Basic Electrometer

ES-9078A

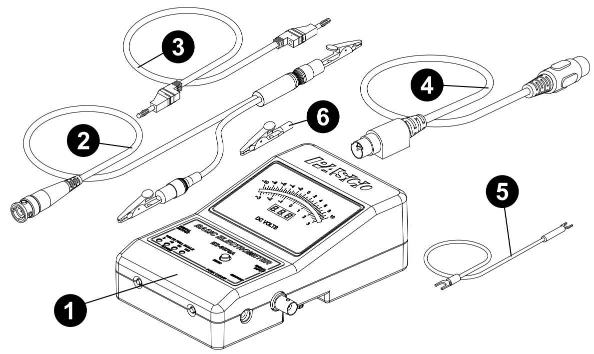
Introduction

The Basic Electrometer is a voltmeter used for direct measurements of voltage and indirect measurements of current and charge. Because of its high impedance of 10^{14} ohms, it is especially suited for measuring charge in electrostatic experiments. It has a sensitivity nearly one thousand times that of a standard goldleaf electroscope, a center-zero meter display that directly indicates charge polarity, and a digits display. The Basic Electrometer measures charges as low as 10^{-11} coulombs. The device can also output a signal to a PASCO analog interface. These features make electrostatics demonstrations and labs more quantitative and easier to perform.

The Basic Electrometer is powered by four AA-alkaline batteries (included). These batteries can be easily replaced by opening the back casing of the electrometer.

> **IMPORTANT:** When replacing batteries, DO NOT touch any of the components or wires in the integrated circuit panel. The components and wires are all static sensitive and may be damaged by touch.

Equipment



Included items:

1. **Basic Electrometer** (ES-9078A)
2. **Signal input cable** (BNC-to-alligator clip)

   Connects to the BNC jack at the Signal Input port.
3. **Banana plug patch cord**

   Connects to the Ground port on the Basic Electrometer.
4. **Interface cable** (Mini DIN-to-8-pin DIN plug)

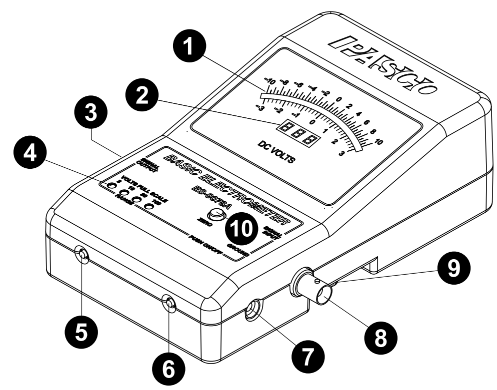
   Connects between the Signal Output port of the Basic Electrometer and a PASCO analog interface.
5. **Grounding cable**

   Features insulated spade lug connectors and a one gigaohm resistor. To be used with the Basic Variable Capacitor (ES-9079).
6. **Alligator clip**
7. **4× AA-cell alkaline batteries** (not pictured)

Recommended equipment:

- Faraday Ice Pail (ES-9042A)
- Charge Producers and Proof Plane (ES-9057C)
- Basic Variable Capacitor (ES-9079)
- 850 Universal Interface (UI-5000) or 550 Universal Interface (UI-5001)
- PASCO Capstone (required for 850 Universal Interface) or SPARKvue data collection software

Features



1. **Meter display**
2. **Digits display**
3. **Signal Output port**

   Connect interface cable here to output signal to an analog interface.
4. **Voltage range indicators**

   Indicate the selected measurement range.
5. **Voltage range selector button**

   Press to change the selected voltage range.
6. **ON/OFF button**

   Press to turn the device on or off.
7. **Ground port**

   Connect device to earth ground via this port.
8. **Signal Input port**

   Connect signal input cable to BNC jack here.
9. **Access to battery compartment**

   Loosen both thumbscrews to remove the case and access the batteries.
10. **ZERO button**

    Push to zero meter and remove excess charges.

Get the software

You can use the sensor with SPARKvue or PASCO Capstone software. If you're not sure which to use, visit pasco.com/products/guides/software-comparison.

SPARKvue is available as a free app for Chromebook, iOS, and Android devices. We offer a free trial of SPARKvue and Capstone for Windows and Mac. To get the software, go to pasco.com/downloads or search for **SPARKvue** in your device's app store.

