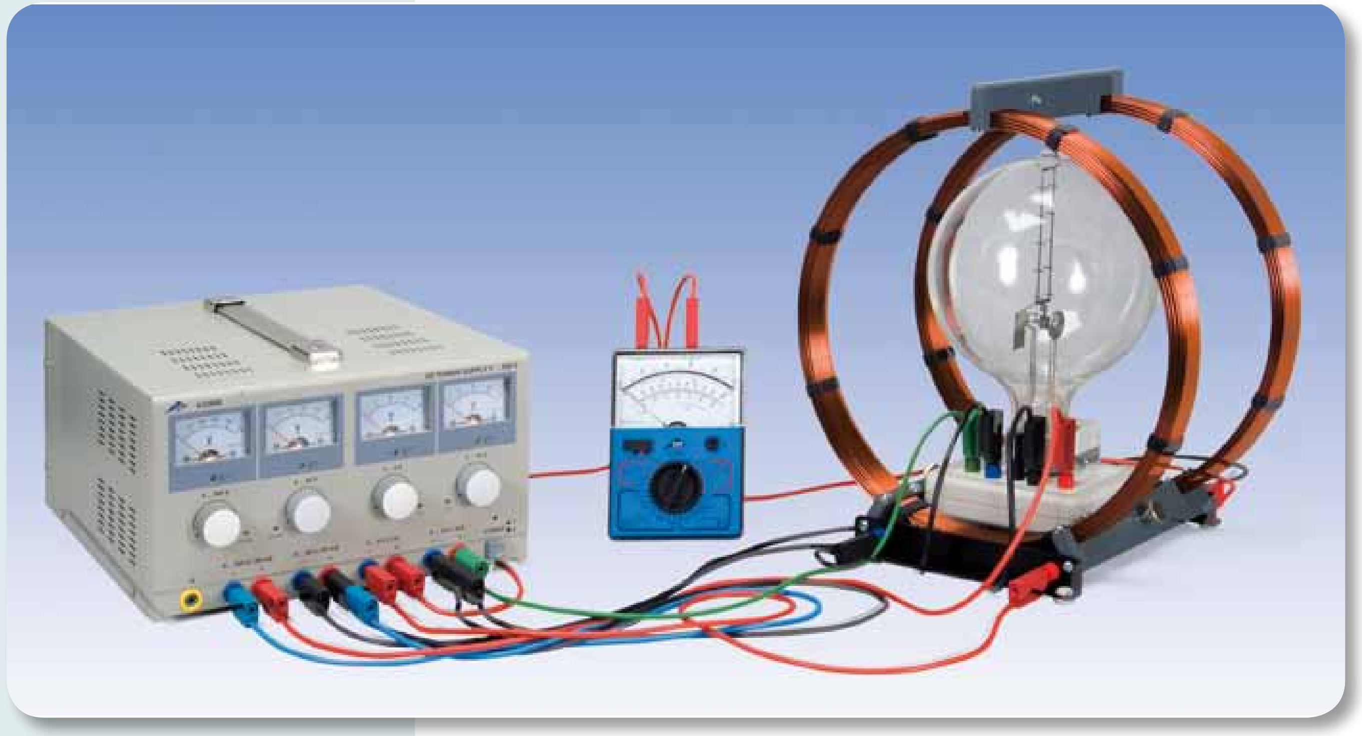
FINE-BEAM TUBE



EXPERIMENT PROCEDURE

- **Demonstrate the deflection of electrons in a uniform magnetic field into a closed circular path.**
- **Determine the Helmholtz current I_H as a function of the accelerating voltage of the electron gun U for a constant path radius r.**

OBJECTIVE

Determine the specific charge of an electron.

SUMMARY

In the fine-beam tube, the path of electrons in a uniform magnetic field can be observed as a clearly delineated ray. This means that the radius of the circular path can be directly measured with a simple ruler. From the path radius *r*, the magnetic field *B* and the electron gun's accelerating voltage *U* the specific charge of an electron *e/m* can be calculated.

