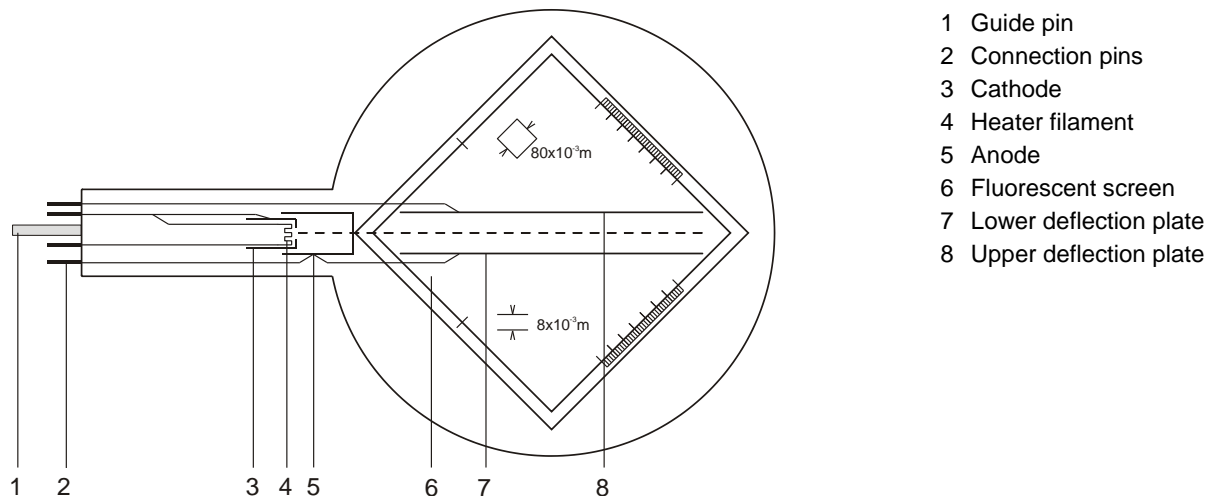


## Thomson Tube S 1000617

### Instruction sheet

09/22 HJB, DA



- 1 Guide pin
- 2 Connection pins
- 3 Cathode
- 4 Heater filament
- 5 Anode
- 6 Fluorescent screen
- 7 Lower deflection plate
- 8 Upper deflection plate

### 1. Safety instructions

Hot cathode tubes are thin-walled, highly evacuated glass tubes. Treat them carefully as there is a risk of implosion.

- Do not subject the tube to mechanical stresses.
- Do not subject the connection leads to any tension.
- The tube only may be used with tube holder S (1014525).

If voltage or current is too high or the cathode is at the wrong temperature, it can lead to the tube becoming destroyed.

- Do not exceed the stated operating parameters.

When the tube is in operation, the terminals of the tube may be at high voltages with which it is dangerous to come into contact.

- Only use safety experiment leads for connecting circuits.
- Only change circuit with power supply equipment switched off.
- Only exchange tubes with power supply equipment switched off.

When the tube is in operation, the stock of the tube may get hot.

- If necessary, allow the tube to cool before dismantling.

The compliance with the EC directive on electromagnetic compatibility is only guaranteed when using the recommended power supplies.

### 2. Description

The Thomson tube is intended for investigating the deflection of electron beams in electrical and magnetic fields. It can be used to estimate the specific charge of an electron  $e/m$  and to determine the electron velocity  $v$ .

The Thomson tube comprises an electron gun which emits a narrow, focussed ribbon of cathode rays within an evacuated, clear glass bulb. A tungsten 'hairpin' filament hot cathode is heated directly and the anode takes the form of a cylinder. The deflection of rays can be achieved electrostatically by means of a built-in plate capacitor formed by the pair of deflection plates or magnetically with the help of the Helmholtz coils S (1000611) magnetically. The cathode rays are intercepted by a flat mica sheet, one side of which is coated with a fluorescent screen and the other side of which is printed with a millimetre graticule so that the path of the electrons can be easily traced. The mica sheet is held at  $10^\circ$  to the axis of the tube by the two deflecting plates.

### 3. Technical data

Filament voltage:	≤ 7,5 V AC/DC
Anode voltage:	2000 V – 5000 V DC
Anode current:	0.1 mA approx. at 4000 V
Deflector plate voltage:	350 V max.
Distance between plates:	8 mm approx.
Fluorescent screen:	90 mm x 60 mm
Glass bulb:	130 mm diam. approx.
Total length:	260 mm approx.

