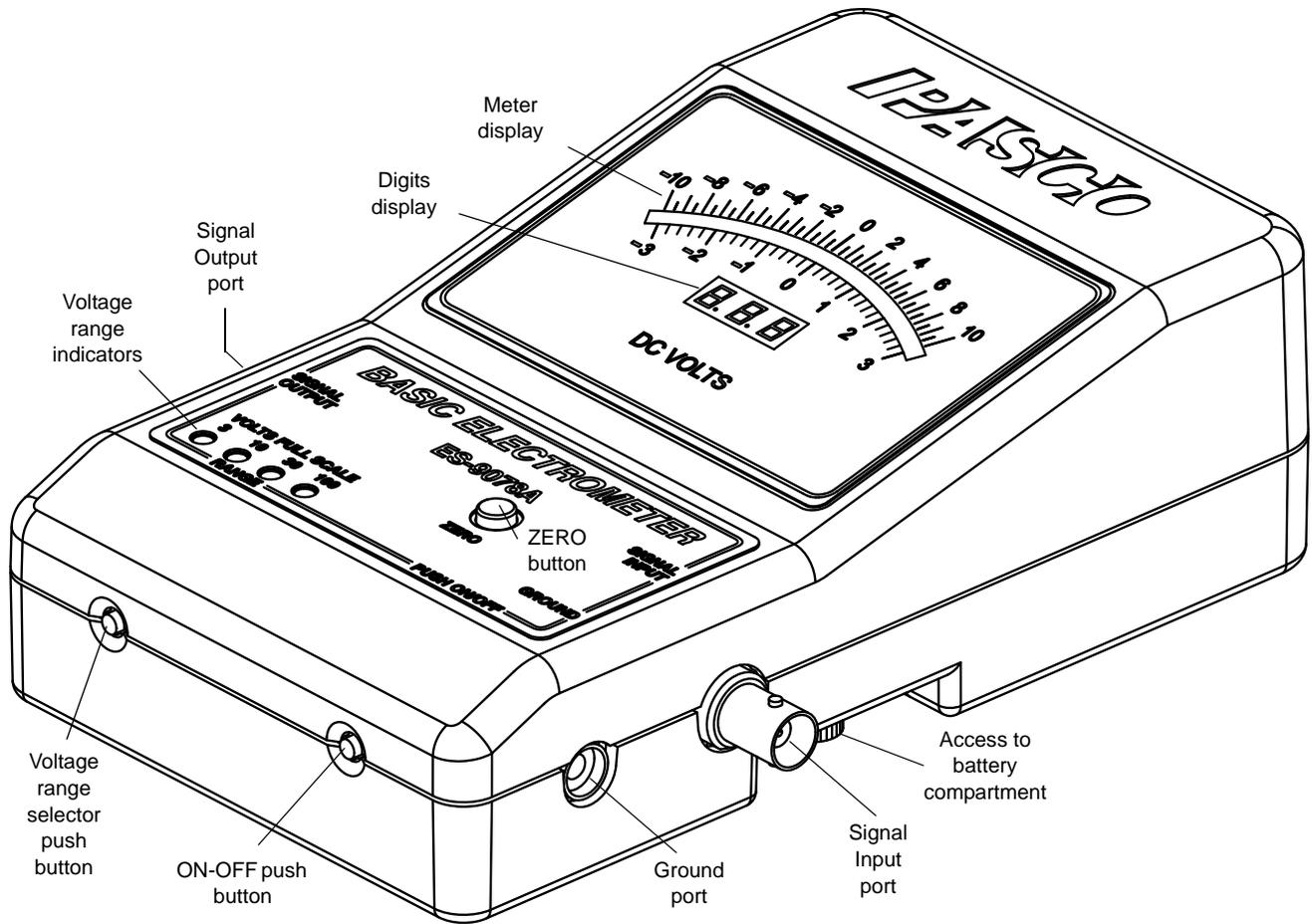




Basic Electrometer

ES-9078A



Included Items	Included Items
Basic Electrometer	Banana Plug Patch Cord*
BNC to Alligator Clip Cable*	Alligator Clip*
Grounding Cable*	AA-Cell Alkaline Battery (4) (not shown)
Interface Cable*	(*shown on page 2)

Other Equipment

Other PASCO equipment is recommended for use with the Basic Electrometer.