If you have installed the software previously, check that you have the latest update:

SPARKvue: Main Menu > Check for Updates

PASCO Capstone: Help > Check for Updates

Operation

The following sections explain how to safely set up and use the Basic Electrometer.

Setup

1. Connect the BNC plug of the signal input cable (test lead) to the BNC jack on the side of the Basic Electrometer. To lock the cable in place, line up the pegs on the BNC jack with the slots on the plug, push the plug onto the jack, and turn the plug clockwise until secure.
2. Use the banana plug patch cord to connect the Ground port of the electrometer to an earth ground.
3. Press the **ON/OFF** button to turn the electrometer on. The digits display, meter display, and one of the voltage range indicators will light up.
4. Press the **ZERO** button to zero the electrometer. The LED of the meter display will align with the "0" mark, and the digits display will show **0.0**.
5. Press the **Voltage range selector** button to select the desired voltage range (3, 10, 30, or 100).

The range setting refers to the voltage input required to produce a full-scale meter deflection. For example, a setting of 30 means that the meter will be fully deflected by a voltage of 30 V.

Important points for general operations

> **IMPORTANT:** ALWAYS follow these guidelines to prevent personal injury or damage to the device!

- NEVER use the Basic Electrometer to measure potentials greater than 100 V.
- Never connect the electrometer to an electrostatics generator, such as a Van de Graaff generator or a Wimhurst machine.
- Avoid touching the input leads until you have grounded yourself to an earth ground. A person walking across a rug on a cool, dry day can easily acquire a potential of several thousand volts.
- Always press the ZERO button between measurements to discharge any excess charge from the electrometer. Shorting the test leads together is insufficient, as there may still be stray charges within the circuitry.
- For best results, ALWAYS connect the electrometer to an earth ground, such as a water pipe or the ground wire from a 120 VAC socket, during experiments. Only an earth ground can provide a sufficient drain for excess charge buildup during the experiment.
- The experimenter should also be grounded during the experiment. To do this, touch one hand to an earth ground just before or during measurements.

Measuring voltage

The Basic Electrometer can be treated as an infinite impedance voltmeter. To use the electrometer as a voltmeter, connect the signal input cable leads to the battery, set the voltage range, and read the voltage on the meter or digits display.

Measuring charge via induction

Under most conditions, the best way to measure charge is via induction. Use a proof plane and a Faraday ice pail, such as those included with the Electrostatics System (ES-9080B) and shown below.

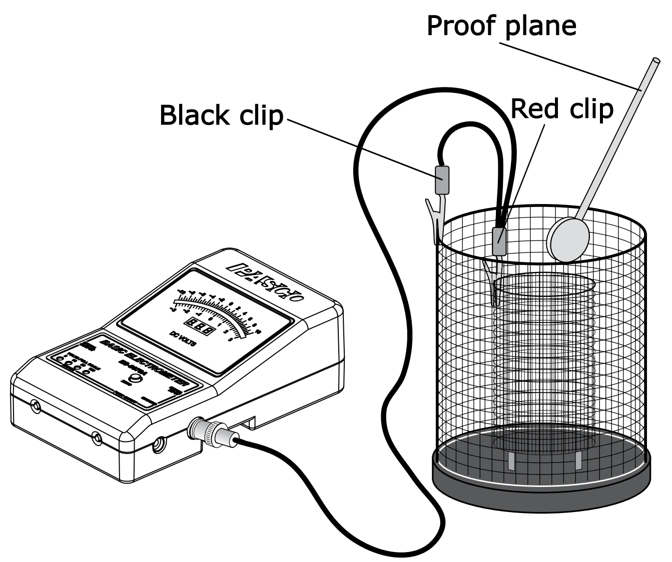


Figure 1. The Basic Electrometer connected to a Faraday ice pail using the Signal Input cable.

The proof plane is simply a small conductive disk mounted on an insulating handle. To sample the charge distribution on a charged object, simply touch the object with the proof plane, then place the proof plane inside the inner cylinder of the ice pail, *without* touching the cylinder. A charge of equal magnitude and sign is induced on the surface of the ice pail and can be read by the Basic Electrometer.

By always using the proof plane and ice pail, the capacitance will be the same for all measurements, and the charge on the proof plane will always be proportional to the voltage reading on the electrometer.

