Application of relativistic quantum mechanics in radial problems and E/M equations

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Abstract. This research is pure research in the field of pure physics. The background of the research that I did there was doing pure research in the field of physics. The subject of this research is to use the e / m measurement tool. This study aims to (1) study the influence of the magnitude of the electron velocity and the magnitude of the magnetic field on the electron path, (2) determine the e/m ratio in calculations. The results showed that the magnitude of the electron path radius is directly proportional to the magnitude of the electron velocity and inversely proportional to the magnitude of the magnetic field acting on it. Meanwhile, the calculation result for fixed current is 16.84% and the fixed voltage is 14.15%, in this case the size of the electron path is directly proportional to the magnitude of the speed of the electron path, and inversely proportional to the magnitude of the magnetic field acting on the electron.

1. Introduction
One of Thomson's experiments was to determine the specific magnitude of the charge or the ratio between charge and electron mass. The method used is the electron beam deflection in a homogeneous magnetic field and electric field [1]. The tool in this experiment will make the electron beam deflected to form a circle pattern. By measuring the accelerator potential (V), the current through the Helmhotz deflection coil (I), before and the radius of the electron beam pattern (r), the e/m of the electron can be determined.

If a charged particle q moves in a magnetic field B with velocity v, then the particle will experience a force:

\[ F = qv \times B \]  \hspace{1cm} \text{(1)}

And if the electron's path is perpendicular to the magnetic field, then it can be written in the form of a scalar as follows.

\[ F = evB \]  \hspace{1cm} \text{(2)}

An example of the use of speed selector is a famous experiment conducted by J.J Thomson in 1897 where he showed that the rays in the cathode tube could be deflected by electric and magnetic fields so that it could be known that they contained electrically charged particles [2-4]. By measuring the magnitude of the irregularities of the light particles caused by this electric and magnetic field, Thomson can show that all particles have a relatively equal charge to mass (e / m) ratio. He also showed that particles with a ratio of charge to mass can be obtained by using any material for the cathode. The particles contained in this ray, now called electrons and are the basic ingredients of all matter [5,6].
The principle used by Thomson in making these measurements is that if an electron's charge moves in a space under the influence of a magnetic or electric field, the charge will experience a force so that the movement of electrons will deviate. The existence of physical phenomena is considered as the movement of the electron charge in the magnetic and electric fields just as particles are thrown horizontally in the earth's gravitational field.

The system used consists of a cathode tube and a coil that functions to generate a magnetic field. This coil is called the Helmholtz coil which is used to eliminate the earth's magnetic field and to provide a constant magnetic field in a narrow and confined space [7].

When the cathode is electrified, the cathode will glow due to the collision of electrons in it so that it can cause electrons from the cathode to jump from the cathode and enter the magnetic field region of the coil flowing electric current. If the direction of the speed of the electron is perpendicular to the direction of the magnetic field, then the electron will move in a circle in the cathode tube [8,9]. Magnetic force provides the centripetal force needed for circular motion to occur. We can connect the velocity of the electron v with the radius of the path r and the magnetic field B by making a total force equal to the mass of the electron m times the centripetal acceleration v²/r which corresponds to Newton's second law. The total force in this case is the same as evB because v and B are perpendicular to each other.

2. Materials and methods
This type of research is experimental and the steps of the experiment are as follows: Positioning the toggle switch to the measurement position e/m, Positioning the current regulator for helmholtz coils in the off position, Connecting the power supply and the measuring instrument, slowly adjusting the flow control knob to the direction of the coil clockwise rotation. DC ammeters are no more than 2 amperes [10].

![Figure 1. Measurement position e/m.](image)

Turn on the heater and electrode power supply until a while until the cathode is hot. When it is hot, it will observe the electron beam radiating and forming a circle due to the influence of the coil magnetic field [11]. Noting that the electron beam is parallel to the coil, if it is not yet aligned the tube can be rotated to obtain the condition, Reading the ammeter's appointment of the coil current and accelerating voltage, Measuring the radius of the electron beam carefully. Avoid parallax by using the mirror behind
Read the radii of both sides of the scale and averaged, Make 5 observations for different coil currents and accelerating voltages [12,13].

![Figure 2. Fillament Anode to Katode.](image)

The hot filament releases cathode electrons, and when given potential difference then the electrons move accelerated towards the anode. Electron with mass \( m \) and charge \( e \), after being accelerated by the potential difference, \( V_a \) will move with a velocity of \( V \) so that the potential energy is converted to kinetic energy.

### 3. Results

A description of the data will be presented to measure current and voltage in electricity in the following Table 1:

| No | Voltage (v) | Fingers (cm) |
|----|-------------|--------------|
| 1  | 5.0         | 5.5          |
| 2  | 5.5         | 5.0          |
| 3  | 5.6         | 4.0          |
| 4  | 7.0         | 4.2          |
| 5  | 9.0         | 5.5          |

A description of the data will be presented to measure current and voltage in electricity in the following Table 2:

| No | Current (A) | Fingers (cm) |
|----|-------------|--------------|
| 1  | 16.0        | 3.5          |
| 2  | 17.2        | 4.0          |
| 3  | 17.7        | 6.0          |
| 4  | 18.2        | 5.5          |
| 5  | 20.5        | 8.0          |

