OPPA European Social Fund
Prague & EU: We invest in your future.

MOTION OF AN ELECTRON IN CROSSED ELECTRIC AND MAGNETIC FIELDS

OBJECT

The object of the experiment is to investigate the behaviour of an electron in crossed electric and magnetic fields set up inside the vacuum diode.

1. Measure the dependence of the anode current I_a inside the vacuum diode on the magnetic field induction B for two magnitudes of the anode voltage $U_a = 50$ V and 60 V.
2. Make the plot I_a versus B and find the critical magnetic induction B_c.
3. Determine the specific charge e/m of the electron.

THEORY

The vacuum diode with coaxial electrodes is utilized to make this measurement. Electrons leaving the diode cathode are accelerated due to the electric field that is set up in the space of the diode between the anode and the cathode. The electric field points from the anode to the cathode. Due to their negative charge the electrons move toward the anode. Their velocity v directly before striking the anode can be determined from the relation

$$\frac{1}{2}mv^2 = eU_a \quad ,$$

where m is the mass of the electron, e is its charge and U_a is the anode voltage.

If the magnetic field is set up inside the diode in the perpendicular direction to the electron motion the electrons will be subjected to the force

$$\boldsymbol{F} = e \, (\boldsymbol{v} \times \boldsymbol{B}) \quad ,$$

where v is the vector of velocity of electrons and B denotes the magnetic induction vector of the magnetic field. The vector B points in direction of the axis of the diode. The magnitude of the force F equals $F = e \, v \, B$ and its direction is perpendicular both to the direction of the electron motion and to the direction of the magnetic induction vector B. Consequently, due to this force the electron path will be curved.

The homogeneous magnetic field inside the coil depends on the magnetizing current I_m flowing through the coil. The construction of our diode makes possible for the magnitude of the magnetic field could be expressed with a good accuracy as

$$B = 0.0202 I_m, \quad [I_m] = A$$
$$[B] = T$$

(1)

It is obvious that if the magnitude of the magnetic induction increases the number of electrons striking the anode will decrease and so the anode current will have to decrease, too.

The dependence of the anode current I_a on the magnetic induction B is plotted in the following figure.
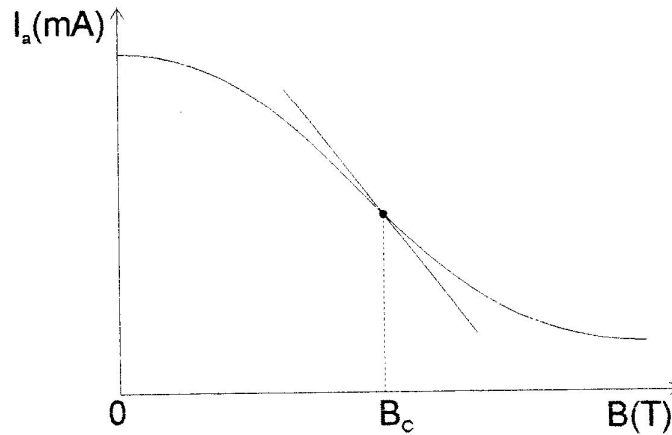
Graph I_a versus B.

Due to various unwanted effects (the non-zero initial speed of electrons, the non-ideal geometry of the real magnetron, slight changes in the current passing through the coil) the current I_a does not droop to zero at once but it falls slowly. As the critical magnitude B_c of the magnetic field is taken a such magnitude of the magnetic field for which the I_a vs. B curve has the inflection point.

When the value of the magnetic induction reaches the critical value B_c the majority of the electrons move in circles whose centers rest on the axis of symmetry of the diode and their radii are nearly equal to the anode radius R_a. This presumption yields the following relation
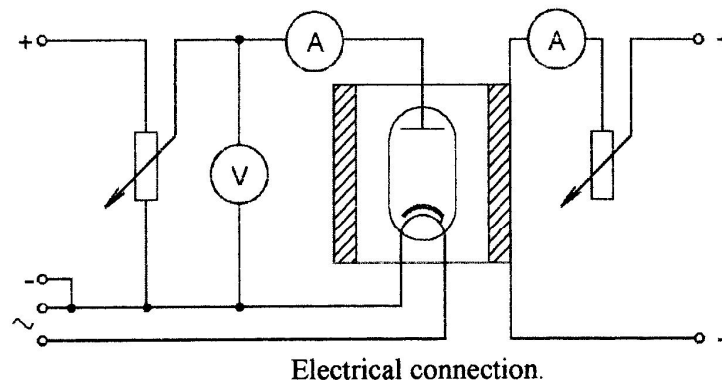
$$\frac{1}{2} mR^2 \left(\frac{1}{2} \frac{e B_c}{m} \right)^2 = e U_a .$$

From here we obtain the expression for the specific charge

$$\frac{e}{m} = \frac{8 U_a}{R_a^2 B_c^2} .$$

(2)

PROCEDURE

1) Set up the experimental arrangement as shown in the figure.

Electrical connection.

2) Set up the magnetizing current at zero value.
3) Set up the first prescribed anode voltage.
4) Make the change in the magnetizing current step by step so that the change in the anode current may be equal to 0.1 mA only. The maximum allowed value of the magnetizing current is 2A.
5) Use the expression (1) to determine the magnetic field.
6) Plot the graph I_a versus B and find the inflection point of the curve – apply the graphical derivative method (see the appendix).
7) The corresponding value of B_c is substituted in the formula (2) to calculate the specific charge of the electron.
8) Change the anode voltage and repeat the measurements.
9) Compare the calculated values with the accepted one that is $(e/m)_{acc} = 1.76 \times 10^{11}$ C/kg.
10) Find the relative error

$$\frac{\delta(e/m)}{e/m} = \frac{(e/m)_{calc} - (e/m)_{acc}}{(e/m)_{acc}} \times 100\% .$$

SEMESTER WORK INSTRUCTIONS

Create a program, which will simulate the trajectory of an electron dependent on its initial velocity and direction, electric field intensity and magnetic induction. The program must allow separate change of any of three components (x,y,z) of any of these three vectors **v**, **E**, **B**.

OPPA European Social Fund
Prague & EU: We invest in your future.