BASIC PRINCIPLES

Electrons in a fine-beam tube are deflected into a circular path by a uniform magnetic field. The tube contains neon gas at a precisely defined pressure so that gas atoms become ionised by collision with electrons along the path thus causing them to emit light. This means the path of the electrons can be viewed directly and the radius of the curvature can simply be measured with a ruler. Since the accelerating voltage of the electron gun $U$ and the magnetic field strength $B$ are both known, the radius of the path $r$ can be used to determine the specific charge of an electron $e/m$:

An electron moving at velocity $v$ in a direction perpendicular to a magnetic field $B$ is subject to a Lorentz-force that acts in a direction orthogonal to both the movement and the magnetic field:

$$ F = e \cdot v \cdot B $$

This gives rise to a centripetal force on the electron:

$$ F = \frac{m \cdot v^2}{r} $$

such that it moves in a circular path of radius $r$. Therefore

$$ e \cdot B = \frac{m \cdot U}{r} $$

The velocity $v$ is dependent on the accelerating voltage $U$ applied to the electron gun:

$$ v = \sqrt{\frac{U}{m}} $$

Therefore the specific charge of the electron is given by:

$$ \frac{e}{m} = \frac{2 \cdot U}{r \cdot (B \cdot v)^2} $$

EVALUATION

The magnetic field $B$ is generated by a pair of Helmholtz-coils and is proportional to the current $I_H$ that passes through each of the coils. The coefficient of proportionality $k$ can be determined from the coil radius $R = 147.5$ mm and the number of turns in the coil $N = 124$ per coil:

$$ B = k \cdot I_H \text{ where } k = \frac{\mu_0}{4\pi R^2} N $$

This means that all the components needed to calculate the specific change are known.

Fig. 1: Deflection of electron of velocity $v$ in a magnetic field $B$ by a Lorentz-force $F$ into a closed circular path of radius $r$.

Fig. 2: Fine-beam tube with spherically-shaped luminous trace of electrons in the magnetic field.