

**Instruction Sheet  
for the PASCO  
Model ES-9078**

# **BASIC ELECTROMETER**



## **Introduction**

The Model ES-9078 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 1000 times that of a standard gold-leaf electroscope, a center-zero meter that directly indicates charge polarity, and measures charges as low as  $10^{-11}$  coulombs.

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, easily replaced by opening the back casing of the electrometer.



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.

## **EQUIPMENT**

### **Parts included:**

- Basic Electrometer (ES-9078)
- Associated Cables, four (4)

### **Additional parts required:**

- Faraday Ice Pail (ES-9042A)
- Proof Plane
- Basic Variable Capacitor (ES-9079)
- Pasco Computer Interface (Model 750, 500 or 300)

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## 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.

2. Connect the test lead to the input connector of the electrometer.
3. Connect the ground post of the electrometer to an earth ground.
4. Push the power button ON. One of the range switch LEDs will blink twice in quick succession.
5. To zero the meter, press the ZERO button. You're now ready to use the electrometer to measure charge, current or voltage.
6. Set the range switch to the desired voltage range. The range setting refers to the voltage input required to produce a full-scale meter deflection (e.g., a setting of 30 means that a full scale meter deflection indicates a voltage of 30 volts).



### Important Points for General Operations:

1. Between measurements, always press the Zero button 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. Note that on the most sensitive scale (3 volts), the meter may not return to exactly zero when the Zero button is pressed. This is normal and will not affect the accuracy of the reading.
2. DO NOT use the mechanical zero adjust screw to set the meter to zero, unless power is off.
3. 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.

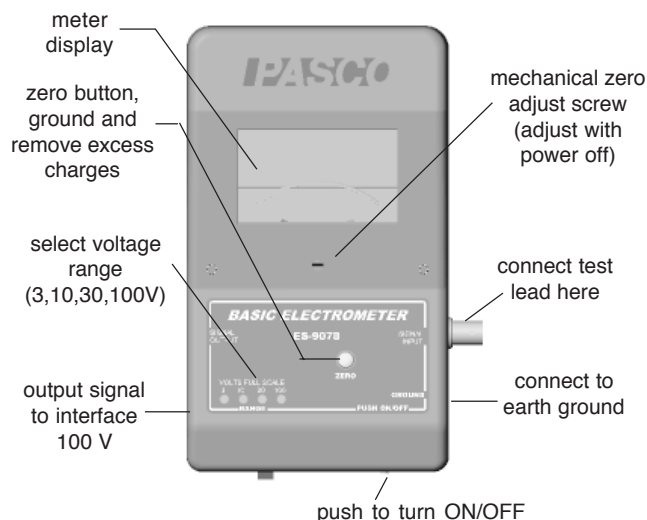


Figure 1. Electrometer panel controls

## Setup Procedure

1. Before turning on the electrometer, check that the meter reads zero. If not, turn the Mechanical Zero Adjust screw, located just below the meter face, until it does.

## Measuring Voltage

The electrometer can be thought of as an infinite impedance voltmeter. To show that the electrometer is like a voltmeter, connect the leads to the battery, set the range (3, 10, 20, 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 Demonstration Electrostatics System, and shown in Figure 2. 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.

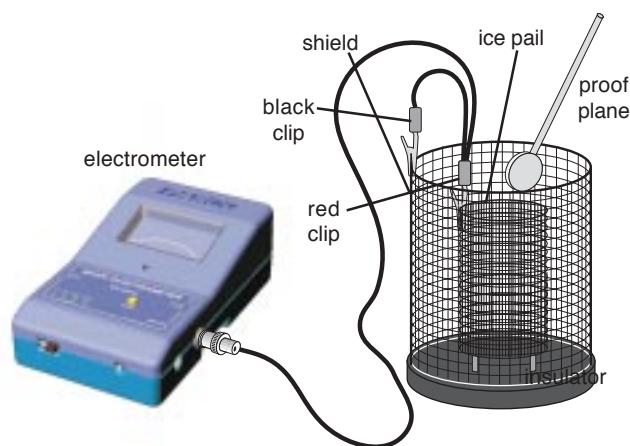


Figure 2. Using a Faraday Ice Pail

### 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 3.  $C_E$  represents the internal capacitance of the electrometer, plus the capacitance of the leads and the capacitance of the Ice Pail, if being used.

