Analysis appendix

Data Tables

8cm CCW		8cm CW	
volts (V)	current (A)	volts (V)	current (A)
148.5	1.355	148.3	1.248
168.6	1.446	168.4	1.325
187.9	1.520	188.1	1.400
207.7	1.604	208.0	1.474
227.9	1.674	228.2	1.546
247.5	1.752	247.8	1.613

10cm CCW		10cm CW	
volts (V)	current (A)	volts (V)	current (A)
149.0	1.117	148.6	0.960
168.6	1.177	168.9	1.021
188.0	1.234	187.6	1.089
208.2	1.301	208.3	1.165
227.6	1.367	227.4	1.205
248.1	1.422	248.0	1.260

Table 1: Current through Helmholtz coils required to maintain 8 and 10cm beam diameter, respectively, for given anode-cathode voltages (resulting in different beam velocities), in clockwise (CW) and counter-clockwise (CCW) orientations.

Variables and Equations

Variable	Name	Value and/or SI Unit
V	Voltage applied to anode	$kg \cdot m^2 \cdot s^{-3}$
I	Current through Helmholtz coils	$C \cdot s^{-1}$
K	Coefficient determining field strength at coil center	$(7.73 \pm 0.04) \cdot 10^{-4}\, T \cdot A^{-1}$
R	Radius of Helmholtz coils	$0.154 \pm 0.005\, m$
K_R	Effective flux density for given distance from center of coils	$\alpha T \cdot A^{-1}, \alpha \in [0,1]$
B_T	Total effective field in Helmholtz coils	T
B_E	Field contributed by Earth's magnetic field	T
B_I	Field contributed by current in coil	T
I_l	Current in high-current orientation for measurement pair	$C \cdot s^{-1}$
I_s	Current in low-current orientation for measurement pair	$C \cdot s^{-1}$
r	Radius of electron beam	m

Table 2: Variables used in all equations and analysis

An electron traveling through a potential difference of V Volts gains kinetic energy

$$eV = \frac{1}{2} m v^2$$

If the electron then travels through a uniform magnetic field $\vec{B}$, a force $e\vec{v} \times \vec{B}$ acts on the electron. Assuming the direction of travel is exactly perpendicular to the field lines of $\vec{B}$, we have

$$evB = \frac{mv^2}{r}$$

Rearranging and combining, we get

$$\frac{e}{m} = \frac{2V}{B^2 r^2}.$$

A series of anode voltage and Helmholtz current data pairs are taken by increasing V, and maintaining the radius r constant. B is calculated using $K_r I$. These measurements are repeated for the same voltages with the apparatus rotated 180^o, such that the effects of the Earth's magnetic field are counteracted and can be measured.

Sample calculation

For V = 250, I = 1.6825 (average of CCW and CW measurement pair):

$$\frac{e}{m} = \frac{2 \cdot 250}{7.73 \cdot 10^{-4} \cdot 1.6825 \cdot 0.08} = 1.847 \cdot 10^{11}$$

The real value is $1.76 \cdot 10^{11}$, so this measurement is within 5% of the real value.