repeat this, but let the ball touch the inside of the cup. The charges on the ball and the cup neutralize each other, leaving the input charged. (This process effectively transfers the charge from the ball to the $Q$ input.)
The charge measured stays at this value, even when the ball is removed.

Zero the instrument, and once again charge one of the balls. The other ball is discharged to zero (⏚).

Now, let the two balls touch each other. For symmetry reasons, the charge is distributed evenly on the two balls – which is demonstrated: Make one of the balls touch the bottom of the faraday cup – the meter goes halfway to the reading in the previous experiment. Repeat this with the other ball without zeroing – and now the meter reaches the same reading as before.

**The plate capacitor**

A 4315.10 or 4315.20 plate capacitor (resp. 15 or 22 cm) is used with 4316.00 dielectric (plates of PVC) and 4316.80 distance pieces.

Place one plate horizontally by means of a retort stand base and connect it to zero (⏚). Place the other plate on top of it with either one or more dielectric plates or distance pieces between.

A 4410.02 insulated rod is connected to a current limited, grounded high voltage supply making it easy to charge the upper capacitor plate with it. Connect the negative pole of the high voltage supply to zero.

Another rod is connected to the $Q$ input of the electrometer. Set the range switch to 500 nC. Zero the instrument.

Now, charge the upper capacitor plate with the tip of the rod connected to the high voltage supply. Remove the rod again and discharge the capacitor through the electrometer with the tip of the other insulated rod. If the pointer goes off scale, select a lower voltage and try again. If on the other hand the reading is too low to be precise, you may just repeat the charge/discharge cycle. Count how many times you repeat, and divide the reading by this number. The charge (for one charging) is called $Q$.

Read the value of the high voltage $U$.

The capacitance $C$ is given by

$$C = \frac{Q}{U}$$

This should be compared with the theoretical expression which is

$$C = \varepsilon_r \varepsilon_0 \frac{A}{d}$$

Where $\varepsilon_r$ is the relative permittivity for the dielectric (1 for air) $\varepsilon_0$ is the permittivity of vacuum, $A$ is the area of one of the plates and $d$ is the distance between them.

Repeat the experiment with varying distance (more PVC plates or distance pieces).

Eventually the area dependency may be investigated by switching between the 15 cm and the 22 cm plate capacitor.

**Connecting the high voltage supply directly to the electrometer must be avoided!**

## SPECIFICATIONS

**I input:**

| | |
|---|---|
| Input range: | - 500 pA … + 500 pA |
| Shunt resister: | 1 GΩ |
| Low pass filter: | fc = 2 Hz, 4th order (Butterworth) |
| Max. input voltage: | - 1000 … + 1000 V |

**Q input:**

| | |
|---|---|
| Input range: | - 500 nC … + 500 nC |
| Shunt capacitor: | 1 µF +/- 5 % 250 V (polypropylene) |
| Max. input voltage: | - 70 … + 70 V |

**Output:**

| | |
|---|---|
| Nominal output range: | - 500 … + 500 mV |
| Max. output: | - 1,9 V … + 1,2 V |
| Error, I: | max. +/- 2 % of full range 500 mV |
| Error, Q: | max. +/- 5 % of full range 500 mV |
| Load: | min. 100 Ω, max. 1 nF |

**Power supply:**

| | |
|---|---|
| Consumption: | 9V, 20 mA |
| Battery: | 9 V (6LR61) |
| Battery lifetime: | about 25 hours |

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