H28792 Electrometer **NFU 285**

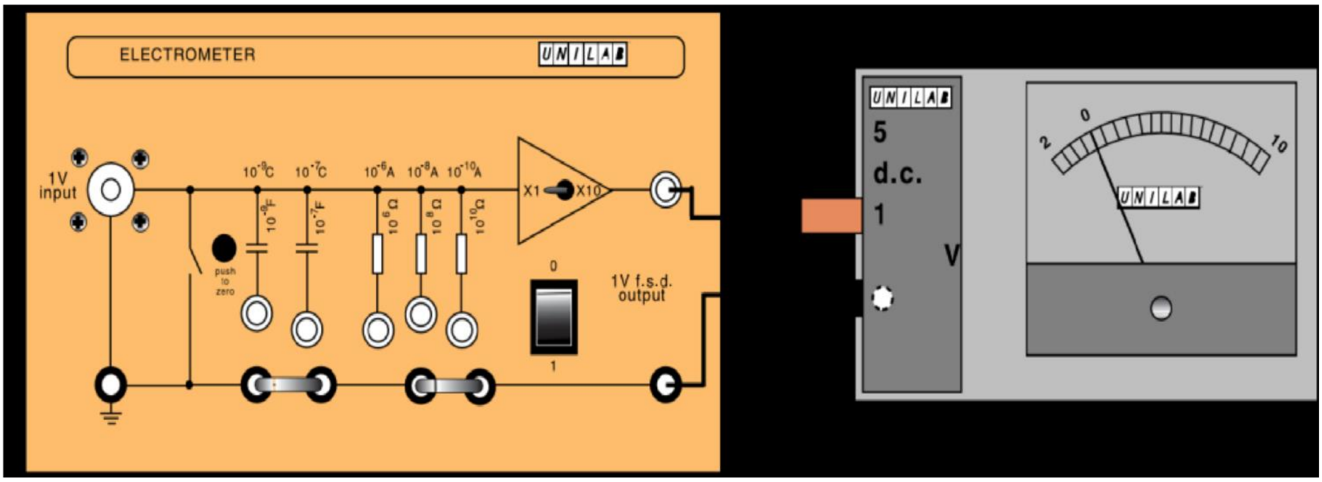
Purpose

To use the electrometer, a 1V f.s.d. meter should be connected to the output terminals. The amplifier has gains of x1 and x10 - depending on the switch position. Whatever the quantity being measured, a potential difference, between 0 and 1V has to be applied to the input and this produces an output voltage equal to the input voltage for the x1 gain setting, and 10 times greater for the x10 setting.

Small currents may be measured by connecting one of the high value resistors in the electrometer using the connecting link B. For example, using a gain of x1: if the 1010Ω resistor is used a 1 volt reading on the voltmeter would mean that the current through the resistor was I = V / R = 1 / 1010 = 10-10A Currents down to 10-6A, 108A, 10-10A, and using the x10 gain: 10-7A, 10-9A, 10-11A can be measured.

Small charges can be measured by connecting one of the small capacitors in the electrometer using the connecting link A. The unknown charge Q is transferred to this capacitor, C and causes a potential difference V across it which acts as the input potential difference. For example, using a gain of x1: if the 10-9F capacitor is used, a 1 volt reading on the meter would mean that the charge on the capacitor would be Q = VC = 1 x 10-9 = 109 coulombs.

Charges of the order of 10-9 and 10-7 coulombs, and using the x10 gain 10-10 and 10-8 coulombs can be measured. If the capacitance of the object bringing charge to the input is small, compared to the selected internal capacitance, C, then charge transfer will be almost complete.
In both of the above cases the input impedance of the amplifier is so large that negligible current flows into it and so has no significant effect on the above calculations.



version R01234.15.03

Apparatus details

The Electrometer has been designed for maximum flexibility and ease of use. It has an internal PP3 - 9 volt-battery, which is connected through the On/Off switch. Replacement of this battery is described in Appendix 2.

