Al- Mustaqbal University

College of Science

Medical Physics Department

second Stage

Atomic physics

Lecture TWO: Determining the specific charge

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Objective of the Experiment:

To determine the ratio of the electron charge to its mass (e/m).

Apparatus:

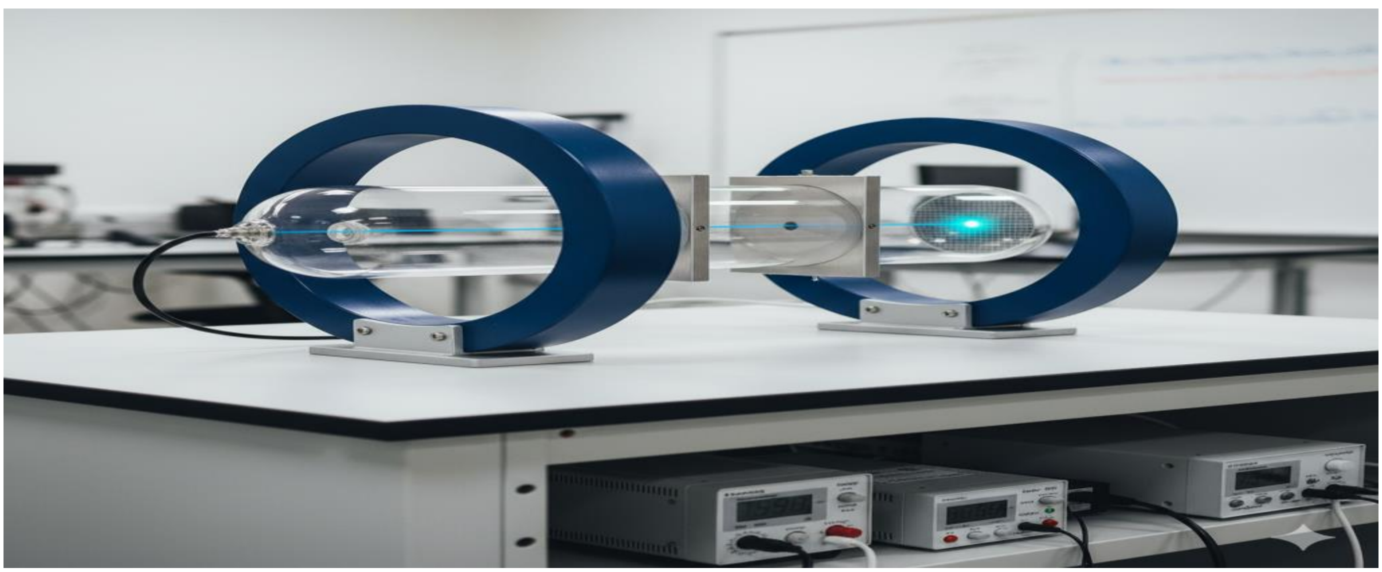
1. Cathode ray tube

2. Base with Helmholtz coils

3. Power supply (10 kV)

4. AVO meter (to measure coil current)

5. Connecting wires

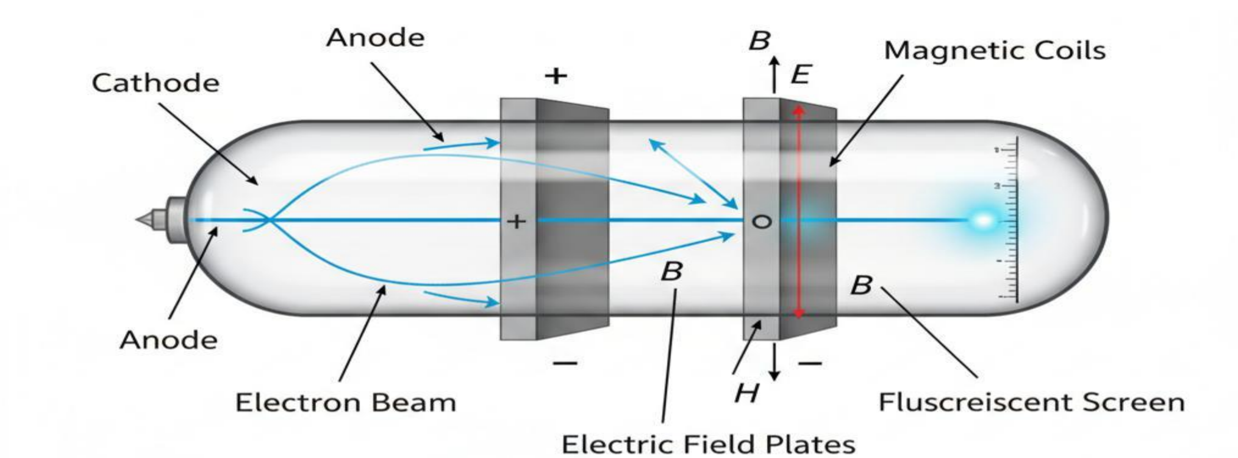


Theory:

