PROPERTIES OF ELECTRONS APPARATUS

PEA001

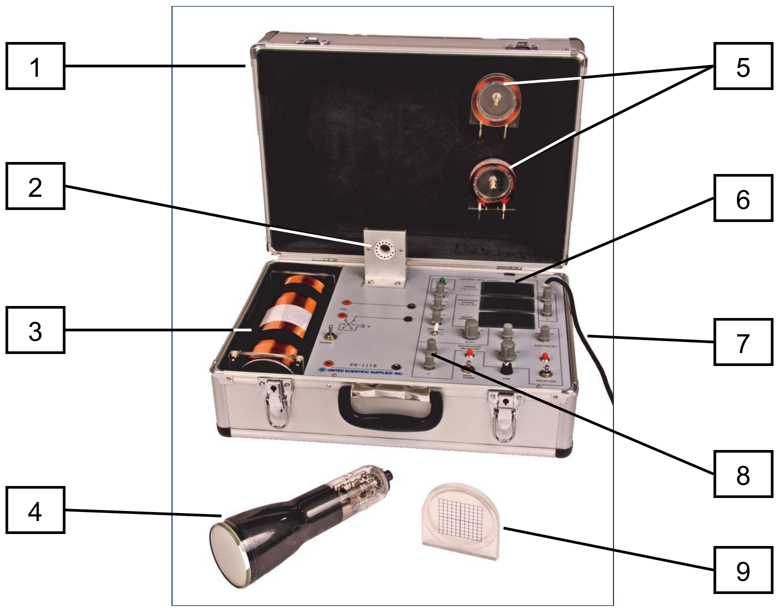

Figure 1

1. Description

The Complete Properties of Electrons Apparatus is a compact device based on a built-in CRT that allows the electrical and magnetic properties of an electron beam to be investigated and permits measurement of the electron charge to mass ratio, *e/m*.

2. Components and Specifications

Components

Refer to *Figure 1*

1. Removable Case Lid
2. Socket for CRT
3. Axial Field Solenoid
4. CRT
5. Transverse Field Coils (2)
6. LED Displays for Voltage and Current
7. Power Cable
8. Voltage and Current Controls
9. Screen Grid

Specifications

CRT (see page 3 also):

Screen diameter:	75 mm
Grid pitch:	10 mm

Transverse Field Coils:

Mean diameter:	67 mm
Number of turns:	530 per coil

Specifications—continued

Axial Field Solenoid:			
	Mean Diameter:	93 mm	
	Length:	228 mm	
	Number of turns:	1300	
Power supplies:			
CRT:		Cathode Voltage:	-750V... -1400 V
		Focus Voltage:	+200V... +400V
		Grid Voltage:	-4V... -80V
Electrostatic deflection:		X-deflection:	approx. ±100V
		Y-deflection:	approx. ±100V
Magnet supply:		0...9V, 0.155A transverse, 0...7.7V, 2.0A axial	
Power requirement:		110 V/60 Hz	
Case:			
	Dimensions:	470x 330 x 215 (mm)	
	Weight:	approx. 10 kg	

Accessories included:

Magnet patch cables (2) for transverse coils.