Recommended Equipment*	Recommended Equipment*
Faraday Ice Pail (ES-9042A)	Basic Variable Capacitor (ES-9079)
Charge Producers and Proof Plane (ES-9057C)	PASCO Interface and Data Acquisition Software

*See the PASCO catalog or the web site at www.pasco.com for more information

Introduction

The Model ES-9078A is a voltmeter used for direct measurements of voltage and indirect measurements of current and charge. Because of its high (“infinite”) 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 electrometer can also output a signal (± 10 V) to a PASCO interface.

With these features, you’ll find that your electrostatics demonstrations and labs are easier to perform and, with quantitative data, are more informative. The electrometer is powered by four AA-alkaline batteries (included) which can be easily replaced by opening the back casing of the electrometer.



NOTE: 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.

The Basic Electrometer includes four cables and a spare alligator clip.

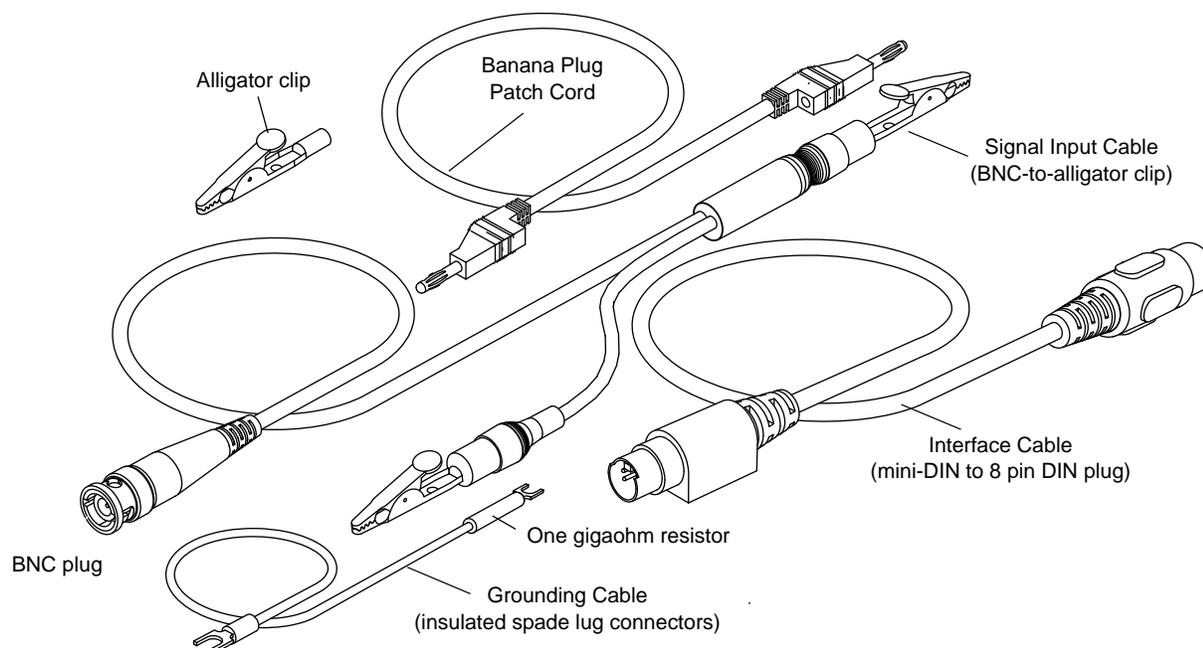


Figure 1: Cables and clip

The Banana Plug Patch Cord connects to the Ground port on the Basic Electrometer. The Signal Input Cable connects to the BNC jack at the Signal Input Port. The Interface Cable connects between the Signal Output port of the Electrometer and a PASCO interface. (NOTE: A PASPORT Analog Adapter PS-2158 is required to connect the cable to a PASPORT interface.) The Grounding Cable has a one gigaohm resistor and is intended for use with the ES-9079 Basic Variable Capacitor.