To determine \( C \ (e / m) \) for each experiment for a fixed current:

| No | Current (A) | Voltage (V) | Fingers (cm) | \( C \) | \( \frac{C_i - C}{2} \) |
|----|-------------|-------------|--------------|--------|-----------------|
| 1  | 15.50       | 5.0         | 5.5          | 18.34 x 10^5 | 3.36 x 10^{18} |
| 2  | 15.50       | 5.5         | 5.0          | 24.89 x 10^5 | 6.19 x 10^{18} |
| 3  | 15.50       | 5.6         | 4.0          | 38.06 x 10^5 | 1.44 x 10^{19} |
| 4  | 15.50       | 7.0         | 4.2          | 43.58 x 10^5 | 1.89 x 10^{19} |
| 5  | 15.50       | 9.0         | 5.5          | 32.21 x 10^5 | 1.03 x 10^{19} |
| Total | 157.08 x 10^5 | 13.91 x 10^{20} |
4. Discussion
To study the effect of electron velocity and magnitude of the magnetic field on the electron trajectory, qualitative analysis is used, namely by analyzing equations, namely: For the amount of electron acceleration [14]. Thus, the magnitude of the electron velocity is directly proportional to the square root of the accelerator potential difference [15]. This means that the greater the potential difference, the greater the electron velocity, as well as the experimental data. V gets bigger, the radius of the path of the electron gets bigger. So it can be said that the greater the speed of electrons, the greater the radius of the electron's path [16].

\[ B = \frac{N_0 I}{(5/4)^{3/2} a} \]

Thus, the magnitude of the magnetic field B is directly proportional to the current I. From the experimental data, the greater the current flowing, the radius of the electron path will be smaller. So the radius of the electron's path is inversely proportional to the magnitude of the magnetic field.

Derive the equation

\[ B = \frac{N_0 I}{(5/4)^{3/2} a} \]

Under the Biot Savart law

\[ dB = \frac{\mu_0 I}{4\pi} \frac{dl \sin \theta}{r^2} \]

We will analyze the magnetic field in the direction of the x-axis only, so that

\[ dB = \frac{\mu_0}{4\pi} r a d\theta \frac{1}{\frac{5}{4} a^2} \]

\[ dB = \frac{\mu_0}{4\pi} \frac{a}{\frac{5}{4} a^2} - l d\theta \]

\[ dB = \frac{\mu_0}{4\pi} \frac{1}{\frac{5}{4} a^2} - l d\theta \]

Then the last equation is integrated

\[ \int dB = \int_0^{2\pi} \frac{\mu_0}{4\pi} \frac{1}{\frac{5}{4} a^2} - l d\theta \]

Voltage for Helmozt coils, ripplays must be <1%. This is because the magnetic field produced by the ripple is stable and homogeneous. As well as efforts made so that the current used to generate a magnetic field from the Helmoltz coil comes from the alternating voltage rectifier [17].

The results of the e/m experiments when compared to the standard e / m have the accuracy of 16.84% for experiments using fixed current and 14.15% for experiments with fixed accelerators. This means that the results of the experiment are still far when compared with the data in the literature book. The experimental results show that when the voltage value (V) remains while the value of the electric current (I) changes the greater, the diameter of the electron path will be smaller. If the greater the current is stronger the magnetic field produced by the Helmholtz coil is getting bigger too. A large magnetic field will deflect the electrons strongly so that the diameter of the electron path decreases because the diameter of the electron is inversely proportional to the magnetic field. If the value of the electric current (I) is fixed while the voltage value (V) changes the greater the diameter of the electron path will be even greater because V is directly proportional to the square of R [18].
Values diverge slightly from the literature for several reasons. Things that greatly affect the results of this experiment include the first value of the current and voltage which is always changing to change the power supply even though we have set it to a certain value. This of course greatly affects the current and voltage values to be recorded. In addition, the electron beam in the cathode tube is actually not a thin line (thick line), in the sense that there is an inner diameter and an outer diameter, so that in observation it is quite difficult to determine the actual diameter, from the electron path. Another reason is also because when observing the path of the electron is quite dark, so it is possible in the parallax error (eye error in reading the scale).

There are many physicists who have done this experiment. So there is nothing new to do this experiment. But the experiments carried out are relatively expensive and difficult to reach for students or students to carry out special modern physics experiments to calculate the electron value of e/m. Therefore, the authors conducted experiments determining electron e/m using 10-inch black and white television tubes and Helmholtz reels.

High pressure electricity that flows through a metal plate produces light that flows from the cathode to the anode called the cathode ray. These low pressure glass cups are then called cathode ray tubes. Cathode rays darken the tube. The cathode ray is not visible to the eye but its presence is detected through a glowing tube because the cathode ray collides with the glass tube. Joseph John Thomson then conducted research to determine the comparison of the charge prices of electrons and their mass (e/m) [19].

The results show that the cathode ray can be deflected by electric and magnetic fields. In this experiment, the cathode ray tube came from a television (TV), which had provided heating filament voltage and acceleration voltage Va. In the Youke Deflection television section given to the filament at the end of the television tube, the cathode releases electrons, while the electrons that move towards the anode are only large electrons. Because it is amplified by the acceleration of the voltage, the electrons touch the layer. The appearance of the television tube is only a beam of light because the electrons hitting atoms cause the atoms to become excited, followed by excitation by emitting visible light [20].

5. Conclusions
Difficulty in arranging I and V so that it is always constant. This is circumvented by managing the device carefully so that it can be obtained. This is overcome by carefully reading the scale of the measuring instrument. Parallax error occurs, which is the observer's error when measuring the radius of the electron beam. Where the direction of the eye with the scale shown is not perpendicular so as to obtain slightly different results. Random errors are environmental influences that cause I and V to be constant but can be changed. There are many physicists who have done this experiment. So there is nothing new to do this experiment. But the experiments carried out are relatively expensive and difficult to reach for students or students to carry out special modern physics experiments to calculate the electron value of e/m. Therefore, the authors conducted experiments determining electron e/m using 10-inch black and white television tubes and Helmholtz reels.

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