Manual

Front Panel Description

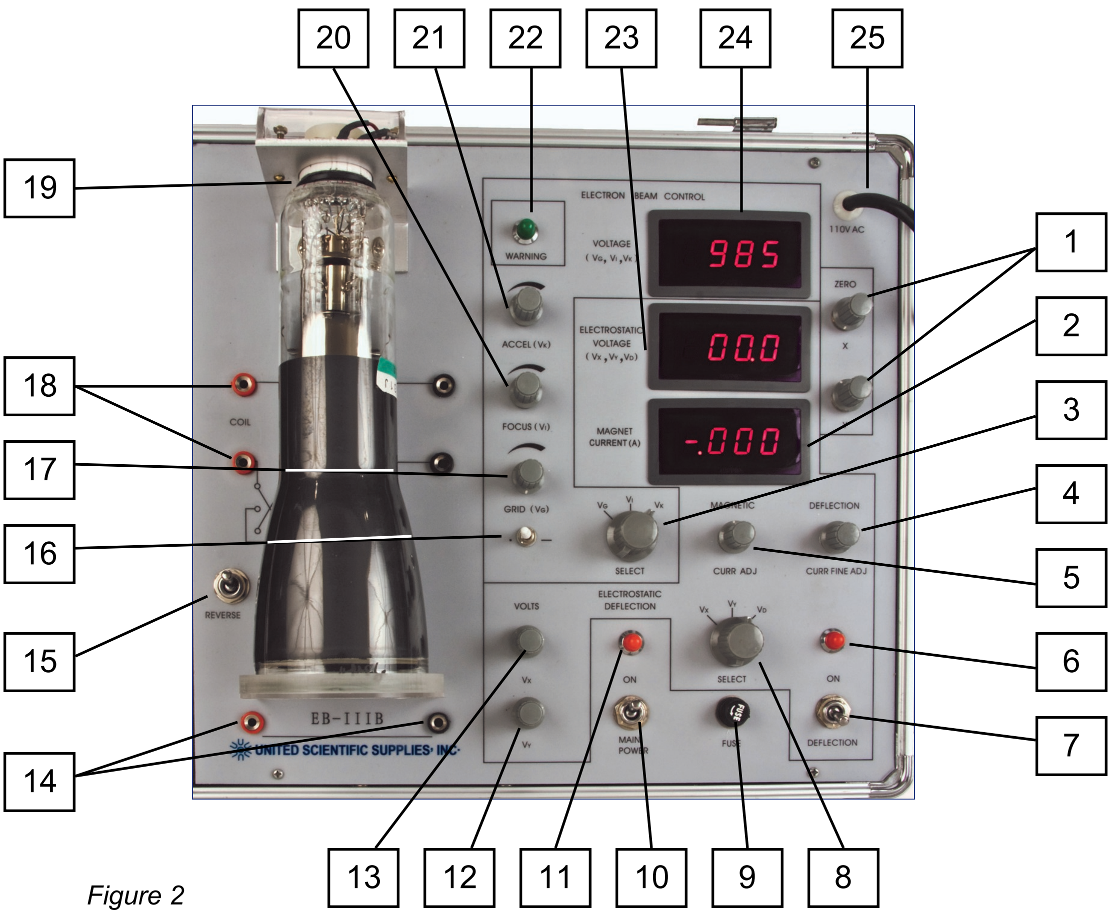

Figure 2

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Refer to *Figure 2*:

1. Zero point adjust knobs (X and Y, 10 turns)
2. LED display for magnet current
3. CRT voltage selector switch (V_G, V_I, V_K)
4. Magnet current fine adjust knob (10 turns)
5. Magnet current coarse adjust knob (10 turns)
6. Deflection power supplies indicator lamp
7. Deflection power supplies on/off switch
8. Electrostatic deflection selector switch (V_X, V_Y, V_D)
9. Fuse (2A instrument type—20 mm)
10. Main power on/off switch
11. Main power indicator lamp
12. Electrostatic deflection voltage adjustment knob—Y-axis (V_Y, 10 turns)
13. Electrostatic deflection voltage adjustment knob—X-axis (V_X, 10 turns)
14. Sockets for connecting axial magnetic field solenoid (using supplied patch cords)
15. Transverse magnetic field reversing switch
16. Electrostatic deflection V_X voltage AC/DC switch
17. CRT grid voltage adjustment knob (V_G, 10 turns)
18. Sockets for connecting transverse magnetic field coils (2 pairs—coils plug in directly)
19. CRT socket
20. CRT focus voltage adjusting knob (V_I, 10 turns)
21. CRT accelerating voltage adjusting knob (V_K, 10 turns)
22. Overload warning lamp
23. LED display for electrostatic deflection voltages (V_X, V_Y, V_D)
24. LED display for CRT voltages (V_G, V_I, V_K)
25. Power cord

CRT Description

The supplied CRT is a 8SJ31J tube on a 14-pin base. Its overall length is 240 mm, with a neck diameter of 51.4 mm and a flat screen of 75 mm diameter . The electrode arrangement and the base pin designations are shown in *Figure 3*:

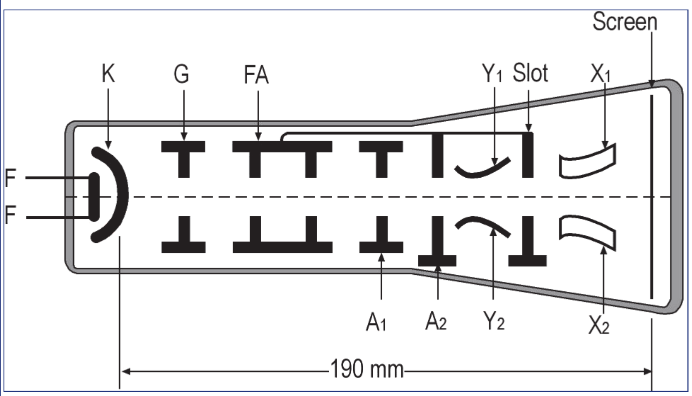

Figure 3a

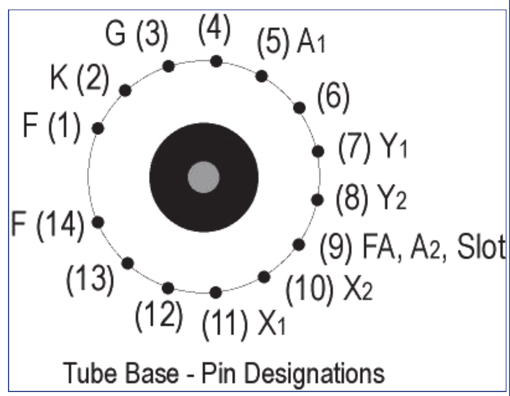

Figure 3b

F = Filament, K = Cathode, G = Grid, FA = Focus Anode, A_1, A_2= Anodes, X_1, X_2 = X-axis Deflection Plates, Y_1, Y_2 = Y-axis Deflection Plates.