Operation

The controls on the front panel of the electrometer are explained in Figure 1. Whether you're using the electrometer to measure voltage, current, or charge, the following procedure should be followed each time you turn on the electrometer.

More information on making accurate measurements is provided in the sections that follow.



Warning:

1. Never use the electrometer for measuring potentials more than 100 volts.
2. Never connect the electrometer to an electrostatics generator, such as a Van de Graff generator or a Wimhurst machine.
3. 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.

Setup

1. Connect the BNC plug of the signal input cable (test lead) to the BNC jack on the side of the electrometer. Line up the pegs on the BNC jack with the slots on the BNC plug. Push the plug onto the jack and turn the plug clockwise one-quarter turn until it is 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 push button to turn the electrometer on. The digits display, the meter display, and one of the voltage range indicators will light up.
4. Press the ZERO button to zero the electrometer. The light emitting diode (LED) of the meter display will align with the "0" mark and the digits display will show "0.0".

You're now ready to use the electrometer to measure charge, current or voltage.

5. Press the voltage range selector push 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 a full scale meter deflection indicates a voltage of 30 volts.

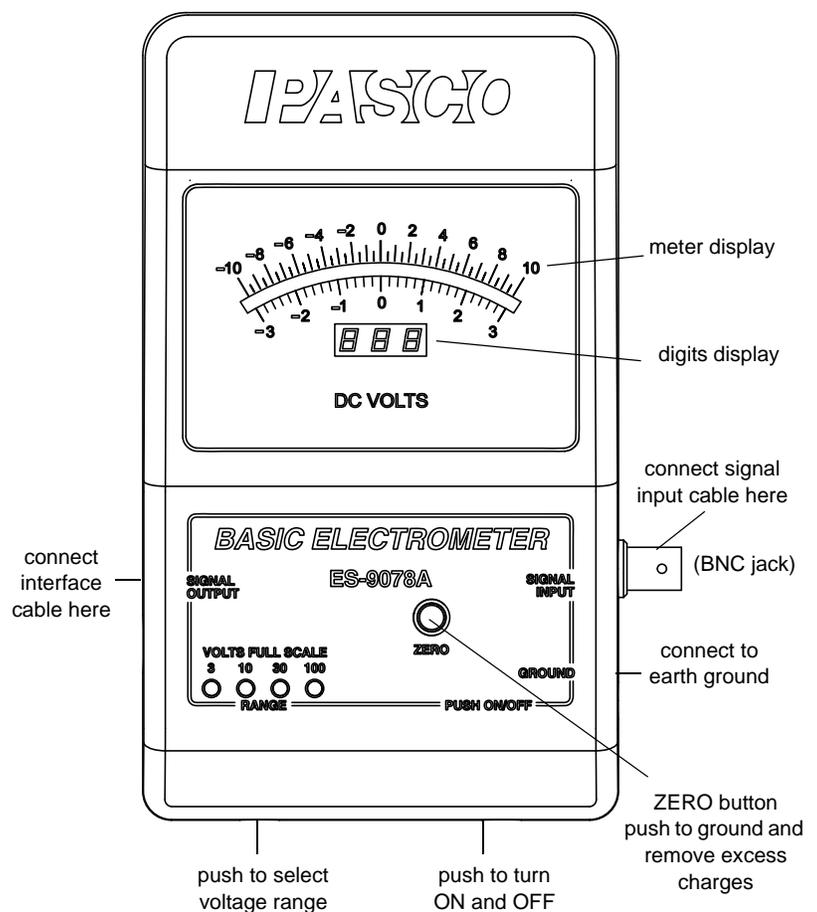


Figure 2: Electrometer Top Panel



Important Points for General Operations:

- Always press the ZERO button between measurements to discharge all excess charge from the electrometer. Shorting the test leads together is insufficient. There may still be stray charges within the electrometer circuitry.
- For good results, it is essential that the electrometer be connected to an earth ground (a water pipe or the ground wire from a 120 VAC socket). Only an earth ground provides a sufficient drain for excess charges that may build up during an experiment.
- It is also helpful if the experimenter is grounded. Just touch one hand to a good earth ground just before, or during measurements.

