

Laboratory #13: Charge-to-Mass Ratio for the Electron

Goal: Measure the ratio between the charge of the electron and its mass.

Equipment: Electron tube with Helmholtz coils (CENCO 71267), Power supply for plate and filament (PASCO SF-9585A), Ampere meter 0-1A AC (mechanical), Power supply for grid (DC 60V), Power Supply for B field (MG PS10AD), DMM.

(A) The physics

Electrons as discrete particles have been discovered and extensively studied by J.J. Thomson (1856-1940). By investigating the curvature of trajectories in magnetic fields a value for e/m can be obtained. The currently accepted value is $e/m = 1.75890 \cdot 10^{11}$ C/kg.

The kinetic energy of an electron that has been accelerated by a potential difference V_{acc} is given by $V_{acc}e = mv^2/2$. The force F on a charge e moving with velocity v perpendicular to a uniform magnetic field B , is $F = Bev$. The force F is always perpendicular to the velocity, and hence, the electrons move on a circle in such a way that $mv^2/r = Bev$. From the above one finds:

$$\frac{e}{m} = \frac{2V_{acc}}{B^2 r^2} \quad (1)$$

(B) Experiment:

A pair of Helmholtz coils, a coil arrangement that gives a fairly uniform magnetic field over a large region, supplies the magnetic field. Helmholtz coils consist of two coils wound in rings of radius R , whose planes are parallel to each other and separated by R . At distances less than 4 cm from the midplane the magnetic field differs less than 1% from its central value which is given by

$$B_z(z=0) = \frac{8\mu_0 I N}{\sqrt{125} R}, \quad (2)$$

where $\mu_0 = 4\pi \cdot 10^{-7}$ kg m C⁻², R is the coil radius, I the current through the coil, and N the number of windings in each of the two coils ($N=119$). Calculate the B field for $I=1$ A. Does one have to worry about the Earth magnetic field?

The electron tube (see fig.1) contains a heated filament from which electrons are emitted. To increase the life of the tube, do not operate the filament with more than 0.8A heating current. The energy of the electrons is determined by the plate (P) voltage, V_{acc} . The grid

(G) is really an einzel lens that can be adjusted to focus the electron beam. The electron beam is bent in a circle and strikes the target plane (see fig.2). Four concentric, fluorescent rings are marked on that plane with radii 0.50, 1.00, 1.50, and 2.00 cm. The filament is mounted 2.5 mm below the target plane (Fig.2). Does one have to take this into account when determining the bending radius of the electrons?

Take a series of measurements of the bending radius as a function of the B field. Try different target radii and vary the electron energy (V_{acc}). Also explore reversing the field direction, and turning the apparatus by 180° to reverse the effect of the Earth magnetic field. Deduce the e/m value for each measurement and compile your results. Are the measurements consistent? Is there a dependence on any of the varied parameters? State a final value for e/m and compare with the accepted value.

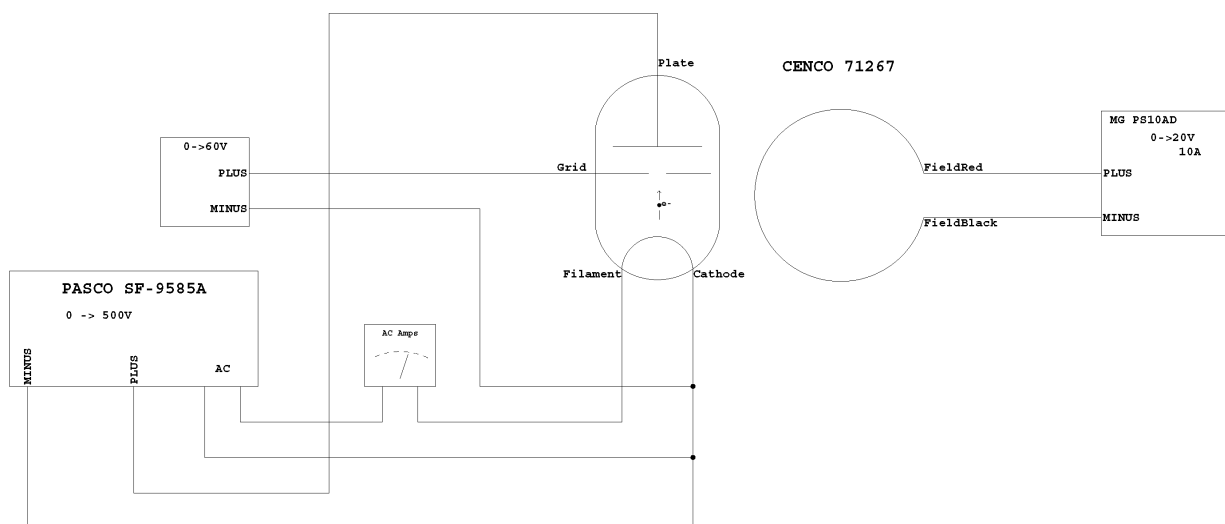


Fig 1

Fig 2