### 4. Operation

To perform experiments using the Thomson tube, the following equipment is also required:

1 Tube holder S	1014525
1 High voltage power supply 5 kV (115 V, 50/60 Hz) or (230 V, 50/60 Hz)	1003309 1003310
1 Helmholtz pair of coils S	1000611
1 Power supply 500 V (115 V, 50/60 Hz) or (230 V, 50/60 Hz)	1003307 1003308

#### 4.1 Setting up the Thomson tube into the tube holder

- The tube should not be mounted or removed unless all power supplies are disconnected.
- Press tube gently into the stock of the holder and push until the pins are fully inserted. Take note of the unique position of the guide pin.

#### 4.2 Removing the Thomson tube from the tube holder

- To remove the tube, apply pressure with the middle finger on the guide pin and the thumb on the tail-stock until the pins loosen, then pull out the tube.

#### 4.3 Rotating the Thomson tube in the tube holder

- The Thomson tube can be rotated carefully around its own axis by about  $\pm 4^\circ$  in the tube holder. By rotating the tube, the visibility of

the electron beam on the screen can be improved depending on the experimental settings.

### 5. Example experiments

#### 5.1 Magnetic deflection

- Set up the tube as in Fig. 2.
- Set up the coils in Helmholtz geometry.
- Turn on the high-tension power supply.
- Energise the Helmholtz coils and observe the path of the beam.

The path of the luminous beam is circular, the deflection being in a plane perpendicular to the electromagnetic field.

At fixed anode voltage the radius decreases with increasing coil current.

With a fixed coil current the radius increases with increasing anode potential, indicating a higher velocity.

An electron of mass  $m$  and charge  $e$  moving perpendicular to a uniform magnetic field  $B$  at velocity  $v$  is deflected by the Lorentz force  $Bev$  onto a circular path of radius  $r$ .

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

#### 5.2 Electric deflection

- Set up the tube as in Fig 3.
- Turn on the high-tension power supply.
- Switch on the deflector plate voltage and observe the path of the beam.

An electron with velocity  $v$  passing through the electric field  $E$  produced by a plate capacitor held at a voltage  $U_P$  with a plate spacing  $d$  is deflected into the curved path of a parabola governed by the equation:

$$y = \frac{1}{2} \cdot \frac{e}{m} \cdot \frac{E}{v^2} \cdot x^2 \quad (2)$$

where  $y$  is the linear deflection achieved over a linear distance  $x$ .

### 5.3 Calculating $e/m$ und $v$

#### 5.3.1 By means of magnetic deflection

- Set up the experiment as in Fig 2.

The velocity is dependent on the anode voltage  $U_A$  such that:

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

Solving equations 1 and 3 simultaneous gives the following expression for the specific charge  $e/m$ :

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

$U_A$  can be measured directly,  $B$  and  $r$  can be determined experimentally.

##### 5.3.1.1 Calculating $r$

The radius of curvature  $r$  can be obtained directly from point A at which the electron beam emerges from the luminescent screen (refer to Fig. 1).

According to the Pythagorean theorem:

$$r^2 = c^2 + b^2 = c^2 + (r - a)^2 = c^2 + r^2 - 2ra + a^2$$

$$r = \frac{c^2 + a^2}{2a} \quad (5)$$

Thus, for emergence along  $k = k' = 80$  mm, we can say:

$$c^2 + a^2 = d^2 = k^2 + e^2$$

$$a^2 = f^2 = \frac{1}{2}g^2 = \frac{1}{2}(k - e)^2$$

$$\Rightarrow r = \frac{(80^2 \text{ mm}^2 + e^2)}{\sqrt{2}(80 \text{ mm} - e)} \quad (6)$$

where  $e$  can be read directly from the scale.

##### 5.3.1.2 Calculating $B$

The magnetic flux  $B$  of a magnetic field generated by the Helmholtz coils in Helmholtz geometry and the coil current  $I$  can be calculated:

$$B = \left(\frac{4}{5}\right)^{\frac{3}{2}} \cdot \frac{\mu_0 \cdot n}{R} \cdot I = k \cdot I \quad (7)$$

where  $k$  = in good approximation 4,2 mT/A with  $n = 320$  (windings) and  $R = 68$  mm (coil radius).