Measuring Voltage

The electrometer can be thought of as an infinite impedance voltmeter. To show that the electrometer is like a voltmeter, connect the signal input cable leads to the battery, set the range (3, 10, 30, or 100 volts full scale), and read the voltage on the meter.

Measuring Charge

Induction Charges

Under most conditions, the best way to measure charge is by induction. Use a proof plane and a Faraday ice pail, such as those included with PASCO's Electrostatics System (ES-9080), and shown in Figure 3..

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 it 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 electrometer.

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

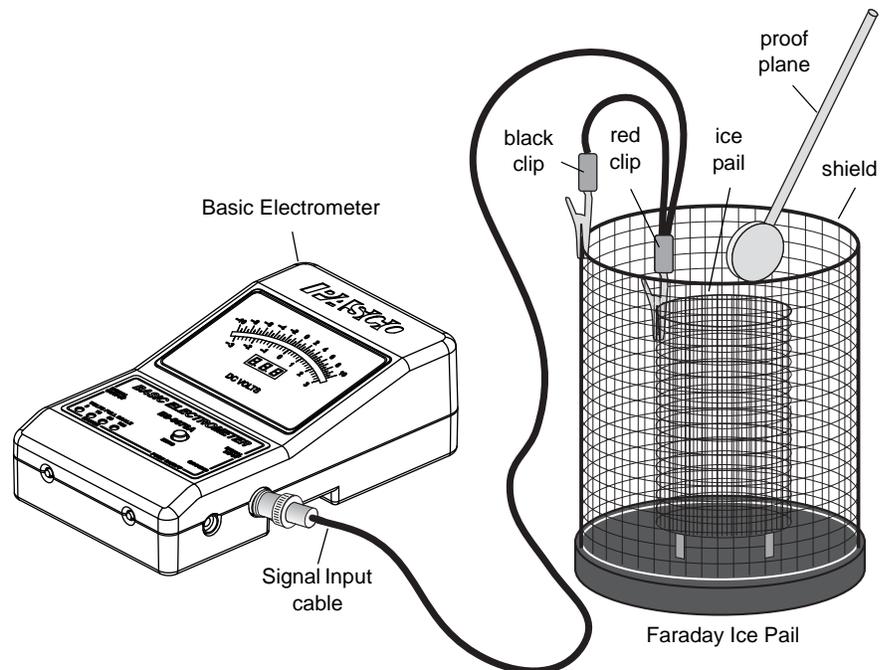


Figure 3: Electrometer with Faraday Ice

Contact Charges

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

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. The readings of the electrometer will always be of volts, not of coulombs. The polarity of the voltage, however, directly shows the type of charge being sampled. If you need quantitative rather than qualitative charge measurement, values for the charge can be computed according to the relationship $Q = CV$, where V is the voltage across a known capacitor of capacitance C .

The electrometer can be thought of as an infinite impedance voltmeter in parallel with a capacitor, C_E , as shown in Figure 4. C_E represents the internal capacitance of the electrometer, plus the capacitance of the leads and the capacitance of the Ice Pail, if being used.

When a charged object is placed across the electrometer leads (or in the ice pail), a voltage V displays on the meter. If the value C_E is known, the value of the charge can be calculated as $Q = C_E V$.

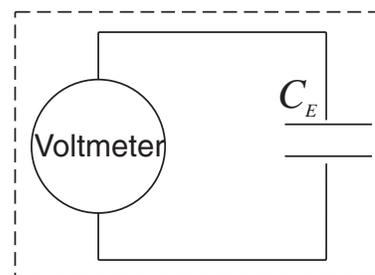


Fig. 4: Ideal Schematic of the Electrometer

The capacitance of the electrometer alone is around 27 picofarads (pF). However, if the sampled object adds significant capacitance, the situation becomes as shown in Figure 5.

To accurately calculate the amount of charge, total capacitance $C_E + C_{ext}$ must be determined. In any case, for quantitative measurements of charge, you need to have an accurate value for C_E ($C_{ext} \gg C_E$), unless you are certain that the object you are measuring has a high enough capacitance to disregard C_E . (This is not true, for example, when using the ES-9079 Basic Variable Capacitor.)

