EXPERIMENT PROCEDURE

- **Observing the thermionic emission of charge-carriers from a heated cathode.**
- **Determining the polarity of the emitted charge-carriers.**
- **Estimating the specific charge (charge-to-mass ratio) of the charge-carriers.**

OBJECTIVE

Determine the polarity of the charge-carriers

SUMMARY

In the Perrin tube, the electron beam can be deflected into a Faraday cup by applying a homogeneous magnetic field. The charge of the electrons can be observed by connecting an electroscope to the Faraday cup, and its polarity can be determined by comparison with an electric charge of known polarity.

REQUIRED APPARATUS

Quantity	Description	Number	
1	Perrin Tube S	**1000616**	
1	Tube Holder S	**1014525**	
1	Helmholtz Pair of Coils S	**1000611**	
1	High Voltage Power Supply 5 kV (230 V, 50/60 Hz)	**1003310**	**or**
	High Voltage Power Supply 5 kV (115 V, 50/60 Hz)	**1003309**	
1	DC Power Supply 0 – 20 V, 0 – 5 A (230 V, 50/60 Hz)	**1003312**	**or**
	DC Power Supply 0 – 20 V, 0 – 5 A (115 V, 50/60 Hz)	**1003311**	
1	Kolbe's Electroscope	**1001027**	
1	Set of 15 Safety Experiment Leads, 75 cm	**1002843**	

BASIC PRINCIPLES

In the Perrin tube, a focused electron beam falls onto a fluorescent screen, where it is observed as a bright dot. A Faraday cup is placed at 45° to the electron beam, and the electrons can then be deflected into it by applying a magnetic field. The flow of charge can be measured through a separate electrical connection.

In the experiment, the electron beam is deflected by the homogeneous magnetic field of a Helmholtz coil pair into the Faraday cup, which is connected to an electroscope. From the observed charging or discharging of the electroscope by the electron beam entering the Faraday cup, it is possible to determine the polarity of the charge-carriers.
It is also possible to estimate the specific charge of the charge-carriers, since the radius of curvature r of the curved path into the Faraday cup is known. The centripetal force acting on the charge-carriers in this curved path is given by the Lorentz force as follows:

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

e: Carrier charge, m: Mass of the charge-carrier,
B: Magnetic flux density.

Also, the velocity v of the charge-carriers depends on the anode voltage U_A as follows:

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

Combining Equations 1 and 2 gives the following expression for the specific charge (charge-to-mass ratio) of the charge-carriers:

(3) $$\frac{e}{m} = \frac{2 \cdot U_A}{(B \cdot r)^2}$$

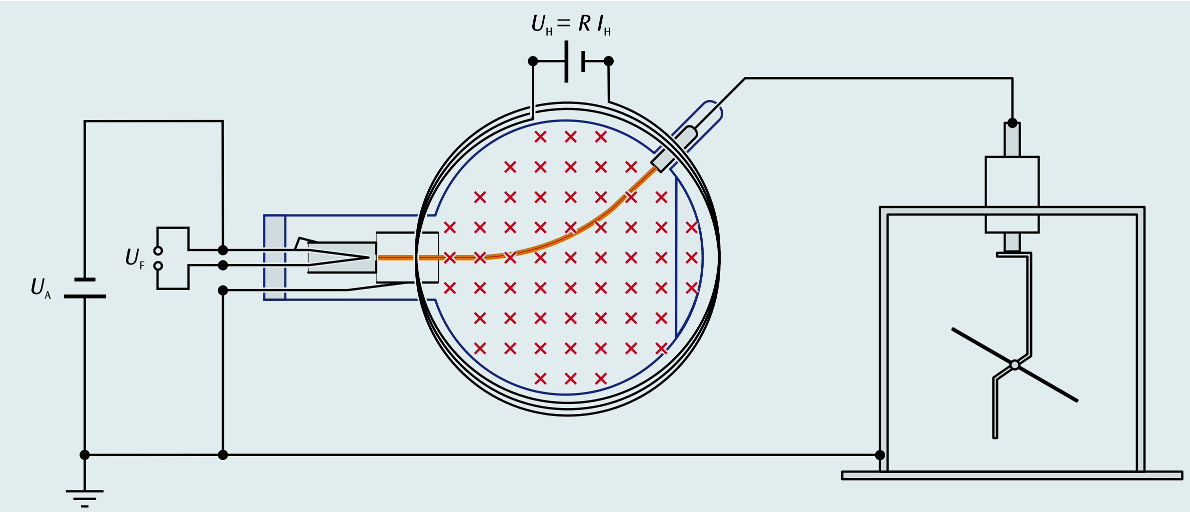

Fig. 1: Schematic diagram of the Perrin tube

EVALUATION

The radius of curvature r of the curved path to the Faraday cup is 160 mm. The anode voltage U_A is known.

The magnetic field B is generated by a Helmholtz coil pair and is proportional to the current I_H through each of the coils. The proportionality factor k can be calculated from the coil radius R = 68 mm and the number of turns on each coil, which is N = 320. Thus:

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