Experiment 16: The Specific Charge of the Electron (online version)

OBJECTIVE

The purpose of this experiment is to observe the trajectory of moving charges (electrons) in a uniform magnetic field and to extract the charge-to-mass ratio of an electron measuring the radius of the electron's orbit for a given electron speed and the magnetic field induction.

THEORY

If a charged particle is moving in the magnetic, the Lorentz force

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$$

is acting upon it. Here q is the particle's charge, **v** is particle's velocity, and **B** is the magnetic field induction. The Lorentz force is perpendicular to both **v** and **B**. If the particle's velocity is perpendicular to the magnetic field, it remains so and the particle is moving in the plain perpendicular to **B**. In this case the magnitude of the Lorentz force becomes

$$F = qvB.$$

If **B** is uniform, the trajectory is a circle, and the Lorentz force plays the role of the centripetal force:

$$F = qvB = m\frac{v^2}{R}.$$

From here one finds the radius of the particle's trajectory:

$$R = \frac{mv}{qB}.$$

In the general case, the particle's trajectory is a helix. The particle is moving with a constant velocity along **B** (as there is no force in this direction) and makes the circle in the plain perpendicular to **B**, as explained above. If one measures the radius of the trajectory for a given velocity and the magnetic field induction, one can extract the charge-to-mass ratio of the particle:

$$\frac{q}{m} = \frac{v}{RB}. \quad (1)$$

The experiment will be carried out for the electron: $q=e$, $m=m_e$.

THE ONLINE EXPERIMENT

In the internet one can find codes (so-called applets) showing the motion of the charged particle in the magnetic field. Older implementations use Abobe Flash and SWF files. However, for security reasons acceptance of these techniques by internet browsers was reduced. Whereas the Microsoft Edge still supports both types of applets, Google Chrome does not play SWF and offers to download the file instead. To play the downloaded file, one can use a free standalone SWF player. Support of the Adobe Flash is blocked in Chrome by default but it can be allowed in Chrome's settings at chrome://settings/content/flash for the current session. Safari also does not like these two kinds of applets. iPads cannot play them as well.

The modern kind of applets well supported by the browsers is based on the HTML. There are demonstrations of the motion of the charged particle in the magnetic field online. However, these are pure online demonstrations unsuitable for using as online labs.

One can see that the security issues seriously damaged the effort to build online physics labs.

For our purposes, we can use the SWF applet

A) https://applets.kcvs.ca/magneticFieldParticle/pInMagneticField.swf

and/or the Adobe Flash applet

B) https://www4.uwsp.edu/physastr/kmenning/flash/Charged_particle_magnetic_field.html

As a demonstration of the motion in the general case (helix in 3D), one can use

C) https://ophysics.com/em8.html

THE PROCEDURE

Use either A) or B) that offer a comparable functionality. In A) the charge is fixed to the electron charge and the mass is fixed to the electron mass, whereas in B) the charge is measured in the units of the electron charge e and the mass is measured in the units of the electron mass m_e. If you use B), choose the charge equal to the electron charge and the mass equal to the electron mass. The speed v and the magnetic field B can be chosen arbitrarily both in A) and B). The radius R can be measured in A) with the help of the measuring tool (See the instructions in Tools), while in B) the radius is shown in a special window.

Run the applet for several combinations of v and B and measure R for each of them. Calculate the charge-to-mass ratio for each trial using Eq. (1). Put the results in the table

Trial	v (m/s)	B (T)	R (m)	e/m_e
1				
2				
3				
4				
Mean	N/A	N/A	N/A	…

Compute its average value and compare it with the value found in the tables of physical quantities (calculate the percentage deviation, as usual).