Measuring Small Currents

The small current is passed through one of the high value resistors in the Electrometer and the potential difference V developed across this resistor is measured. (I = V / R) (In practice, on the x1 range, the output meter gives the current x the multiplication factor marked above the resistor used on the Electrometer.)

- Arrange the small disk just below the gauze inside the Ionization Chamber.
- Connect the ionization chamber to the Electrometer input using the Coaxial Socket.
- Connect the 10 Ω resistor in the Electrometer using the connecting link (B).
- Switch the gain of the Electrometer to x10. (The Electrometer is now measuring 10-11A.)
- Connect a 6V battery between the 6V
- Electrometer and the Ionization Chamber casing as shown.
- Connect a 1 volt f.s.d. meter to the Electrometer output and switch on.
- Light a splint and bring the flame an ammeter
- Under teacher supervision: Using forceps, bring a small radioactive source (eg: 5µCi radium) near to the gauze. The radioactive source is emitting particles which ionise the air.

Photoelectric effect

- Clean the top of the small disc probe with emery paper and near to the gauze. The flame ionises the air molecules, gently blow the ions down through the gauze. Observe the meter reading. The electrical circuit is: ions carry electric arrange it just below the gauze inside the ionization chamber.
- Connect the ionization chamber to the Electrometer input using the Coaxial Socket.
- Connect the 1010Ω resistor in the electrometer using the connecting link (B).
- Switch the gain of the electrometer to x10. (The electrometer is now measuring 10-11A.)
- Connect a 6V battery between the Electrometer and the Ionization Chamber casing. The negative of the battery is connected to the black (ground) terminal of the Electrometer. The positive is connected to the Ionization Chamber.
- Connect a 1 volt f.s.d. meter to the Electrometer output and switch on.
- Place an ultra-violet lamp over the ionization chamber and switch on.
  CARE - DO NOT LOOK DIRECTLY AT THE ULTRA-VIOLET LIGHT. Look at the meter - it should be giving a steady reading. Without touching the equipment, turn off the lamp and verify that the reading is due to the ultra-violet lamp. (A word of warning - the meter is being used at its most sensitive, and electrostatic charge on your clothing could give a false reading. It is best to keep your hand away from the ionization chamber when making measurements).

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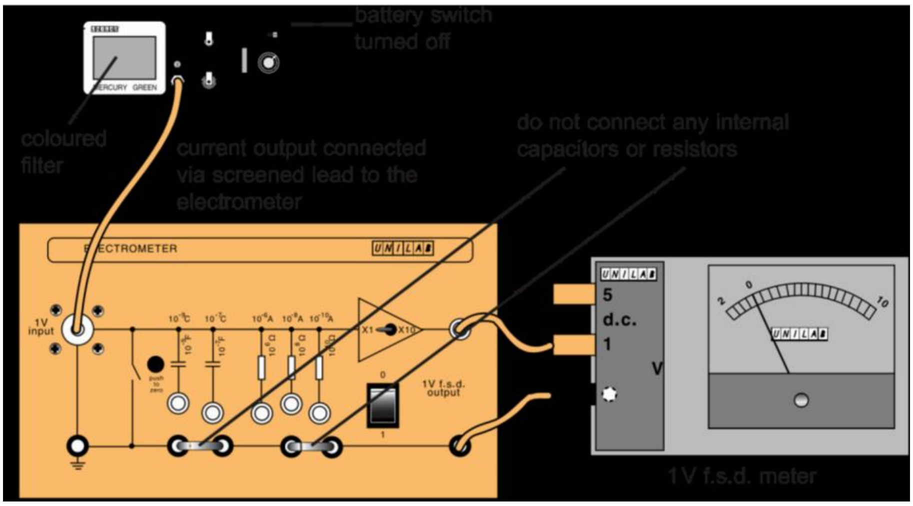
When ultra-violet light falls on a metal, electrons can be ejected with kinetic energy 1/2mv2. Planck suggested this was related to the frequency f of the ultra-violet light according to the equation: hf = 1/2 mv2 + W0 h is known as Planck's Constant. W0 is a constant for the metal and represents the energy needed to just remove the electron with no kinetic energy from the metal structure.