NOTE! Take care when inserting the CRT into the CRT socket (19). The pins are easily damaged by rough handling. Carefully line up the gap between pin 1 & pin 14 with the gap in the socket (at 3 o'clock viewed from the front) Do not force the CRT into the socket. Never insert or remove the CRT into/from the socket with the main power switched on.

Functions of the Controls

1. THE CRT CONTROLS (*Figure 2*, #'s 1, 3, 17, 20, 21, 22, & 24)

The CRT operates with the anode (A_1 in *Figure 3a*) at ground potential and the cathode (K) at –750V…-1400V. The grid (G) and the focus anodes (FA, A_2) serve to control the brightness and sharpness of the electron beam spot on the screen.

The CRT voltage selector switch (3 in *Figure 2*) controls which of the CRT voltages are shown on the CRT LED display (24).

The voltages are adjusted using three ten-turn potentiometers for the acceleration (21), focus (20), and grid voltage (17) respectively.

The zero controls (1) adjust the position of the beam spot on the screen in the X and Y directions.

2. THE ELECTROSTATIC DEFLECTION CONTROLS (*Figure 2*, #'s 6, 7, 8, 12, 13, 16, & 23)

These controls apply voltages to the two pairs of deflection plates for the X and Y directions (X_1, X_2, Y_1, & Y_2 in *Figure 3a*).

The deflection power supplies switch (7 in *Figure 2*) activates the X– and Y– deflection voltages and illuminates the indicator light (6).

The electrostatic deflection selector switch (8) controls which pairs of plates are activated (X, Y, or both—"D") and which voltage is indicates on the electrostatic deflection LED display (23).

The voltages are adjusted using the two ten-turn potentiometers (13 for X, 12 for Y) and the voltage can be switched between D.C. and A.C. using the toggle switch (16).

3. THE MAGNETIC FIELD CONTROLS (*Figure 2*, #'s 2, 4, 5, 6, 7, 14, 15, & 18)

These controls supply power to the external transverse and axial magnetic field coils and indicate the current supplied.

The transverse field coils plug directly into the two pairs of sockets (18) which connect them in series, while the axial field solenoid fits over the CRT and is connected to the pair of sockets (14) using the supplied patch cords.

The deflection power supplies switch (7 in *Figure 2*) activates the magnet power supply and illuminates the indicator light (6).

The magnet current in each case is controlled by two ten-turn potentiometers (4 & 5, coarse and fine adjustment) and indicated on the magnet current LED display (2).

For the transverse field, the direction of the current in the coils can be reversed using the toggle switch (15).

3. Safety

The Complete Properties of Electrons Apparatus is self-contained; all high voltages are enclosed internally for safety, and the built-in displays eliminate the need to connect multimeters externally. However, care should always be taken when working with electrical apparatus under power. Particular attention should be paid to the following points:

- The CRT is a sensitive tube containing high voltages. Never insert or remove it while the power is turned on. Ensure that the pins are properly seated in the socket before starting an experiment, and handle the tube carefully when it is not attached to the apparatus.
- The power supply for the magnetic field coils can produce up to 30V. Never attach or remove the coils, or connect/disconnect the patch cords with the power turned on. Do not touch the coils or sockets while the coils are energized.
- If the overload warning lamp (22) illuminates during an experiment, reduce voltage and turn off the magnetic field immediately. Determine the cause of the overload before continuing with the experiment.

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4. Setup

Undo the latches on the front of the case and remove the lid by sliding it to the right. Place the lid in a conveniently accessible place — the transverse magnetic field coils and patch cords are stored in the lid. Carefully remove the CRT from inside the axial field solenoid and insert it into the CRT socket (19) as described on page 3. The front end of the CRT should be supported on the cradle attached to the back of the screen, as shown in *Figure 4*. Plug the unit into a wall outlet and turn on the main power switch located on the lower right of the front panel.

Figure 4

5. Experiments

The Complete Properties of Electrons Apparatus is designed for the following basic experiments:

- 5.1 Electron Behavior in an Electric Field
  - 5.1.1 Electron deflection in a transverse electric field
  - 5.1.2 Electron paths in an inhomogeneous longitudinal electric field
- 5.2 Electron Behavior in a Magnetic Field
  - 5.2.1 Electron deflection in a transverse magnetic field
  - 5.2.2 Spiral electron path in a longitudinal magnetic field
    Determination of e/m

The Complete Properties of Electrons Apparatus is all that is required to perform all these experiments — no additional accessories are required.

