

# OPERATING INSTRUCTIONS

## Mass of the Electron Apparatus No. 30818

### 1. Introduction

The Mass of the Electron Apparatus is used to measure the ratio of charge to mass of the electron, and to study the deflection of electrons in a simple cathode ray tube. Electrons are emitted near the socket of the tube and travel along the length of a tube, passing through two perpendicular plates of deflecting plates. Because of their different orientations, one pair of plates deflects the electrons vertically, the other horizontally, when a potential difference is applied across each pair of plates. The beam then strikes the coated face of the tube, and light is emitted.

The deflection due to an applied potential may be studied with this tube. Observing the electron beam in known electric and magnetic fields enables the user to calculate the mass of the electron. The beam is accelerated and given a small transverse velocity by the plates in the tube, and is deflected by an axial magnetic field created by a solenoid (not included) which fits over the CRT's plastic "jacket."

### 2. Description

The apparatus centers around a 5cm-diameter cathode ray tube inside a clear plastic casing. A 5mm grid over the face of the tube permits direct measurement of electron beam deflection. The CRT rests on an inclined stand that carries banana jacks for connection of the filament, the anode, and the cathode to the power supply. Separate jacks for the two sets of deflection plates (the "X-X" and "Y-Y" plates) are provided. A focus knob allows the user to adjust the sharpness of the beam. A power supply such as the Universal Power Supply is required for operation. The mass of the electron experiment also requires an air core solenoid. See section 6, "Accessories," for recommendations.

### 3. Setup

**Caution! This apparatus uses 500 VDC and can cause painful shocks unless all instructions are followed carefully. Do not turn on the power supply until all connections are made. Always turn off the power supply before changing the positions of the banana plugs. At the end of each experiment, turn off the power supply first, and always remove the banana plugs from the power supply before removing them from the apparatus.**

These instructions assume the use of the Universal Power Supply. Other power supplies that give the same voltages are acceptable as long as their outputs are not connected to ground, since the required connections are made internally in the CRT stand. If other power supplies are used, be sure to supply the correct voltage, 6.3 VAC, to the filament of the tube. Excessive voltage will burn out the filament and destroy this expensive apparatus.

Make sure that the power supply is turned off, and connect it to line voltage. Leave the power supply off while making connections. Connect the two green filament jacks on the tube stand to the two green banana jacks on the upper left-hand corner of the Universal Power Supply, using banana plug

patch cords. Use another patch cord to connect the CRT's blue banana jack, marked "Cathode," to the purple -250 VDC jack on the center strip of the power supply. Connect the red CRT "Anode" banana jack to the red +250 VDC power supply jack.

**Caution! If the patch cords were connected to the power supply and not plugged into the base, the plug ends would have a 500 VDC potential difference between them if the power supply were turned on at this point. Be sure to observe the proper connection sequence with the power supply off, plug the cords into the jacks in the stand, then into the power supply; then turn the power supply on.**

The circular measurement grid rests over the CRT, but is not enclosed in the casing. By pressing gently and carefully against the rubber-coated outside edge, it can be rotated to align it with the deflection axes of the tube. Since the grid is not enclosed, it can be knocked free by excess pressure; to prevent this from happening, turn it by pressing on opposite sides of the grid at the same time (that is, by pressing at each end of a diameter). Equal pressure on both sides will ensure that the grid stays evenly placed over the tube. If finger pressure is not sufficient to move the grid, a small hole is provided. Insert a pencil point into the hole and use it to turn the grid.

Make sure that all of the leads are properly connected, and turn on the power supply. The CRT takes about a minute to warm up; when it is ready, a green dot will appear on the screen. The focus knob is on the center of the right-hand panel when the user is looking into the CRT. Turn this knob until the light spot is as small as possible, and appears to be a tiny dot. The beam is now focused. Connect a patch cord to one of the X deflection jacks on the right-hand panel. The spot will become a line on the screen due to stray pickup on the lead. Rotate the grid until the X axis marked on the grid is parallel to the line on the screen. This procedure orients the grid properly relative to the deflecting electrodes in the tube. It is very important for correct measurement of beam deflection by the magnetic field.

The undeflected spot may not be exactly at the center of the beam, but results will still be acceptable. The beam is deflected inside the tube so that it can be rotated by the magnetic field. If the tube is used as an oscilloscope, a DC potential is applied to the deflection plates to center the beam.

