EXPERIMENT 1: SPECIFIC CHARGE OF THE ELECTRON - e/m

Related Topics

Cathode rays, Lorentz force, electron in crossed fields, electron mass, electron charge.

Principle

Electrons are accelerated in an electric field and enter a magnetic field at right angles to the direction of motion. The specific charge of the electron is determined from the accelerating voltage, the magnetic field strength and the radius of the electron orbit.

Tasks

Determination of the specific charge of the electron (e/m_0) from the path of an electron beam in crossed electric and magnetic fields of variable strength.

Theory and Evaluation

If an electron of mass m_0 and charge e is accelerated by a potential difference U it attains the kinetic energy:

$$\boldsymbol{e \cdot U = \frac{1}{2} \cdot m_0 \cdot v^2} \tag{1}$$

where $\boldsymbol{v^2}$ is the velocity of electron.

In a magnetic field of strength $\vec{\boldsymbol{B}}$ the Lorentz force acting on an electron with velocity $\vec{\boldsymbol{v}}$ is:

$$\vec{\boldsymbol{F}} = \boldsymbol{e} \cdot \vec{\boldsymbol{v}} \times \vec{\boldsymbol{B}}$$

If the magnetic field is uniform, as it is in the Helmholtz arrangement the electron therefore follows a spiral path along the magnetic lines of force, which becomes a circle of radius r if $\vec{\boldsymbol{v}}$ is perpendicular to $\vec{\boldsymbol{B}}$.

Since the centrifugal force $\frac{m_0 \cdot v^2}{r}$ thus produced is equal to the Lorentz force, we obtain

$$\boldsymbol{v = \frac{e}{m_0} \cdot B \cdot r}$$

where $\boldsymbol{B}$ is the absolute magnitude of $\vec{\boldsymbol{B}}$.

From equation (1), it follows that

$$\boldsymbol{\frac{e}{m} = \frac{2\,U}{(B \cdot r)^2}}$$

To calculate the magnetic field **B**, the first and fourth Maxwell equations are used in the case where no time dependent electric fields exist. We obtain the magnetic field strength $\mathbf{B_z}$ on the z-axis of a circular current I for a symmetrical arrangements of 2 coils at a distance a from each other:

$$B_z = \mu_0 \cdot I \cdot R^2 \left\{ \left(R^2 + \left(z - \frac{a}{2} \right)^2 \right)^{\frac{3}{2}} + \left(R^2 + \left(z + \frac{a}{2} \right)^2 \right)^{\frac{3}{2}} \right\}$$

with $\boldsymbol{\mu_0} = 1.257 \text{ x } 10^{-6}$ V.s/A.m and **R**=radius of the coil

For the Helmholtz arrangement of two coils (a=R) with number of turns *n* in the center between the coils one obtains

$$B = \left(\frac{4}{5} \right)^{\frac{3}{2}} \cdot \mu_0 \cdot n \cdot \frac{I}{R}$$

For the coils used, R=0.2 m and *n*=154.

Literature value: $\boldsymbol{{}^{e}/_{m_0} = 1.759 \; x \; 10^{11}}$ **A.s/kg**

Equipment

Narrow beam tube, Helmholtz coils, Power suppliers, Digital Multimeters

Fig.1: Experimental set-up for determining the specific charge of the electron.

Set-up and Procedure

The experimental set up is as shown in Fig. 1. The two coils are turned towards each other in the Helmholtz arrangement. Since the current must be the same in both coils, connection in series is preferable to connection in parallel. The maximum permissible continuous current of 5 A should not be exceeded. If the polarity of the magnetic field is correct, a curved luminous trajectory is visible in the darkened room. By varying the magnetic field (current) and the velocity of the electrons (acceleration and focussing voltage) the radius of the orbit can be adjusted, such that it coincides with the radius defined by the luninous traces. When the electron beam coincides with the luminous traces, only half of the circle is observable. The radius of the circle is then 2, 3, 4 or 5 cm. For detailed description of the narrow beam tube, please refer to the operating instructions. If the trace has the form of a helix this must be eliminated by rotating the narrow beam tube around its longitudinal axis.

	r = 0.02 m		r = 0.03 m		r = 0.04 m		r = 0.05 m	
U(V)	I	e/m (10^{-11}) (A.s/kg)	I	e/m (10^{-11}) (A.s/kg)	I	e/m (10^{-11}) (A.s/kg)	I	e/m (10^{-11}) (A.s/kg)
100								
120								
140								
160								
180								
200								
220								
240								
260								
280								
300								