Measuring charge via contact

Charges can also be measured by contact. If you touch the inner cylinder of the ice pail with a charged object, such as a charged proof plane, the electrometer reading will generally remain mostly unchanged. This is because the total capacitance is only negligibly affected by the proof plane. However, this may not always be the case.

Any charge measurement with the electrometer is indirect, based on the knowledge that the amount of charge on an object is proportional to the potential difference produced by the charge. Therefore, the electrometer readings will always be measured in volts, not coulombs. However, the polarity of the voltage directly shows the type of charge being sampled. If quantitative charge measurement is needed rather than qualitative data, charge can be measured using the equation $Q = CV$, where V is the voltage across a known capacitor of capacitance C.

The Basic Electrometer can be thought of as an infinite impedance voltmeter in parallel with a capacitor C_E, as shown in Figure 2. C_E represents the internal capacitance of the electrometer, plus the capacitance of the leads and the ice pail if these are being used. When a charged object is placed across the electrometer leads (or into the ice pail), a voltage V is displayed on the meter. If the value C_E is known, the value of charge can be calculated using the equation $Q = C_E V$.

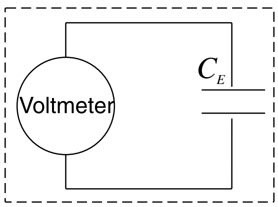


Figure 2. Ideal schematic of the Basic Electrometer.

The capacitance of the electrometer alone is about 27 picofarads (pF). However, if the sampled object adds significant capacitance, the situation changes to what is shown in Figure 3, with C_{ext} being the capacitance of the object. To accurately calculate the amount of charge in this case, the total capacitance $C_E + C_{ext}$ must be determined. This requires an accurate value for C_E, unless you are certain that the object you are measuring has a high enough capacitance to disregard C_E ($C_{ext} >> C_E$). Note that this is *not* the case when using the Basic Variable Capacitor (ES-9079). The following section will explain how to measure the experimental capacitance value of the electrometer, any cables connected to it, and the ice pail.

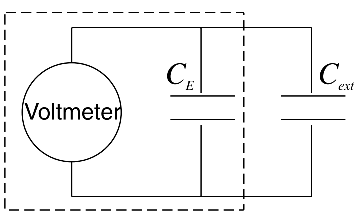


Figure 3. Change in capacitance due to a charged object.

Measuring the capacitance of the electrometer and connectors

When a known capacitor C is charged by a known voltage V, the charge in the capacitor is given by $Q = CV$. If a capacitor with known charge is connected across the leads of the electrometer, it is connected in parallel with the internal capacitance C_E of the electrometer, ice pail, and cables. Therefore, the total capacitance becomes $C + C_E$. The known capacitor will discharge across the Basic Electrometer, and the voltage V_E can be read. Since the total charge of the system is still Q, we know that:

$$CV = (C + C_E)V_E$$

Use this procedure to measure a precise value of the capacitance provided by the electrometer and connected instruments:

1. Obtain a low leakage capacitor (polypropylene or air dielectric) of known value C around 30 pF.
2. Charge the capacitor with a known voltage V. This voltage should NOT be higher than 100 V, as this is the limit of the electrometer.
3. Remove the charged capacitor from the power supply used to charge it. Be careful *not* to ground it in any way to avoid accidentally removing the charge.
4. Connect the charged capacitor across the electrometer input leads. (If you want to include the capacitance of the ice pail, connect the capacitor across the pail and shield of the ice pail instead.)
5. Record the voltage V_E indicated by the electrometer.
6. Calculate the total capacitance using this equation:

$$C_E = \frac{C(V - V_E)}{V_E}$$

Measuring current

The Basic Electrometer can also be used for indirect current measurements. To do this, connect the electrometer leads across a known resistance in the circuit and measure the voltage. Using Ohm's Law ($V = IR$), determine the current from this voltage value. Due to the electrometer's extremely high input impedance, the electrometer will have a negligible effect in most circuits. However, note that the voltage drop across the resistor *must* be within the voltage range of the electrometer (100 V maximum).

If hooking the electrometer across a known resistance in the circuit is not convenient, the following procedure can be used instead:

1. Connect a precision resistor between the input leads of the electrometer.
2. Break the circuit and reconnect it in series with the precision resistor, as if you were connecting it to a standard ammeter.
3. Measure the voltage across the resistor.
4. Using Ohm's Law, calculate the current through the resistor.