## 4. Operation

**4.1 Deflection of Electrons:** Mark the position of the light spot on the plastic grid with a water-soluble felt-tipped pen. This is the zero point from which deflections are measured. Note the magnitude and directions of the deflections and determine the voltage between the X plates in each case. Measure the deflections at several voltages for this and the opposite configuration, and plot the deflection  $S$  as a function of the deflecting voltage  $V_d$ . Evaluate the deflection per volt from the graph, and determine whether it is the same for all voltages.

In most applications of a CRT, the deflection is measured and used to determine the deflecting voltage, making the CRT in effect a very fast voltmeter. The voltage required to get a deflection of 1cm is called the sensitivity of the CRT. Is the sensitivity of the CRT the same for horizontal and vertical deflections? CAUTION: Disconnect the wires at the power supply before shifting them from the X connection to the Y connection.

Given that the X plates and Y plates are identical in construction, which deflection plates are closer to the face of the tube?

Find the sensitivity when you have accelerating voltages of 500 V (connect the cathode to -250 V) and of 250 V (connect the cathode to 0 V). How does the sensitivity depend on the accelerating voltage?

**4.2 The Mass of the Electron:** Set up the apparatus as shown in Fig. 1. Start with an accelerating voltage of 250 V, with neither the coil nor the Y deflection plates connected to the power supply. At each stage, mark the position of the light spot on the grid with a water-soluble felt-tipped pen. Note the position of the light spot with the deflecting plates turned off. Note also that the velocity of the electrons has a small component perpendicular to the axis of the tube.

Observe the point at which the electrons hit the front of the tube if the Y plates are not connected, but the current in the coil is gradually increased from zero. Also note where the electrons hit if there is no current in the coil and a voltage across the Y plates, with the top Y plate positive. (It is best to disconnect the coil entirely for this step, to make sure that no residual current gets through.) Determine what changes occur in the point at which the electrons strike the face of the tube when there is a constant voltage across the Y plates and the current in the coil is gradually increased from zero.

Using this information as a base, find a current  $I_1$  for which the line makes a right angle with the line for no current, as shown in Fig. 2.

As electrons enter the magnetic field, the component of their velocity along the axis of the tube is  $v_0 = \sqrt{2eV_a/m}$

where  $V_a$  is the accelerating voltage and  $e$  and  $m$  are the charge and mass of the electron, respectively.

The voltage across the Y plates initially gave the electrons a velocity in the Y direction, causing a deflection of the beam. The magnetic field turned this velocity, and the regulating deflection, around through  $180^\circ$  by the time the electrons reached the face of the tube (Fig. 3). In the XY plane the electrons moved along a semicircle of radius  $r$  with a speed  $v_n$  given by

$$v_n = eBr/m$$

where  $B$  is the magnetic field strength. Calculate the value of  $B$  for the current  $I_1$ .

The time it took the electrons to move from the center point between the Y plates along the axis of the tube a distance  $D$  to the face of the tube is the same as the time it took to complete the semicircle. In both cases the time is given by the distance divided by the speed:

$$\frac{D}{v_0} = \frac{\pi r}{v_n}$$

Substituting  $v_0$  from Equation 1 and  $v_n$  from Equation 2 into Equation 3 and solving for  $m$  yields  $m = \frac{eB^2D^2}{2V_a}$

The value of  $D$  for this tube is 9.0cm. Calculate the mass of the electron. The mass calculated from this equation should be independent of  $V_a$  and  $B$ , within experimental errors. Repeat the experiment with  $V_a = 375$  V and  $V_a = 500$  V to confirm this.

When the experiment session is finished, the apparatus should be disconnected as follows:

1. Turn off the power supply. Wait a minute until the internal capacitors have had time to discharge.
2. Disconnect the two green, the red, and the blue banana plugs from the power supply.
3. When these disconnections have been made, remove the patch cords from the CRT stand.

When storing the apparatus, make sure that the tube enclosure is secure on the stand. While the tube is secure within the tube enclosure, it is not packed to withstand a fall. To keep the tube safe from damage, tape the enclosure to the stand or hold it in place with a large elastic band when storing the equipment.

#### **4. Maintenance**

The Mass of the Electron Apparatus needs no special maintenance. If any difficulty develops, contact Central Scientific Company, giving all details of the problem. Do not return this apparatus without written authorization from Central Scientific Company.

#### **5. Accessories**

<u>Description</u>	<u>Cat. No.</u>
Universal Power Supply.....	30737
Air Core Solenoid.....	72700-02

Revised 4/88