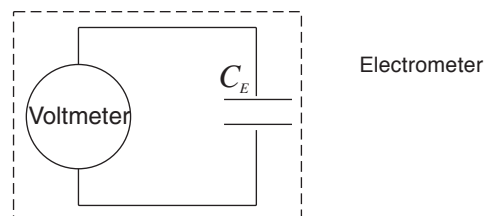
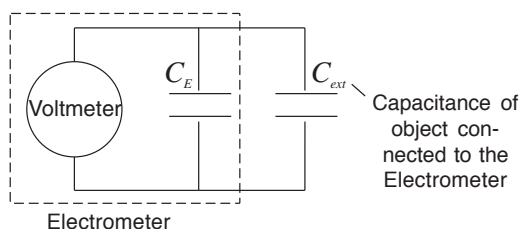


Figure 3. Ideal Schematic of the Electrometer

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  $Q = C_E V$ . The capacitance of the electrometer alone is around 27 pF. However, if the sampled object adds significant capacitance, the situation becomes as shown in Figure 4.



**Figure 4. Change in capacitance due to a charged object**

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  $C_E$ . The capacitors in the PASCO RC Network (ES-9053), for example, are high enough that  $C_E$  need not be considered. This is not true, however, when using the parallel plate variable capacitor (ES-9079).

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 2. 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  $V$ ,

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

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

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).

### Using a Computer with Science Workshop Interface

The signal output connector on the ES-9078 Electrometer provides an output signal for the Science Workshop interface. This provides an output signal for displaying data in analog meters, tables, graphs or oscilloscopes, making data analysis easy.

It is important to remember that the signal output on the ES-9078 has a fixed scale of  $\pm 100$  volts. Changing the range switch on the electrometer has no effect on this scaling. By choosing the Electrometer icon in DataStudio™ or ScienceWorkshop®, displays are shown correctly scaled.

Because of limited resolution on this output, it may be useful to apply gain within the ScienceWorkshop interface to measure voltages of 10 volts or less.

## Specifications

### ES-9078 Basic Electrometer:

Voltage input ranges: 3, 10, 30, 100 volts full scale

Input resistance: approximately  $10^{14}$  ohms

Input capacitance: approximately 27 pF

Accuracy: Analog Meter:  $\pm 3\%$   
ScienceWorkshop output:  $\pm 1\%$

Signal output: Fixed at -100 to + 100 volt range  
(Automatically scaled in DataStudio and ScienceWorkshop)

Batteries: 4 - "AA" (Alkaline recommended)

Battery life: approximately 75 hours

**Note:** This instruction sheet assumes the user is familiar with ScienceWorkshop® or DataStudio™. Users can gain familiarity by working through the tutorials provided in ScienceWorkshop or DataStudio's Online Help.



The exclamation point within an equilateral triangle is intended to alert the user of important operating and safety instructions that will help prevent damage to the equipment or injury to the user.

## ***Technical Support***

### **Feedback**

If you have any comments about the product or manual, please let us know. If you have any suggestions on alternate experiments or find a problem in the manual, please tell us. PASCO appreciates any customer feedback. Your input helps us evaluate and improve our product.

### **To Reach PASCO**

For technical support, call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

fax: (916) 786-3292

e-mail: techsupp@pasco.com

web: www.pasco.com

### **Contacting Technical Support**

Before you call the PASCO Technical Support staff, it would be helpful to prepare the following information:

► If your problem is with the PASCO apparatus, note:

- Title and model number (usually listed on the label);
- Approximate age of apparatus;
- A detailed description of the problem/sequence of events (in case you can't call PASCO right away, you won't lose valuable data);
- If possible, have the apparatus within reach when calling to facilitate description of individual parts.

► If your problem relates to the instruction manual, note:

- Part number and revision (listed by month and year on the front cover);
- Have the manual at hand to discuss your questions.

## ***Warranty***

### **Limited Warranty**

PASCO scientific warrants the product to be free from defects in materials and workmanship for a period of one year from the date of shipment to the customer. PASCO will repair or replace, at its option, any part of the product which is deemed to be defective in material or workmanship. The warranty does not cover damage to the product caused by abuse or improper use. Determination of whether a product failure is the result of a manufacturing defect or improper use by the customer shall be made solely by PASCO scientific. Responsibility for the return of equipment for warranty repair belongs to the customer. Equipment must be properly packed to prevent damage and shipped

postage or freight prepaid. (Damage caused by improper packing of the equipment for return shipment will not be covered by the warranty.) Shipping costs for returning the equipment after repair will be paid by PASCO scientific.

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