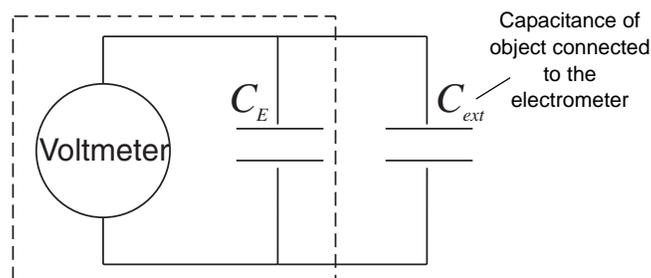


Fig. 5: Change in capacitance due to a charged object

The following process shows you how to measure an experimental value of the capacitance of the electrometer, any cables connected to it, and the ice pail.

Measuring the Capacitance of the Electrometer and Connectors

For all experiments, the electrometer can be thought of as a voltmeter connected in parallel with a capacitor, as shown in Figure 3. The capacitor C_E represents the internal capacitance of the electrometer, plus the capacitance of the leads and the ice pail. Use this procedure to measure a precise value of the capacitance provided by the electrometer and all instruments connected to it. If you are interested in qualitative, rather than quantitative experiments, this procedure is not necessary.

When a known capacitor C , is charged by a known voltage V , the charge in it is given by $Q = CV$. If the known charged capacitor is connected across the leads of the electrometer, it is connected in parallel with the internal capacitance of the electrometer, C_E . The total capacitance becomes $C + C_E$. The known capacitor discharges across the electrometer and a voltage, V_E , is read.

Since the total charge in the system is still just the charge of the known capacitor, we know that $CV = (C + C_E) V_E$.

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 , not higher than 100V (the limit of the electrometer).

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

3. Remove the charged capacitor from the power supply used to charge it, being careful not to ground it in any way, so as not to remove the charge.
4. Connect the charged capacitor across the electrometer input leads. (Or across the pail and shield of the ice pail, if you want to include its capacitance value). Note the voltage V_E indicated by the electrometer.
5. Calculate the total capacitance:

Measuring Current

The electrometer can be used for indirect current measurements.

Connect the electrometer leads across a known resistance in the circuit and measure the voltage. Use Ohm's Law ($V = IR$) to determine the current. Due to the electrometer's exceedingly high input impedance, the effect of the electrometer in the circuit will be

negligible in most circuits. However, the voltage drop across the resistor must be within the voltage range of the electrometer (100 V maximum).

If it is not convenient to hook the electrometer across a known resistance in the circuit, a precision resistor can be connected between the input leads of the electrometer. The circuit can be broken, as for connection to a standard ammeter, and connected in series with the precision resistor.

Again, measure the voltage across this resistor and calculate the current. (The problem with this technique is that the resistance must be high enough to measure a voltage drop, but low enough so it doesn't significantly affect the current through the circuit).

Electrometer with Interface

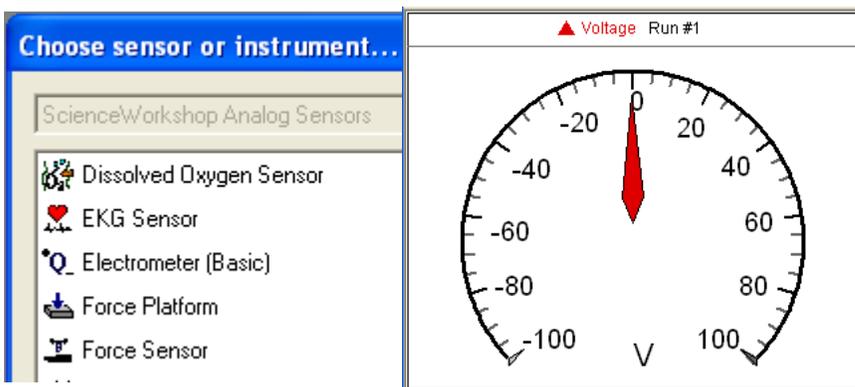
The signal output connector on the ES-9078A Electrometer provides an output signal for a PASCO interface. The interface cable included with the electrometer connects directly to an analog channel on a ScienceWorkshop interface, and connects to a PASPORT interface through a PS-2158 Analog Adapter. This enables the output signal from the electrometer to be recorded, displayed, and analyzed by the data acquisition software.