The first scientist who discovered cathode rays, proved that they are electrons, and determined the ratio of their charge to mass (e/m) was J.J. Thomson. Figure (1) shows the cathode ray tube used in this experiment. It consists of an electron gun (a heated tungsten filament acting as a cathode), a cylindrical anode, and two parallel plates separated by a distance of d = 5.5 cm. Between these plates, there is a

fluorescent screen coated with zinc sulfide, calibrated both horizontally and vertically in centimeters. When an appropriate potential difference is applied between the anode and the cathode, electrons emitted from the heated filament are accelerated toward the anode. Most of them strike the anode, but some pass through the horizontal slit at its center, emerging with a uniform velocity v. These electrons strike the fluorescent screen, producing a bright horizontal line.

In Figure (1), we see Thomson's experiment setup — the cathode ray tube surrounded by Helmholtz coils, which generate a uniform magnetic field. The direction of this field can be controlled by reversing the direction of the current in the coils. The parallel plates inside the tube produce an electric field, while the external devices supply electrical power and measurements. When the electrons are subjected to the magnetic field produced by the Helmholtz coils, the electron beam is deflected due to the magnetic force. This deflection appears as a shift of the luminous spot on the fluorescent screen. The deflection can be controlled by changing the magnetic field strength (i.e., by varying the coil current). If we turn off the current in the Helmholtz coils (so B = 0), the magnetic field disappears, and the electron beam returns to a straight-line path.



Theory and Formulas:

When an electron of charge(e)and mass(m)moves perpendicularly to a magnetic field of flux density(B), it experiences a force that makes it move in a circular path with a radius (r) given by:

$r = mv / (eB)$

Since the electron velocity v is related to the accelerating voltage V between the anode and cathode, we have:

$\frac{1}{2}mv^2 = eV$

Combining both equations and solving for e/m, we obtain:

$e/m = 2V / (B^2r^2)$

The magnetic flux density (B) of the Helmholtz coils is given by:

$$B= \mu_0(4/5)^{3/2}\, n/R.I$$

Where:

$N = 180$ (number of turns per coil)

$R = 15$ cm (radius of each coil)

I = current through the coils (A)

$\mu_0 = 4\pi \times 10^{-7}$ H/m (magnetic permeability of air)

Thus,

$B = 1.17 \times 10^{-3}$ Tesla.

Experimental Procedure:

1. Connect the cathode ray tube circuit as shown in Figure (2).
2. Heat the cathode by applying a potential difference of about 4 kV across the filament.

3. Pass a current I (e.g., $I = 9.08\ A$) through the Helmholtz coils, and measure the vertical deflection (Y) and the horizontal distance (X) of the electron beam on the screen.
4. Repeat step (3) for several values of I.

5. For each current value, calculate the radius of curvature r of the beam using.

6. Tabulate your readings as shown below:

V(v)	D(m)	r= D/2	$r^2(m^2)$
300	0.014		
290	0.125		
280	0.123		
270	0.12		
260	0.118		
250	0.115		
240	0.11		
230	0.107		
220	0.104		
210	0.1		
200	0.095		

7. Plot a graph of r^2 on the x-axis vs. $1/I^2$ on the y-axis. Determine the slope, and calculate the value of e/m using the equation (6).

الميل= $e/m \cdot B^2/2$:. $e/m=$ الميل$\times 2/B^2$

1.Who was the first scientist to measure the ratio of the electron's charge to its mass?

A) Rutherford B) Bohr C) J.J. Thomson D) Einstein

2.What is the main purpose of the specific charge experiment?

A) To determine electron velocity

B) To calculate e/m ratio

C) To find current in the coil

D) To measure resistance

3.What is the function of the Helmholtz coils in this experiment?

A) Produce electric field

B) Generate a uniform magnetic field

C) Measure voltage

D) Accelerate electrons

4.The cathode ray tube is evacuated mainly to:

A) Allow light to pass

B) Prevent air collisions

C) Increase beam brightness

D) Reduce voltage drop

5.What material coats the fluorescent screen in the cathode ray tube?

A) Phosphorus

B) Zinc sulfide

C) Magnesium oxide

D) Sodium chloride

6.Which equation correctly relates kinetic energy to accelerating voltage?

A) $eV = \frac{1}{2}mv^2$ B) $e/m = 2V$ C) $eB = mv$ D) $e = \frac{1}{2}mv^2$

7.What is the unit of magnetic flux density (B)?

A) Tesla

B) Weber

C) Henry

D) Newton

8.The path of an electron in a uniform magnetic field is:

A) Straight

B) Circular

C) Elliptical

D) Random

9.The current in the Helmholtz coils is measured using:

A) Voltmeter

B) AVO meter

C) Ammeter

D) Galvanometer

10.Why does the electron beam deflect when the magnetic field is applied?

A) Due to electric repulsion

B) Due to gravitational force

C) Due to magnetic force

D) Due to collision with air molecules