- Replace the disc probe with magnesium ribbon just below the gauze in the ionization chamber and repeat the experiment. Magnesium has a lower W0 than the metal of the probe - hence the different reading. Alkali metals also (e.g. lithium, sodium, potassium and caesium) have low values of W0 and these are usually used in photoelectric tubes.

Planck's constant

When electromagnetic radiation falls upon an alkali metal, electrons are emitted with kinetic energy determined by the frequency of the radiation according to the equation:

hf = 1/2 mv2 + W0 (eq.1)

where h is Planck's Constant, f is the frequency and W0 is the work function (a constant for the material) and 1/2mv2, the kinetic energy of the electron.
The Electrometer can be used with the Plank's Constant Apparatus (H28615) in order to measure h. This apparatus consists of a photoemissive cell in which the alkali metal alloy (caesium-antimony) is the cathode. The electrons emitted can be attracted to or repelled from a nearby electrode called the anode, depending on the anode voltage

There are three ways the above equipment may be used to measure h.

Method 1

- Connect the current output of the photoemissive cell to the Electrometer using a screened lead, as shown above. Make sure the internal battery switch of the Planck's Constant Apparatus is off.
- Connect the 1V f.s.d. meter to the Electrometer and switch the Electrometer on. No internal resistors or capacitors should be connected in the Electrometer. If light is falling on the photoemissive cell the

Electrometer should give a reading. The electrons emitted from the cathode travel across the cell to the anode which becomes negatively charged.

Because of the very high resistance of the Electrometer which is connected between the cathode and anode, the negative charge builds up and stops the arrival of further electrons. (In practice, because of the small leakage current through the electrometer amplifier this never quite happens - but the effect is negligible). If this measured potential difference is V then:

eV = 1/2mv2max (eq. 2) where e is the charge on the electron.

- A set of coloured filters is supplied with the apparatus, each allowing through a small waveband of light. The shortest wavelength of each waveband corresponds to the maximum kinetic energy acquired by the electron and is the value used in the calculation. Place each filter over the photoemissive cell in turn and measure the potential difference.
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Method 2

- Connect the Electrometer and the 1V meter to the current output of the photoemissive cell as in Method 1. Use the Electrometer in its current measuring mode (see page 1).
- Connect a voltmeter e.g. the UNILAB Easy-Read Meter (H79933) with 20V d.c. Attachment (H30919) between the cathode and anode of the photoemissive cell as shown.
- Switch on the internal battery in the Planck's Constant Apparatus.
- Place the red filter over the photoemissive cell and turn the knob (of the 20k multi-turn potentiometer) on the current through the photoemissive cell, as read by the electrometer, just becomes zero. Note the potential difference across the photoemissive cell from the Easy Read Meter.
- Repeat this procedure with the other filters and note the voltage V required to bring the current through the photoemisive cell to zero, for each colour.

Electrons are ejected from the cathode of the photoemissive cell according to the equation:
hf = 1/2 mv2 + W0 (eq. 1)

The electrons are repelled from the anode by the 'backing off' voltage V. This is increased until even the electrons with the largest kinetic energy fail to reach the anode. (The electrometer reading is zero). In this case:
eV = 1/2 mv2max (eq. 2) using fλ = c these equations can be
combined and rearranged to give**:**

V = hc/e. 1/λ - W0/e (eq. 3) where
h is Planck's Constant c is the velocity of light (3 x 108ms-1) e is the charge on an electron (1.6 x 10-19C) W0 is the work function of the metal ejecting the electron.

Typical Results (see below):
The accepted value of h = 6.6 x 10-34Js. Quantitative photoelectric experiments with simple apparatus are difficult because:
i. of the need for very clean surfaces. ii. the filters allow through a wide range ofwavelengths of light - better results can be obtained using filters with narrower ranges as demonstrated by Method 3.