NOTE: When using the second method, ensure the resistance is high enough to measure a voltage drop, but low enough that it doesn't significantly affect the current through the circuit.

Using the Basic Electrometer with an interface

The Signal Output connector on the Basic Electrometer provides an output signal that can be processed by a PASCO analog interface, such as the 850 Universal Interface (UI-5000) or the 550 Universal Interface (UI-5001). The interface cable included with the electrometer connects directly to an analog port, or to a PASPORT port with the use of an Analog Adapter (PS-2158). Connecting the electrometer to an interface allows the output signal to be recorded, displayed, and analyzed via PASCO Capstone or SPARKvue data collection software.

NOTE: Changing the range switch on the electrometer has no effect on the scaling of the output signal. The data collection software automatically scales the display to an appropriate level.

TIP: Because the output has limited resolution, it may be useful to increase the gain of the analog port or apply a gain within the software when measuring voltages lower than 10 V.

SPARKvue

1. Start SPARKvue, then click **Sensor Data**.
2. Connect your interface to SPARKvue. For instructions on this, see the manual for the interface and the SPARKvue online help.
3. Connect the interface cable from the Signal Output port on the Basic Electrometer to an analog port on the interface.
4. From the **Select measurements for templates** column, select the **Properties** icon next to the name of the channel to which the electrometer is connected.
5. From the list of sensor options, select **Electrometer (Basic)** and select **OK**.
6. Ensure that the box next to **Voltage** is checked in the measurements column, then select **Graph** from the Displays column to open the Experiment Screen. The graph display will automatically adjust to measure voltage versus time.
7. Click **Start** to begin collecting data.

PASCO Capstone

1. Start Capstone, then click **Hardware Setup** in the **Tools** palette.
2. Connect your interface to Capstone. For instructions on this, see the manual for the interface and the Capstone online help.
3. Connect the interface cable from the Signal Output port on the Basic Electrometer to an analog port on the interface.
4. In the **Hardware Setup** tool, locate the image of the connected interface. Click inside the yellow circle over the port to which the cable is connected and select **Electrometer** from the list.
5. Double-click **Graph** in the **Displays** palette to create a new graph display.
6. Click **<Select Measurement>** next to the y-axis and select **Voltage** from the list. The x-axis will automatically be set to measure time.
7. Click **Record** to begin recording data.

Software help

The SPARKvue and PASCO Capstone Help provide information on how to use this product with the software. You can access the help from within the software or online.

SPARKvue

Software: Main Menu > Help

Online: help.pasco.com/sparkvue

PASCO Capstone

Software: Help > PASCO Capstone Help

Online: help.pasco.com/capstone

Specifications and accessories

Visit the product page at pasco.com/product/ES-9078A to view the specifications and explore accessories. You can also download experiment files and support documents from the product page.

Experiment files

Download one of several student-ready activities from the PASCO Experiment Library. Experiments include editable student handouts and teacher notes. Visit pasco.com/freelabs/ES-9078A.

Technical support

Need more help? Our knowledgeable and friendly Technical Support staff is ready to answer your questions or walk you through any issues.

Chat	pasco.com
Phone	1-800-772-8700 x1004 (USA) +1 916 462 8384 (outside USA)
Email	support@pasco.com

Limited warranty

For a description of the product warranty, see the Warranty and Returns page at www.pasco.com/legal.

Product end-of-life disposal

This electronic product is subject to disposal and recycling regulations that vary by country and region. It is your responsibility to recycle your electronic equipment per your local environmental laws and regulations to ensure that it will be recycled in a manner that protects human health and the environment. To find out where you can drop off your waste equipment for recycling, please contact your local waste recycle or disposal service, or the place where you purchased the product. The European Union WEEE (Waste Electronic and Electrical Equipment) symbol on the product or its packaging indicates that this product must not be disposed of in a standard waste container.

CE statement

This device has been tested and found to comply with the essential requirements and other relevant provisions of the applicable EU Directives.

FCC statement

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Battery disposal

Batteries contain chemicals that, if released, may affect the environment and human health. Batteries should be collected separately for recycling and recycled at a local hazardous material disposal location adhering to your country and local government regulations. To find out where you can drop off your waste battery for recycling, please contact your local waste disposal service, or the product representative. The battery used in this product is marked with the European Union symbol for waste batteries to indicate the need for the separate collection and recycling of batteries.