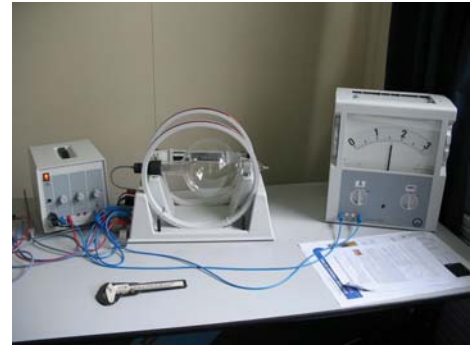


Quick reference guide

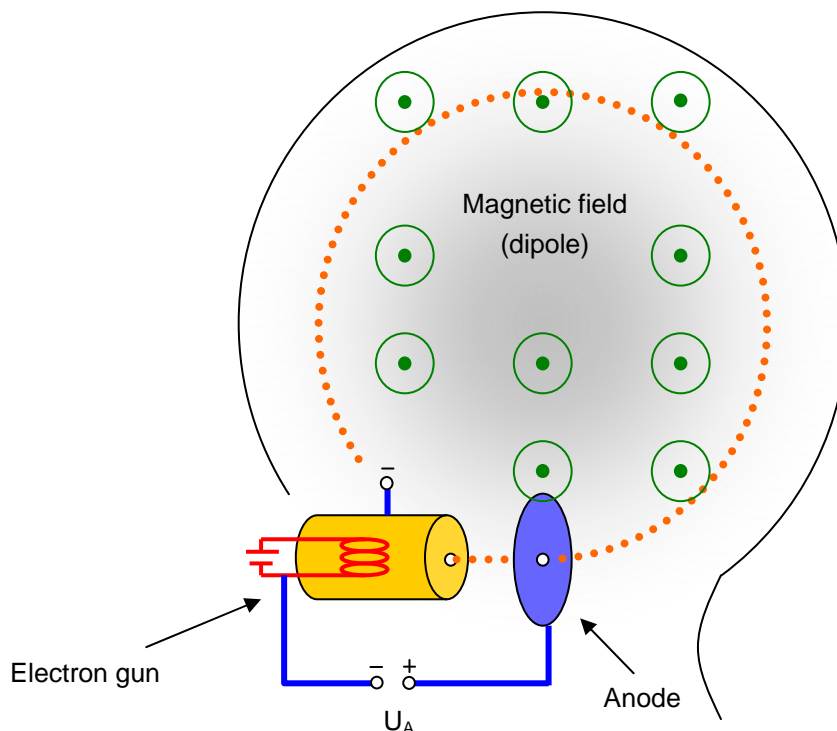
Introduction

A fine beam tube consists of a spherical glass plunger filled with noble gas under low pressure. An electron gun inside the tube (cathode, control grid and anode) generates a beam of electrons. The beam stimulates gas molecules to the emission of light, whereby the beam becomes visible within the tube. The magnetic field of two Helmholtz coils forces the electrons onto a circular path that allows us to determine the specific charge e/m .



Functional principle

- The source of the electron beam is the electron gun, which produces a stream of electrons through thermionic emission at the heated cathode and focuses it into a thin beam by the control grid (or “Wehnelt cylinder”).
- A strong electric field between cathode and anode accelerates the electrons, before they leave the electron gun through a small hole in the anode.
- The fine beam tube contains hydrogen molecules at low pressure, which through collisions with electrons are caused to emit light. This makes the orbit of the electrons indirectly visible
- To demonstrate deflection in magnetic fields and calculate the specific charge e/m the fine beam tube is placed in a magnetic field of two Helmholtz coils.



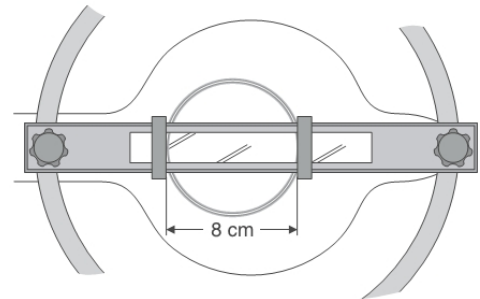
Safety precautions

- Don't touch fine beam tube and cables during operation, voltages of 300 V are used in this experiment!
- Do not exert mechanical force on the tube, danger of implosions!



