Introduction

Heating of the diode’s cathode causes thermal emission of the electrons from the cathode surface. Thermally released electrons then move directly to the anode. Because the diode is placed inside a coil with electric current, those electrons are in fact in two fields: a magnetic (from the coil) and electric (from the diode).

In the setup described above the magnetic field \( B \) is perpendicular to the electric field \( E \) and, of course, to the motion of the emitted electrons too (because the vector \( E \) in the diode points from the cathode to the anode, i.e. is parallel with the emitted electrons path).

If the magnetic field \( B \) is perpendicular to the electron velocity \( v \), the path of the electron is a curve with the curvature radius \( R \) which is in a reverse proportion to the magnitude of magnetic field \( B \) (the larger \( B \), the smaller the electron path radius \( c \)). If the current in the coil increases, the magnitude of magnetic field \( B \) increases too. When it achieves a certain value \( B_0 \), some electrons cannot reach the anode and it results in an abrupt and well recognized decrease of the anode current.

Now we denote the radius and potential of the anode \( a \) and \( \phi_a \), respectively, and, \( c \) and \( \phi_c \) the radius and potential of the cathode in the vacuum tube used, respectively. Then, it is possible to derive the following formula for the specific charge of electron

\[
\frac{e}{m_e} = -\frac{U \cdot a^2}{B_0^2 (a^2 - c^2)^2} \tag{1}
\]

where the \( U = \phi_a - \phi_c \) is the anode voltage (read on the voltmeter \( V \) in the electrical scheme) and \( B_0 \) is the critical magnetic field, the value of which can be calculated as follows:

The magnetic field in the laboratory experimental setup is generated inside a long coil (solenoid) in which case for the magnetic field \( B \) holds:

\[
B = \mu_0 \frac{N}{L} I \tag{2}
\]

where \( \mu_0 \) is permeability of vacuum (\( \mu_0 = 4\pi \times 10^{-7} \text{ Hm}^{-1} \)), \( I \) - current in the coil, \( N \) - number of the coil turns, and \( L \) - the coil length.

Substituting (1) into (2) and taking into account that \( c << a \) we obtain

\[
\frac{e}{m} = -\frac{UL^2}{2\pi^2 N^2 I_k^2 R^2} \cdot 10^{14} \left( \text{C kg}^{-1} \right), \tag{3}
\]

where \( R \) is the radius of the diode (\( R = a \)), \( I_k \) - the critical value of the magnetization current \( I \), i.e., the current corresponding to the critical magnetic field \( B_0 \).
Experimental set-up

Fig.1. The electrical circuit for the measuring of the specific charge of electron. The magnetron itself (consists of the diode and the magnetization coil) is drawn in the upper left part of the scheme. There are also two galvanically separated circuits: the upper circuit serves for the generation of the magnetization current $I_m$, the lower circuit generates the anode current $I_a$. The symbols in the scheme denote following: A ammeter, $U_S$ voltage source for the diode circuit, $R_1$, $R_2$ rheostats, mA milliammeter, V voltmeter, $U_A$ voltage source for the magnetization coil circuit, $U_S$ is the heating voltage for the diode.

Experimental procedure

- After completing and connecting the electric scheme to the voltage sources $U_S$ and $U_A$ wait for approx. 10 min to heat up the cathode. Then set the desired value of the anode voltage $U$ by the potentiometer $R_2$. The value $U$ is kept constant during the measurement and it can be read on the voltmeter $V$.
- Then, by using the rheostat $R_1$, we slowly increase the magnetization current $I_m$, (which we read on the ammeter A). By gradually increasing the current $I_m$, we of course gradually increase also the magnetic field $B$ inside the coil of the magnetron. We already know from the „Introduction“ that this magnetic field has a strong influence on the value of the current $I_a$ between the cathode and anode, so that by changing the magnetization current $I_m$ the anode-cathode current $I_a$ is being changed too. **Although there is no galvanic bond between those two circuits!**
- Measure the dependence $I_a$ on $I_m$ while keeping the value $U$ constant.
- Draw the graph $I_a$ vs $I_m$.
- For better precision perform the described procedure for three different values of the voltage $U$, i.e. draw three graphs $I_a$ vs $I_m$.

Notes: The three dependences $I_a = f(I_m)$ are not straight lines but curves. There is a point on each curve, so called a critical point where the decrease of $I_a$ vs $I_m$ is the most steep – an inflection point – and magnetization current $I_m = I_{k}$ at this point is necessary to know for the calculation of the electron specific charge. Since the critical value of magnetization current $I_{k}$ is obtained from the diagram, it is essential to have enough experimentally measured points for each diagram (if the dependence were a straight line, not so many points would be needed)
- Find the critical point values $I_{k}$ for all three $I_a = f(I_m)$ dependences and use them for the calculation of electron specific charge by using the equation (3).
- Average out the three obtained values of $e/m$.
- The averaged value $(e/m)_{aver}$ is to be compared with the table value of $e/m$.

One of very important kinds of magnetron is a cavity magnetron, invented during World War II for military purpose. At that time it had been used as a very strong source of radio waves for radars and for counterjamming too. Nowadays we also have many applications of microwaves with a magnetron as a source in our everyday life. One of the most common non-military uses of microwaves is, of course, the microwave oven. The same type of magnetron tube (a cavity magnetron) used in wartime radars is powerful enough to heat food rapidly. Even today, nearly all microwave ovens use the same type of magnetron tube that made World War II radars possible.

It is often used in medicine, too. All the known therapeutic uses of microwaves involve the heating of the tissue. Just as the microwave oven heats the food, it can also heat the body, e.g. in diathermia in the treatment of arthritis and other conditions. The use of microwaves seems to be very promising even for detecting tumours, because many types of tumours contain more water that surrounding tissue, so that they warm up more, which warming can be in some way detected. The microwaves are also used by police in radar devices to measure the speed of cars, and they are also emitted by cell phones.