5.1 Electron Behavior in an Electric Field

5.1.1 ELECTRON DEFLECTION IN A TRANSVERSE ELECTRIC FIELD

The CRT generates an electron beam traveling from the socket end of the tube to the screen. *Figure 3a* shows a cross-section along the tube. Electrons are emitted by a cathode K , which is heated by a filament FF. They are extracted from the filament area by a positive potential on the grid G, and pass through to the anode system FA — A_1— A_2, which accelerates them and focuses them into a narrow beam traveling towards the screen

The CRT also has two pairs of electrostatic deflection plates as shown in *Figure 3a.* The plates for the Y-direction (vertical) are located after the electron beam has passed through the anode system, and are separated from the plates for the X-direction (horizontal) by a diaphragm with a vertical slot. The diaphragm is held at the anode potential (A_2) so that the electrons experience no axial acceleration when passing through the Y-plates, and also to isolate the effect of the Y-plates from any influence of the potentials on the following X-plates.

The Y-direction plates will be used in this experiment.

PROCEDURE.

1. Set up the Complete Properties of Electrons Apparatus as described in Section 4 above.

2. With the deflection power supplies switch (7) turned off, turn on the main power switch (10) and wait until the cathode warms up and a bright spot appears on the screen. Set the CRT voltage selector switch (3) to read the grid voltage V_G, and adjust the grid voltage to about –40V using the grid potentiometer (17).

3. Now set the CRT voltage selector switch to read the cathode voltage V_K, and adjust this voltage to about 950 V using the acceleration potentiometer (21). The bright spot on the screen will now appear bright, but generally diffuse. Set the CRT voltage selector switch to read the focus voltage V_I, and use the focus potentiometer (20) to make the spot as sharp as possible. Record the acceleration, grid, and focus voltages.

4. Turn the deflection voltage potentiometers (12 & 13) all the way counterclockwise and set the deflection voltage switch (8) to read the Y-direction voltage V_y . Now turn on the deflection voltage switch (7). The Y-deflection voltage should read zero. Use the X– and Y-zero potentiometers (1) to position the bright spot at the center of the screen grid.

5. Now slowly increase the Y-deflection voltage and observe the behavior of the bright spot. Record the direction of motion of the spot and several pairs of data for the deflection voltage V_y and the distance D of the spot from its original position. Return the deflection voltage to zero, flip the reversing switch (16) to invert the direction of the Y-deflection voltage, and repeat the measurement.

6. Adjust the acceleration voltage to about -1000V as described in step 3, and repeat steps 3 — 5 to obtain measurements for a different acceleration voltage. Repeat for two more acceleration voltages.

7. Plot graphs of D vs. V_y and note what you observe.

EVALUATION.

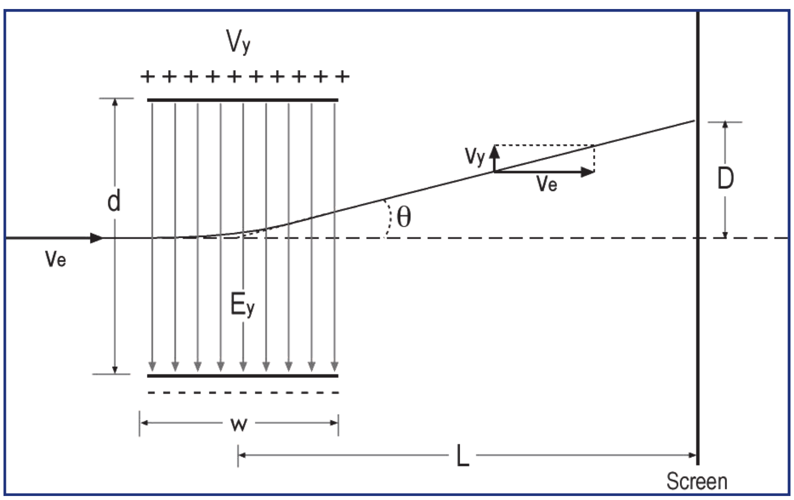

Figure 5

Figure 5 shows an electron beam passing between a pair of plates carrying a potential difference V_y . The plate separation is d, and the deflection of the electron beam when it reaches the screen is D. There is no electric field along the horizontal direction, so the velocity of the electrons in this direction,

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v_e, is constant. In passing through the electric field of the plates, E_y, the electrons are attracted towards the positive plate and acquire a velocity v_y in the Y-direction. After leaving the region of the field, the electrons continue with unchanged velocities until they strike the screen and create the bright spot.

Refer to *Figure 5*.

