**General Description**

The charge-to-mass ratio, $e/m$, of the electron will be measured by observing the path of moving electrons in a uniform magnetic field (see figure 1). Electrons are emitted from a filament by passing a current through it. These electrons are accelerated through a potential, $V_p$, and focussed by a grid. They then enter a region with magnetic field, $B$, perpendicular to the direction of the electron’s motion. The field is set up by the current, $I_{coil}$, through a pair of Helmholtz coils with $N$ turns per coil and radius, $R_{coil}$. The field at the center of the Helmholtz coils is given by:

$$B = \frac{8 \mu_0 N I_{coil}}{\sqrt{125} R_{coil}}$$

where $\mu_0 = 4\pi \times 10^{-7}$ Webers/A-m and $B$ will be in Weber/m$^2$ if $I_{coil}$ is in Amps and $R_{coil}$ is in meters.

The electrons will follow a circular path when they enter the magnetic field. If $R$ is the radius of the path, the $e/m$ is given by (see Appendix):

$$\frac{e}{m} = \frac{2V_p}{B^2 R^2}.$$ 

**Experimental Details:**

1. The electron tube contains the filament, grid, plate and a vertical set of markers that are separated by 1 cm. The tube is filled with a gas that emits blue light when hit by electrons so the path of the electrons is visible.

2. To get a sufficient source of electrons, the current through the filament must be set to at least 0.5A. The plate voltage should be set to about 100V. The grid potential should be adjusted to get a focussed beam.

3. The magnitude and direction of the field can both be varied by changing the current to the Helmholtz coils.

4. Record $V_p$, $I_{coil}$ and $R$.

5. Repeat the measurements for each marker.

6. Measure $R_{coil}$ and record $N$.

**Results**
1. Calculate \( e/m \) for an electron for each of your observations. What are the differences between your values and the accepted value?

2. Do you notice a trend in your values of \( e/m \) as a function of \( R \)? If so, guess what caused it. If there is a systematic trend, does it make sense to average the values you found to report one answer?
Appendix: Derivation of equation for e/m
The force exerted on an electron of charge, e, moving with speed, v, in a magnetic field, B, perpendicular to its velocity is

\[ F = evB. \]

The electrons travel in a circular path of radius R, so

\[ F = ma = m\left(\frac{v^2}{R}\right). \]

Therefore

\[ evB = \frac{mv^2}{R}, \]

and so

\[ \frac{e}{m} = \frac{v}{BR}. \]  

(1)

The electrons are assumed to have negligible kinetic energy when they leave the filament. They acquire energy, eV_p, when accelerated by the plate voltage. Thus their kinetic energy is given by

\[ \frac{1}{2}mv^2 = eV_p \]

or

\[ v = \sqrt{\frac{2eV_p}{m}}. \]

Putting this value for v into equation (1) we find

\[ \frac{e}{m} = \frac{1}{BR}\sqrt{\frac{2eV_p}{m}}. \]

Squaring and cancelling a factor of e/m yields the result

\[ \frac{e}{m} = \frac{2V_p}{B^2R^2}. \]