REQUIRED APPARATUS

Quantity	Description	Number
1	Fine Beam Tube on Connection Base	**1000904**
1	Helmholtz Coils 300 mm	**1000906**
1	DC Power Supply 0 – 500 V (230 V, 50/60 Hz)	**1003308 or**
	DC Power Supply 0 – 500 V (115 V, 50/60 Hz)	**1003307**
1	Analogue Multimeter AM50	**1003073**
1	Set of 15 Safety Experiment Leads, 75 cm	**1002843**
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UE3070700

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:

(1) $$F = e \cdot v \cdot B$$

e: Charge on an electron

This gives rise to a centripetal force on the electron

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

m: Mass of an electron

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

(3) $$e \cdot B = \frac{m \cdot v}{r}$$

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

(4) $$v = \sqrt{2 \cdot \frac{e}{m} \cdot U}$$

Therefore the specific charge of the electron is given by:

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

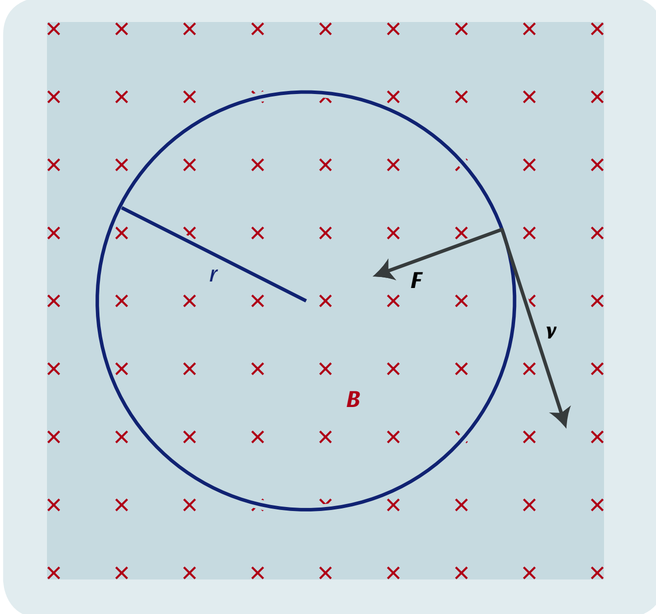

Fig. 1: Deflection of electron of velocity *v* in a magnetic field *B* by a Lorentz-force *F* into a closed circular path of radius *r*.

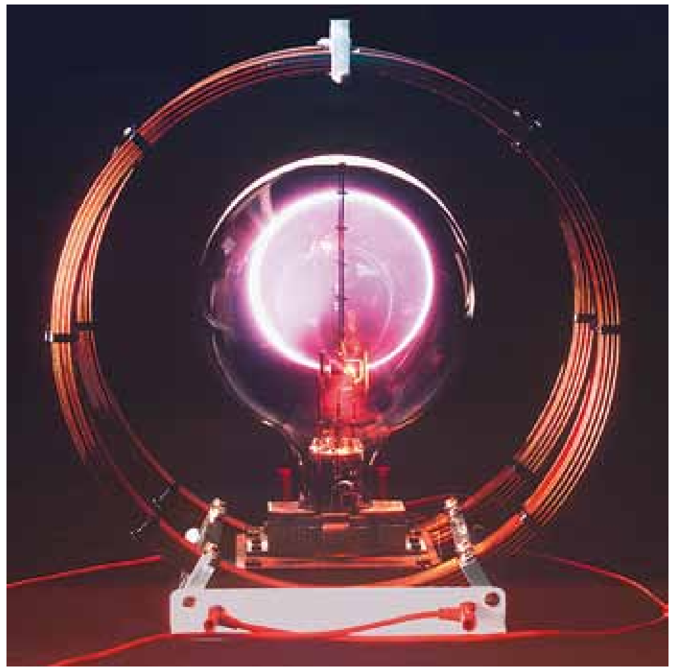

Fig. 2: Fine-beam tube with spherically-shaped luminous trace of electrons in the magnetic field.

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:

$$B = k \cdot I_H \quad \text{where} \quad k = \left(\frac{4}{5}\right)^{\frac{3}{2}} \cdot 4\pi \cdot 10^{-7} \frac{\text{Vs}}{\text{Am}} \cdot \frac{N}{R}$$

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