In the electric field, the electrons experience a force $F_y = e.E_y$ which operates for the time Δt that they spend in the field, so the change in momentum is given by

$$mv_y = F_y.\Delta t = e.E_y.\ \Delta t = e.(V_d/d).\Delta t$$

But $\Delta t = w/v_e$ since v_e is constant, so

$$v_y = (e/m).(V_d/d).(w/v_e)$$

And

$$\tan\theta = v_y/v_e = (e/m).(V_d/d).(w/v_e^2)$$

The energy of the electrons is $(1/2).mv_e^2 = e.V_K$, where V_K is the accelerating voltage.

Substituting: $$\tan\theta = (w/2d).(V_d/V_K) = D/L$$

So $$D = (w.L/2d).(V_d/V_K) = k.(V_d/V_K)$$

The value of the constant k is not easily determined theoretically, because the geometry of the CRT plates is not as simple as in *Figure 5*.

Inspect your graphs of D vs. V_d and determine whether they represent straight lines. Rearrange your data to draw graphs of D vs. $(1/V_K)$ for constant values of V_d and verify this proportionality also.

5.1.2 ELECTRON PATHS IN AN INHOMOGENEOUS LONGITUDINAL ELECTRIC FIELD

In an electric field E, electrons experience a force of magnitude e.E in the direction of the field. If the field is homogeneous, the electrons are simply accelerated and their path is along the field lines without changing direction. However, if the field is inhomogeneous, as in many practical cases, the directions of the field lines change as the electrons move through the field, and so the acceleration experienced by the electrons is continually changing, usually in both magnitude and direction, resulting in complex, curved electron paths.

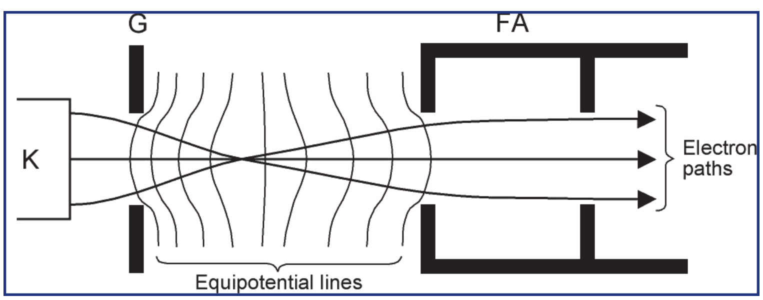

Figure 6

This effect can be used to direct a cloud of electrons and focus them into a narrow beam. The arrangement is known as an electron lens. The electrode combination G — FA — A_1 — A_2 in the CRT serves this purpose. *Figure 6* shows the first part of this process, the extraction of the electron cloud from the area of the cathode K by the grid G, and the formation of an accelerated

beam at the focus/anode FA. The holes in the grid and first focus diaphragm create an inhomogeneous electric field, as *Figure 6* shows. This both accelerates the electrons and deviates their paths. The increasing momentum of the electrons means that their paths do not follow the electric field lines exactly, and this is illustrated by *Figure 7*, which shows how the direction of motion of the electrons follows the electric field less and less as the electrons' speed increases.

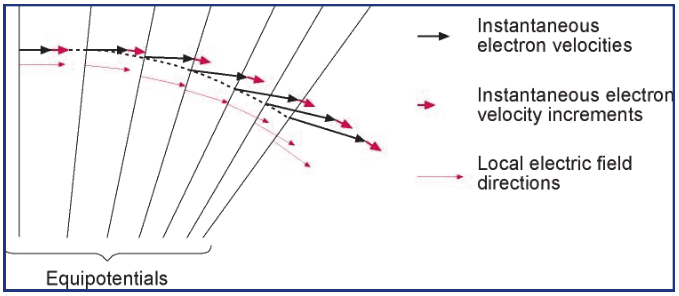

Figure 7

Electron paths through inhomogeneous electric fields are difficult to calculate exactly, and electrode configurations for electron lenses are usually worked out by plotting the electric field and then plotting individual electron paths point by point through the field.

The region between the two diaphragms of the focus/anode FA in *Figure 6* is field free. So all electron paths continue unchanged. The second diaphragm allows only electrons whose paths are close to the axis to pass through to the next electrode set.

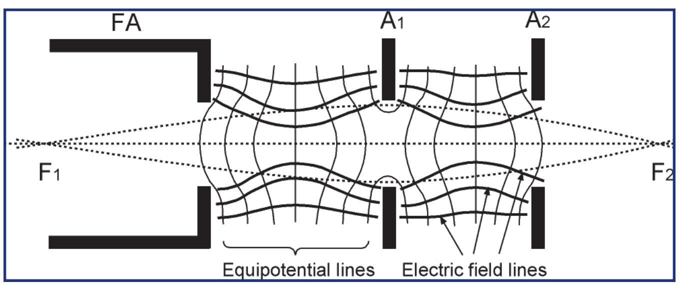

Figure 8

Figure 8 shows the focusing action of the electrode combination FA — A_1 — A_2. The region to the right of the A_2 electrode is free of longitudinal electric fields, so the electrons continue on the paths determined by the electrode combination and strike the screen at F_2. The electron paths through the FA — A_1 — A_2 combination are complex, but the overall effect is equivalent to the effect of a converging lens on a light beam. By adjusting the voltages on FA/A_2 and A_1, the position of the convergence point F_2 can be moved.