Experimental procedure

1. Power up the DC power supply and set acceleration potential $U = 200$ V. Thermionic emission starts after warming up for a few minutes.
2. Add a voltage to the Helmholtz coils using the third knob and look for current I , at which the electron beam is deflected into a closed orbit.
3. Move the **left slide** of the measuring device so that its inner edge, mirror image and escape aperture of the electron beam come to lay on one line of sight.
4. Set the **right slide** for both inside edges to have a distance of 8 cm.
5. Sight the inside edge of the right slide, align it with its mirror image and adjust the coil current I until the electron beam runs tangentially along the slide edge covering the mirror image. The radius of the circle is now $r = 4$ cm.
6. Take the magnetic field B corresponding to this current I out of the following table:



I [A]	B [mT]	e/m_e [10^{12} C/kg]
1,05	0,76	0,433
1,1	0,8	0,391
1,15	0,85	0,346
1,2	0,87	0,330
1,25	0,9	0,309
1,3	0,94	0,283
1,35	0,98	0,260
1,4	1,01	0,245

I [A]	B [mT]	e/m_e [10^{12} C/kg]
1,45	1,06	0,222
1,5	1,09	0,210
1,55	1,12	0,199
1,6	1,16	0,186
1,65	1,2	0,174
1,7	1,24	0,163
1,75	1,29	0,150
1,8	1,31	0,146

7. Determine the specific charge e/m_e using the formula $\frac{e}{m_e} = \frac{2 \cdot U_A}{B^2 \cdot r^2}$ (*) or the table above (only of $U = 200$ V and $r = 4$ cm):
8. Compare (7.) to the theoretical value $e/m_e = 0,176 \cdot 10^{12}$ C/kg!

(*) To determine the specific charge e/m you measure the radius of the circular electron beam in a magnetic field B . The centripetal force at the orbit is equal to the Lorentz force:

$$e \cdot v \cdot B = \frac{m \cdot v^2}{r} \Rightarrow r = \frac{m_e \cdot v}{e \cdot B}$$

The electrons were accelerated by the voltage U_A between anode and cathode. That's why we can calculate the speed of the electrons via the kinetic energy:

$$E_{kin} = \frac{1}{2} \cdot m_e \cdot v^2 = e \cdot U_A \Rightarrow v = \sqrt{2 \cdot \frac{e}{m_e} \cdot U_A}$$

Applying this in the first equation you get an expression for e/m that only contains the parameters U_A , B and r that can easily be measured at the fine beam tube.

$$r = \frac{m_e}{e \cdot B} \cdot \sqrt{2 \cdot \frac{e}{m_e} \cdot U_A}$$

$$\Rightarrow r^2 = \frac{m_e^2}{e^2 \cdot B^2} \cdot 2 \cdot \frac{e}{m_e} \cdot U_A = \frac{m_e}{e} \cdot \frac{2 \cdot U_A}{B^2}$$

$$\Rightarrow \frac{e}{m_e} = \frac{2 \cdot U_A}{B^2 \cdot r^2}$$

Cyclotron

Particle physics: circular accelerators

With rising energy of the accelerated particles LINACs (linear accelerators, see experiment "cathode ray tube") get very long and expensive. That's why the idea of circular accelerators was born: by using magnetic fields to force particles into an orbit (like in the fine beam tube), the *same* accelerating unit can be used multiple times.

The first type of circular accelerators ever built was the cyclotron. The acceleration takes place between two D-shaped electrodes (so-called Dees) by a high frequency AC voltage. A strong magnetic field all over the Dees forces the particles onto an orbit so that the acceleration between the Dees can take place multiple times. After each semicircle particles are accelerated by the electric field between the Dees.