It is important to remember that the signal output on the ES-9078A has a fixed scale of ± 10 volts. Changing the range switch on the electrometer has no effect on this scaling. By choosing the Electrometer icon in DataStudio™ (data acquisition software), displays are shown correctly scaled.

Because of limited resolution on this output, it may be useful to apply a gain within the data acquisition software to measure voltages of less than 10 volts.

Experiment Setup: PASPORT

- Connect the mini-DIN plug of the interface cable to the Signal Output port on the electrometer. Connect the 8-pin DIN plug of the interface cable to the PS-2158 Analog Adapter. Connect the Analog Adapter to a PASPORT Interface.
1. Start DataStudio. If the PASportal window opens, select "Launch DataStudio". If the Welcome to DataStudio screen appears, select "Create Experiment". Otherwise, select "New Activity" from the File menu.
 2. Select "Electrometer (Basic)" from the list of sensors and click OK.
 3. In the Displays list, click the Meter icon. A Meter display of Voltage opens.



Experiment Setup: ScienceWorkshop

- Connect the mini-DIN plug of the interface cable to the Signal Output port on the electrometer. Connect the 8-pin DIN plug of the interface cable to Analog Channel A of the ScienceWorkshop Interface.
1. Start DataStudio. If the Welcome to DataStudio screen appears, select "Create Experiment". Otherwise, select "New Activity" from the File menu.
 2. In the Experiment Setup window, click the Analog Channel A on the icon of the ScienceWorkshop interface.

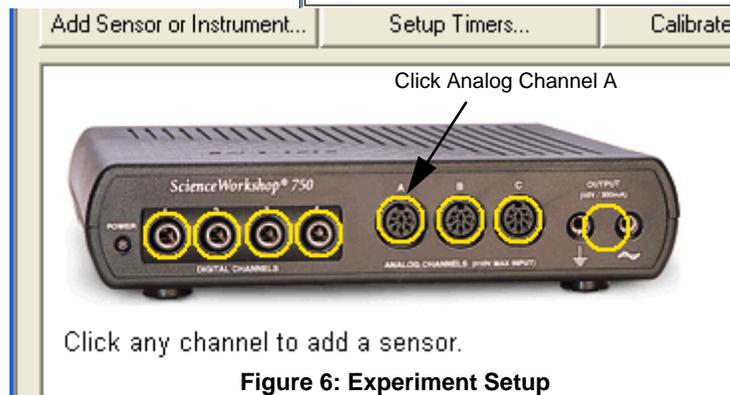


Figure 6: Experiment Setup

3. Select “Electrometer (Basic)” from the list of sensors and click OK.
4. In the Displays list, click the Meter icon. A Meter display of Voltage opens.

Data Recording

Note: Data recording is easier if one person handles the Electrometer and the other equipment and another person handles the computer or data logger.

1. Prepare the Electrometer and equipment. Click “Start” to begin data recording.
2. Rub the two Charge Producers together. Lower the disk of one of the Charge Producers into the Faraday Ice Pail. Watch the Meter display of voltage. Remove the first Charge Producer and put the second Charge Producer into the Faraday Ice Pail.
3. Click “Stop” to end data recording.
4. From the Displays list, click the Graph icon to view a plot of the voltage versus time that was recorded by the Electrometer.

Specifications

Item	Value
Voltage input ranges	3, 10, 30, 100 volts full scale
Input resistance	approximately 10^{14} ohms
Signal output range	-10 to +10 volts (maps to ± 100 V)
Signal output accuracy	$\pm 1\%$
Batteries	four “AA” cells (alkaline recommended)
Battery life	approximately 75 hours

Technical Support

For assistance with any PASCO product, contact PASCO at:

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Roseville, CA 95747-7100

Phone: 916-786-3800 (worldwide)
800-772-8700 (U.S.)

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Web: www.pasco.com

Email: support@pasco.com

For the latest revision of this Instruction Manual, visit the PASCO web site and enter ES-9078A in the Search window.

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The European Union WEEE (Waste Electronic and Electrical Equipment) symbol and on the product or its packaging indicates that this product **must not** be disposed of in a standard waste container.