PROCEDURE.

In this experiment, you will observe the characteristics of the focus effect and investigate the quantitative relationship between the accelerating voltage V_K, the grid voltage, V_G, and the focus voltage, V_I.

1. Set up the Complete Properties of Electrons Apparatus as described in Section 4 above.

2. With the deflection power supplies switch (7) turned off, turn on the main power switch (10) and wait until the cathode warms up and a bright spot appears on the screen. Set the CRT voltage selector switch (3) to read the grid voltage V_G, and adjust the grid voltage to about

–40V using the grid potentiometer (17).

3. Now set the CRT voltage selector switch to read the cathode voltage V_K, and adjust this voltage to about 950 V using the acceleration potentiometer (21). The bright spot on the screen will now appear bright, but generally diffuse.
4. Set the CRT voltage selector switch to read the focus voltage V_I, and use the focus potentiometer (20) to make the spot as sharp as possible. Use the zero adjust potentiometers (1) to center the spot on the screen. Record the acceleration, grid, and focus voltages, V_K, V_G, and V_I.
5. Adjust the grid voltage V_G by a small amount, then readjust the focus voltage V_I to bring the spot back into focus. Record the new values of V_G, and V_I. Repeat this procedure to obtain a series of values of V_I as a function of V_G.
6. Now adjust the grid voltage V_G to make the spot disappear from the screen and record the value of V_G when the spot first disappears.
7. Readjust the acceleration voltage V_K so that the spot reappears, and adjust the focus voltage V_I to make the spot sharp. Record the new value of V_I, and measure a series of pairs of values of V_I as a function of V_G for the new accelerating voltage as in step 5.
8. Repeat steps 6 and 7 until you have measurements for four values of the accelerating voltage, V_K.
9. Draw graphs of V_I vs. V_G for the four values of V_K, and discuss their shape.

5.2 Electron Behavior in a Magnetic Field

5.2.1 ELECTRON DEFLECTION IN A TRANSVERSE MAGNETIC FIELD

A transverse magnetic field can be set up to influence the paths of the electrons in the field-free region between the electrode system and the screen. The two transverse field coils (#5 in *Figure 1*) are plugged directly into the two pairs of jacks (#18 in *Figure 2—see Figure 9*) and the magnetic field strength and direction are controlled by the on/off switch (7), the potentiometers (4) and (5), and the reversing switch (15).

Figure 9

PROCEDURE.

1. Set up the Complete Properties of Electrons Apparatus as described in Section 4 above, and plug the transverse field coils into the two pairs of jacks (18).
2. With the deflection power supplies switch (7) turned off, turn on the main power switch (10) and wait until the cathode warms up and a bright spot appears on the screen. Set the CRT

voltage selector switch (3) to read the grid voltage V_G, and adjust the grid voltage to about –40V using the grid potentiometer (17).

3. Now set the CRT voltage selector switch to read the cathode voltage V_K, and adjust this voltage to about 950 V using the acceleration potentiometer (21). The bright spot on the screen will now appear bright, but generally diffuse. Set the CRT voltage selector switch to read the focus voltage V_I, and use the focus potentiometer (20) to make the spot as sharp as possible. Using the zero potentiometers (1), center the spot on the screen grid. Record the acceleration, grid, and focus voltages.

4. Turn the coarse and fine magnetic field adjustment potentiometers (4) and (5) all the way counterclockwise, and turn on the magnetic field current power switch (7).

5. Using the electrostatic deflection controls (12) and (13), re-center the spot on the screen. Record the electrostatic voltages used for this.

6. Using the potentiometers (4) and (5), gradually increase the current *i* in the coils and observe the deflection S of the spot on the screen. Record several corresponding pairs of values of *i* and S.

7. Return the magnetic field current to its minimum value, then using the potentiometer (21), adjust the accelerating voltage V_K to a different value, readjust the centering of the spot with the zero potentiometers (1), and record a new series of *i* and S values. Repeat this procedure until you have four sets of measurements.

8. Reverse the direction of the magnetic field using the toggle switch (15) and record another four sets of measurements.

9. Draw graphs of S vs. I for each value of V_K, for use in the evaluation below.

EVALUATION.

