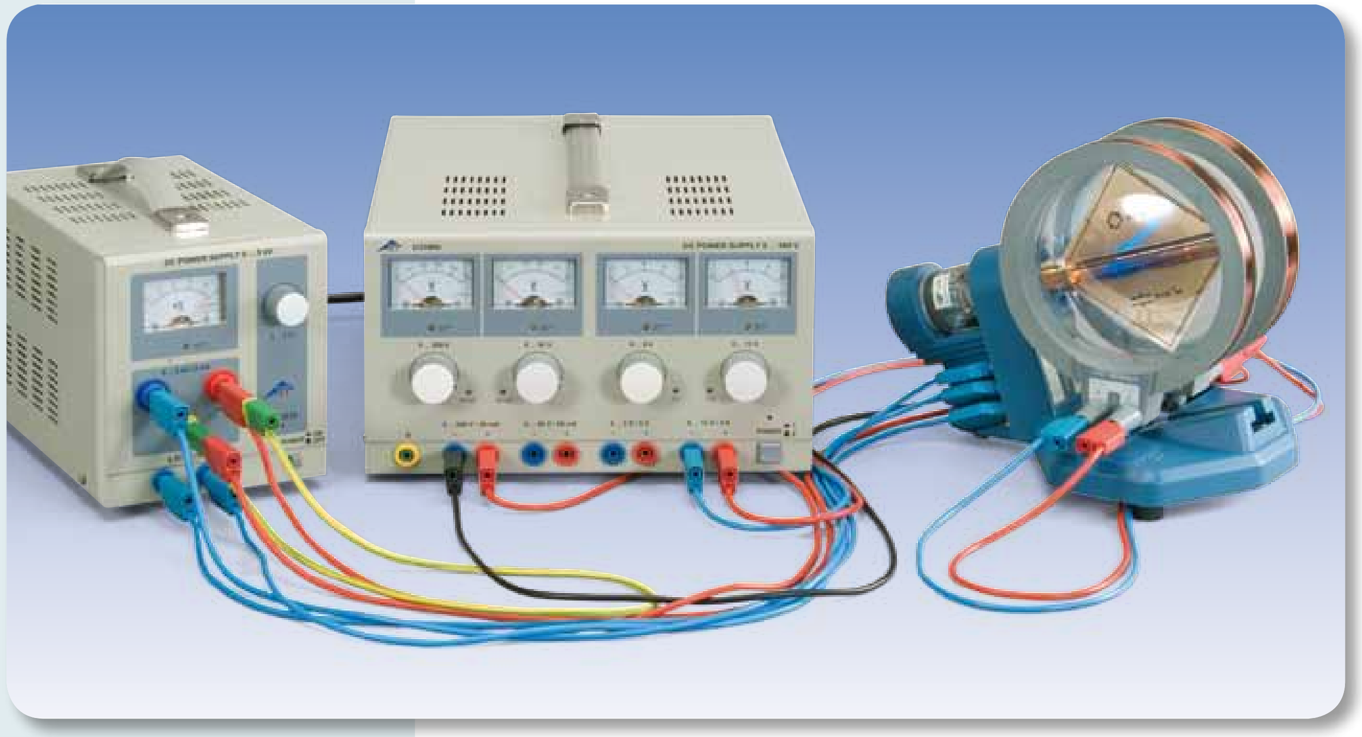
UE3070500 THOMSON TUBE



EXPERIMENT PROCEDURE

- **Investigate the deflection of an electron beam by a magnetic field.**
- **Estimate the specific charge of an electron.**
- **Investigate the deflection of an electron beam by an electric field.**
- **Construct a velocity filter using orthogonal electric and magnetic fields.**

OBJECTIVE

Investigate the deflection of electrons by electric and magnetic fields.

SUMMARY

In a Thomson tube the vertical deflection of a horizontal electron beam can be observed on a fluorescent screen. Such a deflection can be generated by a vertical electric field or by a horizontal magnetic field that is perpendicular to the direction of motion in the horizontal plane.