Method 3

- Repeat the experiment in method 2 in a darkened room, using a Mercury Discharge Tube and Narrow Band Filters (H31614)
- Arrange the mercury lamp so that it shines down vertically on the window of the cell from a height of 1020mm. For safety reasons, do not look at the lamp directly when it is on
- Experiments using spectra and narrowband filters will therefore give results closer to the accepted value

Electrostatics

In electrostatics the Electrometer is used in its charge-measuring form. One of the internal capacitors is connected across the input using connecting link A. The voltmeter should be capable of reading both in the positive & negative directions (i.e. centre zero). Additional items needed are supplied in the Unilab Electrostatics kit (L02719).

Positive and negative charges

- Place a probe into the input socket. A small disc probe or just a 4mm rod will do.
- Connect the output meter (adjusted if necessary so that the needle can swing either to the right or to the left).
- Set the amplifier gain to x10
- Connect the 10-7F capacitor using link A.
- Press the 'push to zero' switch to discharge any residual charge on the capacitor.
- Charge the perspex strip (coloured red) by rubbing it with a cloth. Draw it across the input probe. The meter deflects to the right indicating a positive charge. (Note: sometimes the meter deflects left after the strip has been removed - this is because it is difficult to remove the positive charge from the strip and the capacitor becomes charged negatively by induction when the strip is removed - see section 3.2)
- Repeat the experiment using the PVC strip (coloured grey) this time the meter deflects to the left indicating a negative charge

Electrostatic Induction

- Fit the two perspex support pillars in to their bases and plug the two 32mm diameter metal spheres into the tops of the pillars.
- Place the spheres in contact and bring a negatively charged PVC strip close to one sphere, as shown, separating the spheres at the same time.
- Show that the charges induced on the spheres are equal in magnitude but opposite in sign (the sphere nearest the PVC strip having the positive charge) using the same practical arrangement for the Electrometer as above

Distribution of charge on conductors

Remember to press the 'push to zero' switch to discharge the capacitor before making any readings.

- Plug the 75mm hollow metal sphere in to the top of a perspex support pillar in its base. Charge the sphere negatively by drawing a rubbed PVC strip once or twice across the top

- Connect the internal 10-7F capacitor using link A on the Electrometer. Use the x10 range
- Touch the inside surface of the sphere(but not the edge of the hole) with a 32mm sphere fitted to a perspex pillar. Use the Electrometer to show that it is uncharged
- Touch the outside surface of the hollow sphere with the small sphere. This time it is charged. Charge resides on the outside of a conductor.

Please contact Philip Harris Technical Support for further experimental guides.

Replacement of the internal battery.

The Electrometer is powered by a 9 volt PP3 (6F22) battery. To replace this battery: remove the Philips screws from the right hand side of the Electrometer and remove the right hand end panel.
Remove the battery from its housing and connect a new battery to the clip. Replace the right hand end panel of the electrometer making sure that you do not trap the battery connecting wires.

It is not possible to adjust the gain of the electrometer which is set in the factory.

Safety advice

For your safety, this product should be used in accordance with these instructions; otherwise, the protection provided may be impaired.
This unit is intended for use in DRY conditions. Avoid spillage of water and other liquids on to the unit.

Disclaimer

If the equipment is used in a way not specified by Philip Harris, then the protection provided may be impaired.

Warranty, repairs and spare parts

The Electrometer is guaranteed for a period of one year from the date of delivery to the customer. This warranty does not apply to defects resulting from the action of a user such as misuse, improper wiring, any operations outside of its specification, improper maintenance or repair, or unauthorized modification.

Our liability is limited to repair or replacement of the product. Any failure during the warranty period should be referred to Customer Services.

In the event of a fault, apart from replacing the instrument fuse in the IEC socket, the power supply should be referred to the Philip Harris recommended repair agent.

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Disposal of Waste Electrical and Electronic Equipment (WEEE)

Do not dispose of this product with household waste

- For the proper treatment , recovery and recycling please take this product to an appropriate collection point.
- If you are unsure where this is, contact your Local Authority
- By disposing of this product correctly you will be providing positive help to the environment.

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version R01234.15.03