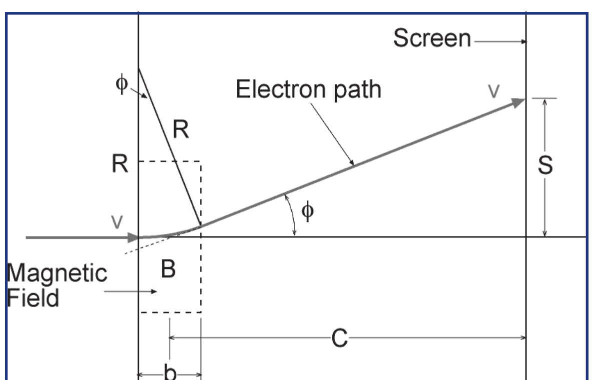

Figure 10

Figure 10 shows the path of the electron beam through a transverse magnetic field of strength B. For this purpose, the field can be taken to be uniform over a distance b, and zero elsewhere. The midpoint of the field is a distance C from the screen.

While the electrons are traversing the magnetic field with a constant axial velocity v, they experience a Lorentz force of magnitude e.v.B at right angles to their direction of motion. This bends their

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path into a segment of a circle whose radius R can be found using the centripetal force equation:

$$e.v.B = m.v^2/R, \text{ so } R = m.v/e.B$$

The velocity v of the electrons can be found from the acceleration voltage V_K:

$$e.V_K = \tfrac{1}{2}.m.v^2, \text{ so } v = \sqrt{(2e.V_K/m)}$$

The electron path is deflected through an angle ϕ by the magnetic field, and $\sin\phi = b/R$. After leaving the field region, the electrons follow a straight path to the screen. Projecting this path backwards into the field region, it meets the axis at the midpoint of b, so

$$S = C.\tan\phi = C.\ (\sin\phi/\cos\phi) = C.\sin\phi/\sqrt{(1-\sin^2\phi)}$$

Substituting for $\sin\phi$, then for R and v, and rearranging, we obtain:

$$S = C.b.\sqrt{(e/2m)}.(B/\sqrt{V_K}) \qquad (1)$$

The magnetic field of the coils is proportional to the current *i*: B = K.*i,* where K is an unknown constant. So equation (1) becomes:

$$S = K.C.b.\sqrt{(e/2m)}.(i./\sqrt{V_K}) = \delta.(i./\sqrt{V_K}) \qquad (2)$$

Thus the S vs. *i* graphs should be straight lines whose slopes are inversely proportional to $\sqrt{V_K}$.

Verify that this is so.

5.2.2 SPIRAL ELECTRON PATH IN A LONGITUDINAL MAGNETIC FIELD

In a longitudinal magnetic field, an electron that has a component of its velocity in any direction normal to the axis (i.e., it is not moving exactly axially) experiences a Lorentz force that causes it to move in a circular path whose radius depends on the strength of the axial magnetic field and the radial component of its velocity. However, while executing this circular motion in the radial direction, the electron continues to move axially, so that the three-dimensional path of the electron is a spiral with the magnetic field direction as its axis.

The beam of electrons in the CRT all have the same velocity, but not exactly the same direction, so they have a range of different radial velocities and a corresponding range of diameters for their spiral paths.

The electron beam in the CRT diverges from a focus point, and is re-focused at the screen. *Figure 11* shows that if a series of circular paths of different diameters coincide at one point, they will do so again after every complete revolution. We can use this property to measure e/m. If the screen spot is focused at a certain magnetic field strength, then the distance between the screen and the first focus must correspond to exactly an integral number of revolutions on the spiral path.

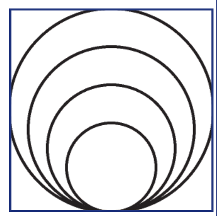

Figure 11

PROCEDURE.

1. Set up the Complete Properties of Electrons Apparatus as described in Section 4 above and fit the axial solenoid completely over the CRT. Connect the solenoid jacks to the power supply jacks (14) using the supplied patch cords (*See Figure 12*).

2. With the deflection power supplies switch (7) turned off, turn on the main power switch (10) and wait until the cathode warms up and a bright spot appears on the screen. Set the CRT voltage selector

Figure 12

switch (3) to read the grid voltage V_G, and adjust the grid voltage to about –40V using the grid potentiometer (17).

3. Now set the CRT voltage selector switch to read the cathode voltage V_K, and adjust this voltage to about 950 V using the acceleration potentiometer (21). The bright spot on the screen will now appear bright, but generally diffuse. Set the CRT voltage selector switch to read the focus voltage V_I, and use the focus potentiometer (20) to make the spot as sharp as possible. Use the zero potentiometers (1) to center the spot on the screen. Record the acceleration, grid, and focus voltages.

4. Turn the deflection voltage potentiometers (12 & 13) and the magnetic deflection potentiometers (4 & 5) all the way counterclockwise and set the deflection voltage switch (8) to read the Y-direction voltage V_y. Turn on the deflection power switch (7) and use the Y-direction voltage potentiometer (12) to deflect the spot 1—2 cm from the center of the screen. Readjust the focus voltage V_I, if necessary, to obtain a sharp spot.