REQUIRED APPARATUS

Quantity	Description	Number
1	Thomson Tube S	**1000617**
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 – 500 V (230 V, 50/60 Hz)	**1003308 or**
	DC Power Supply 0 – 500 V (115 V, 50/60 Hz)	**1003307**
1	Set of 15 Safety Experiment Leads, 75 cm	**1002843**

BASIC PRINCIPLES

In a Thomson tube electrons pass horizontally through a slit behind the anode and impinge upon a fluorescent screen placed at an angle to the electron beam on which they can be observed. Beyond the slot there is a plate capacitor. The electric field between its two plates deflects the electron beam in a vertical direction. In addition Helmholtz coils can be used to rate a magnetic field in a horizontal direction perpendicular to the motion of the electrons that also deflects them in a vertical direction.

An electron moving with velocity *v* through a magnetic field *B* is subject to a Lorentz force given by

(1) $$\mathbf{F} = -e \cdot \mathbf{v} \times \mathbf{B}$$

e: Charge of an electron

The force acts in a direction perpendicular to a plane defined by the direction of motion and the magnetic field. This causes the beam to be deflected vertically, if both the direction of motion and the magnetic field are in the horizontal plane (see Fig. 1). If the direction of motion is perpendicular to a uniform magnetic field, electrons are deflected in a circular path with a centripetal force resulting from the Lorentz-force.

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

m: Mass of an electron, *r*: Radius of path.

The velocity of the electrons depends on the anode voltage U_A so that:

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

This means that measuring the radius of the path allows the specific charge of an electron to be determined as long as the homogenous magnetic field *B* and the anode voltage U_A are both known. Equations (2) and (3) can be combined to give an expression for the specific charge of a electron:

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

If a voltage U_P is being applied to the plate capacitor, electrons are deflected vertically by its electric field *E* with a force

(5) $$\mathbf{F} = -e \cdot \mathbf{E}$$

e: Charge of an electron

This deflection is also vertical (see Fig. 2). The electric field can thus be adjusted in such a way that it precisely cancels out the deflection due to the magnetic field:

(6) $$e \cdot E + e \cdot v \cdot B = 0$$

In this case it is easy to determine the velocity of each electron:

(7) $$v = \left|\frac{E}{B}\right|$$

Such an arrangement of orthogonal electric and magnetic fields in which the deflection of the beam, is cancelled out is sometimes called a velocity filter.

EVALUATION

The magnetic field *B* is generated by a pair of Helmholtz coils and is proportional to the current I_H passing through each coil individually. The coefficient of proportionality *k* can be determined from the coil radius *R* = 68 mm and the number of turns in the coil *N* = 320 per coil:

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

The electric field can be calculated from the voltage U_P and the separation of plates *d*:

$$E = \frac{U_P}{d}$$

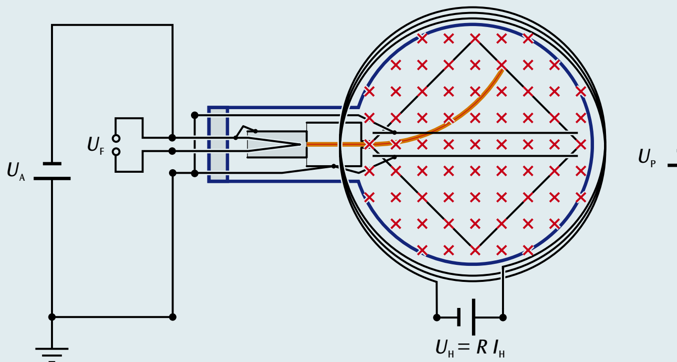


Fig. 1: Schematic of a Thomson tube in a magnetic field.

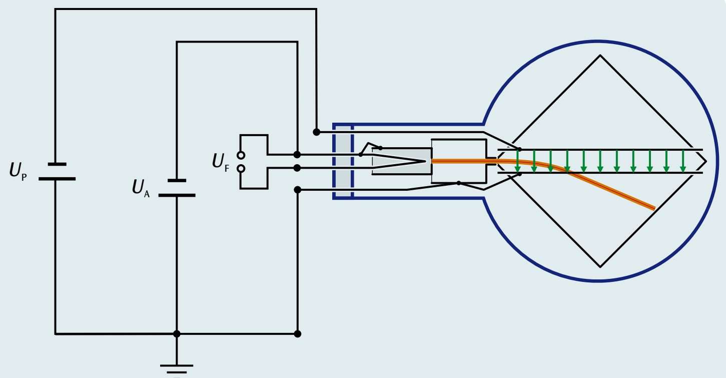


Fig. 2: Schematic of a Thomson tube in an electric field.