5. Using the coarse and fine adjustment potentiometers (4 & 5), slowly increase the axial magnetic field, observing the behavior of the spot. When you find a field setting where the spot is again sharp, record the value of the magnetic field current.

6. Continue increasing the magnetic field, recording the current each time a focus point is found.

7. Return the magnetic field to zero, adjust the accelerating voltage V_K to a different value, and record its new value. Repeat the focus measurements for this new accelerating voltage.

8. Repeat step 8 until you have records for four different accelerating voltages. Use the results to calculate e/m as indicated below.

EVALUATION.

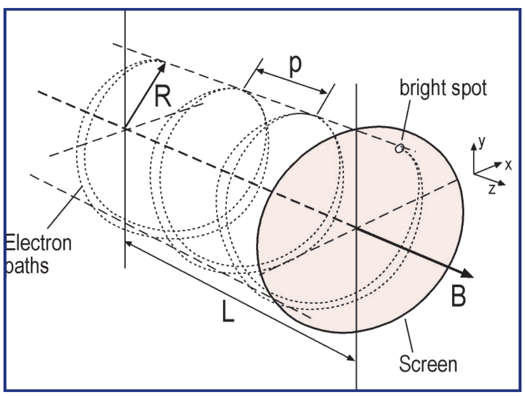

Figure 13

Figure 13 shows electron paths in a longitudinal magnetic field. The distance from the first focus F_1 to the screen is L, and the pitch of the spiral — the distance between successive focus points — is p. R is the radius of the circular path in the x-y plane.

The pitch p is given by : $p = v_z.T$, where v_z is the electron velocity in the z-direction and T is the time the electrons take to make one complete revolution. Setting the Lorentz force equal to the centripetal force, we have:

$$m.v_R^2/R = e.v_R.B, \text{ so } v_R/R = (e/m).B$$

where v_R is the electron's radial component of velocity.

The circumference of the circle is $2\pi.R$, so $T = 2\pi.R/v_R$, and

$$T = 2\pi.m/(e.B), \text{ and } p = v_z.2\pi.m/(e.B)$$

which does not depend on v_R, so the pitch of the spiral is independent of the radial velocity of the electrons.

The radial velocities of the electrons v_R are very small compared to their axial velocity v_z, so we can derive v_z from the total kinetic energy $e.V_K$:

$$e.V_K = ½.m.v_z^2, \text{ and } v_z = \sqrt{(2.e.V_K/m)}$$

So $$p = \sqrt{(2.e.V_K/m)}.2\pi.m/(e.B)$$

Rearranging:

$$e/m = (8\pi^2/p^2).(V_K/B^2) \quad (1)$$

When the spot is focused on the screen, p = L/n (n = 1,2,3…) so equation (1) can be written:

$$B^2 = (m/e).(8\pi^2/L^2).(n^2.V_K) \quad (n = 1,2,3\ldots) \quad (2)$$

Values of B can be calculated from the formula for the field of a solenoid of N turns, diameter D and length L_S carrying a current *i*:

$$B = (4.\pi.N.i \times 10^{-7})/\sqrt{(D^2 + L_S^2)} \quad (3)$$

Use your data, equation (3), and the instrument constants below to plot a graph of B^2 vs. $n^2.V_K$ and calculate e/m from its slope.

INSTRUMENT CONSTANTS:

L = 0.199 m

N = 1300

D = 0.0945 m

L_S = 0.235 m

6. Troubleshooting

With careful treatment and attention to the procedures detailed in this manual, the Properties of Electrons Apparatus will operate reliably for many years.

- If the CRT does not perform as expected, the most likely cause is a poor connection in the socket base due to inadequate seating. Check the insertion of the CRT in the socket to make sure all the pins are properly seated, clean, and not bent or broken.
- If the filament fails to heat up and produce electrons, turn the unit off and carefully remove the CRT from its socket. Measure the resistance between pins 1 and 14 (see *Figure 3b* on page 3) with a multimeter to check that the filament is intact. An open circuit indicates a broken filament, and requires a replacement CRT.
- If the magnetic field coils fail to carry a current as indicated by the display (2), check that the banana plugs on the coils or patch cords are clean and seated properly. Also check the continuity of the coil(s) by measuring their resistance using a multimeter.

For all other problems, contact your United Scientific Supplies distributor.

7. Maintenance

The Complete Properties of Electrons Apparatus needs no special maintenance. Store and operate it in a cool, dry place. Take special care to protect the CRT and its connector from mechanical damage and moisture. Do not operate the unit in a wet environment. Clean it only with a dry cloth after disconnecting it from the power outlet.

8. Accessories and Replacement Parts

The Complete Properties of Electrons Apparatus comes with all necessary accessories. For replacement of lost or broken parts, contact your Pacific Science Supplies distributor.

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