#### 5.3.2 By means of field compensation

- Set up the experiment as in Fig 4.
- Turn on the high-tension power supply units and deflect the beam electrically.
- Energise the Helmholtz coils and adjust the voltage in such a way that the magnetic field compensates the electric field and the beam is no longer deflected.

The magnetic field compensates the deflection of the electron beam caused by the electric field:

$$e \cdot E = e \cdot v \cdot B$$

The velocity  $v$  can be calculated:

$$v = \frac{E}{B} \quad (8)$$

where  $E = \frac{U_P}{d}$ . For the calculation of  $B$  refer to point 5.3.1.2.

The specific charge  $e/m$  can be calculated:

$$\frac{e}{m} = \frac{1}{2 \cdot U_A} \cdot \left(\frac{E}{B}\right)^2 \quad (9)$$

**Note:** The magnetic field generated by the Helmholtz coils influences the electrons direction of flight before they reach the electric field of the plate capacitor. Therefore, even for optimally set compensation conditions, the electron beam cannot fly exactly along the zero line. Small deviations from the zero line are to be expected.

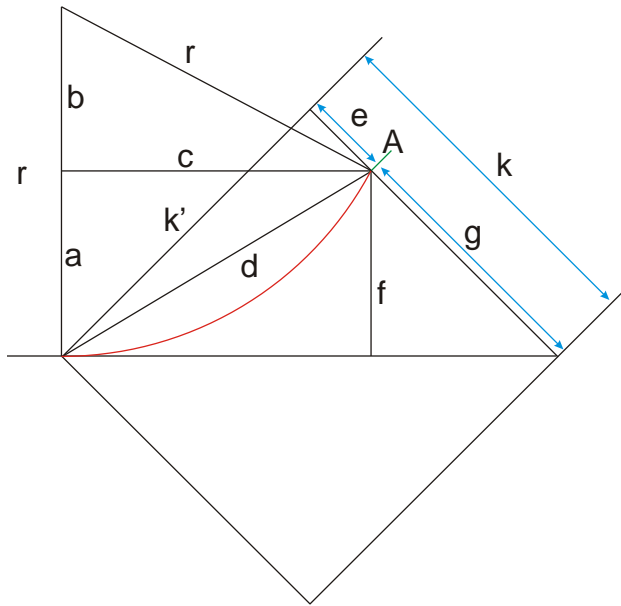


Fig. 1 Determining  $r$

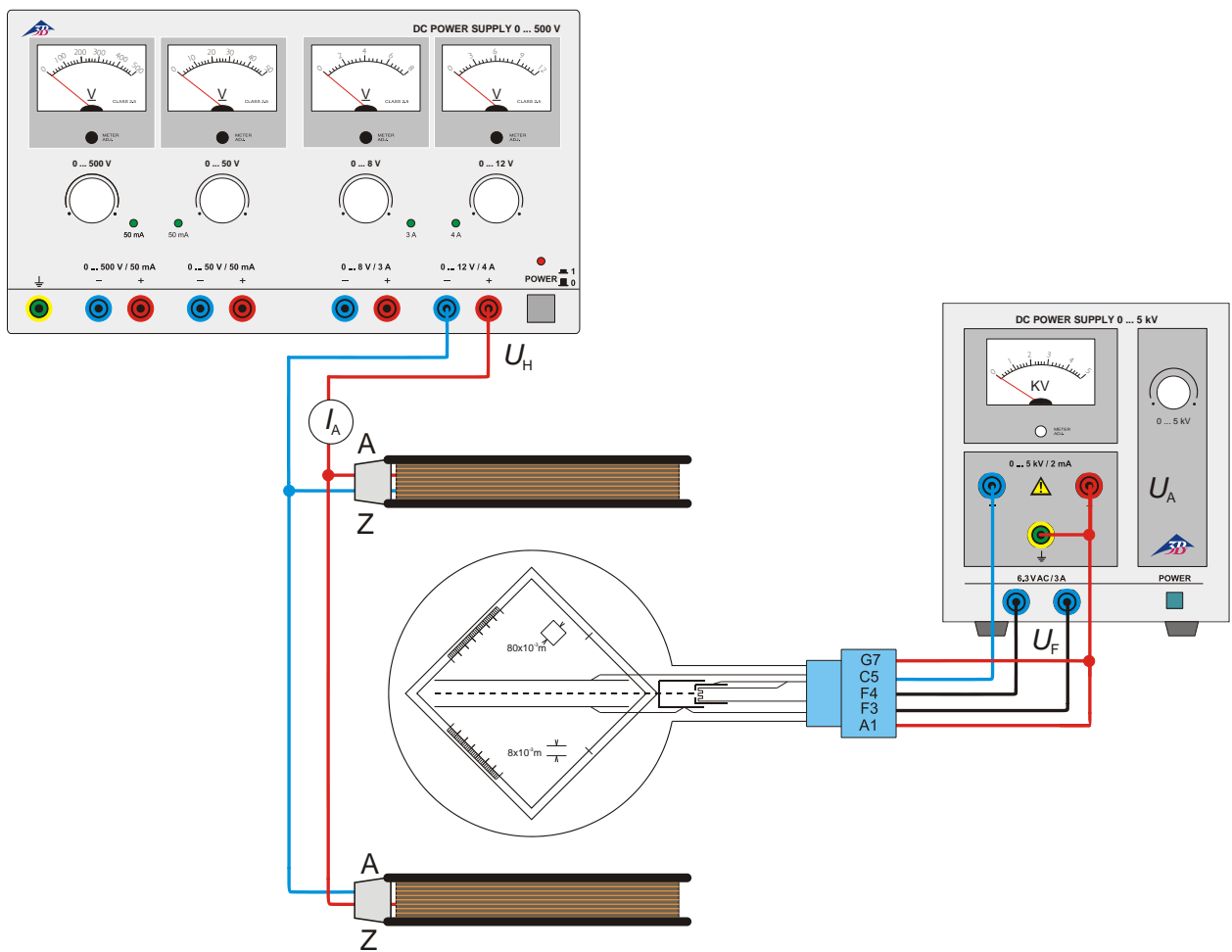


Fig. 2 Magnetic deflection

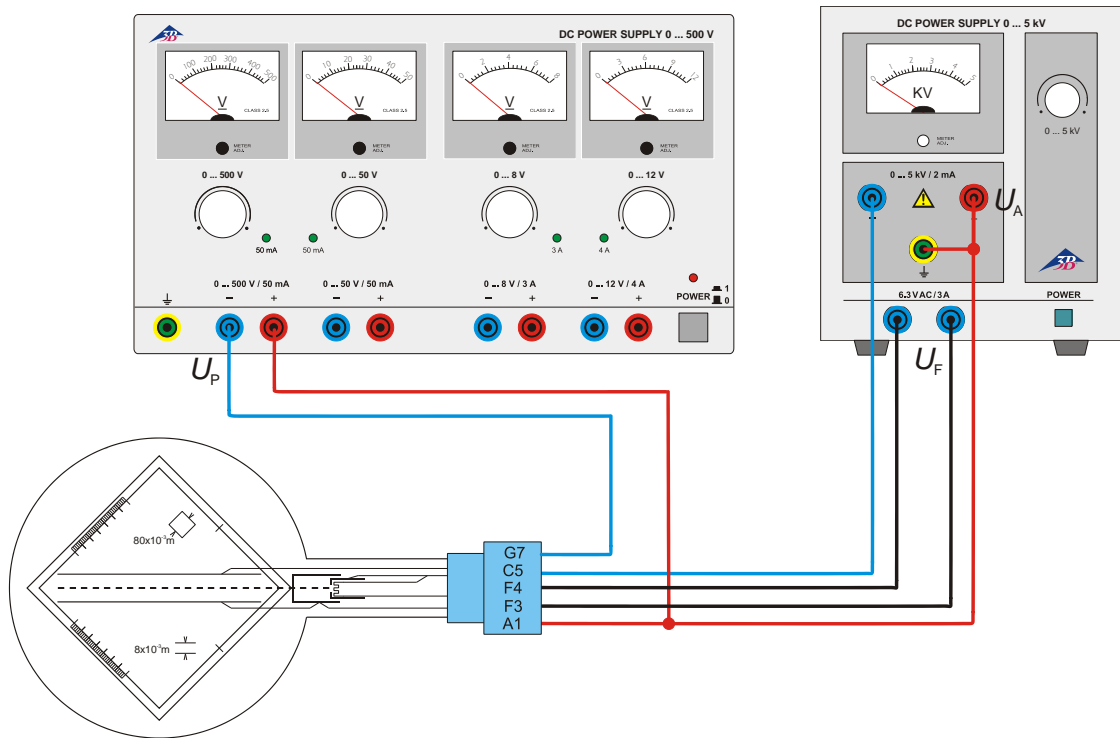


Fig. 3 Electric deflection

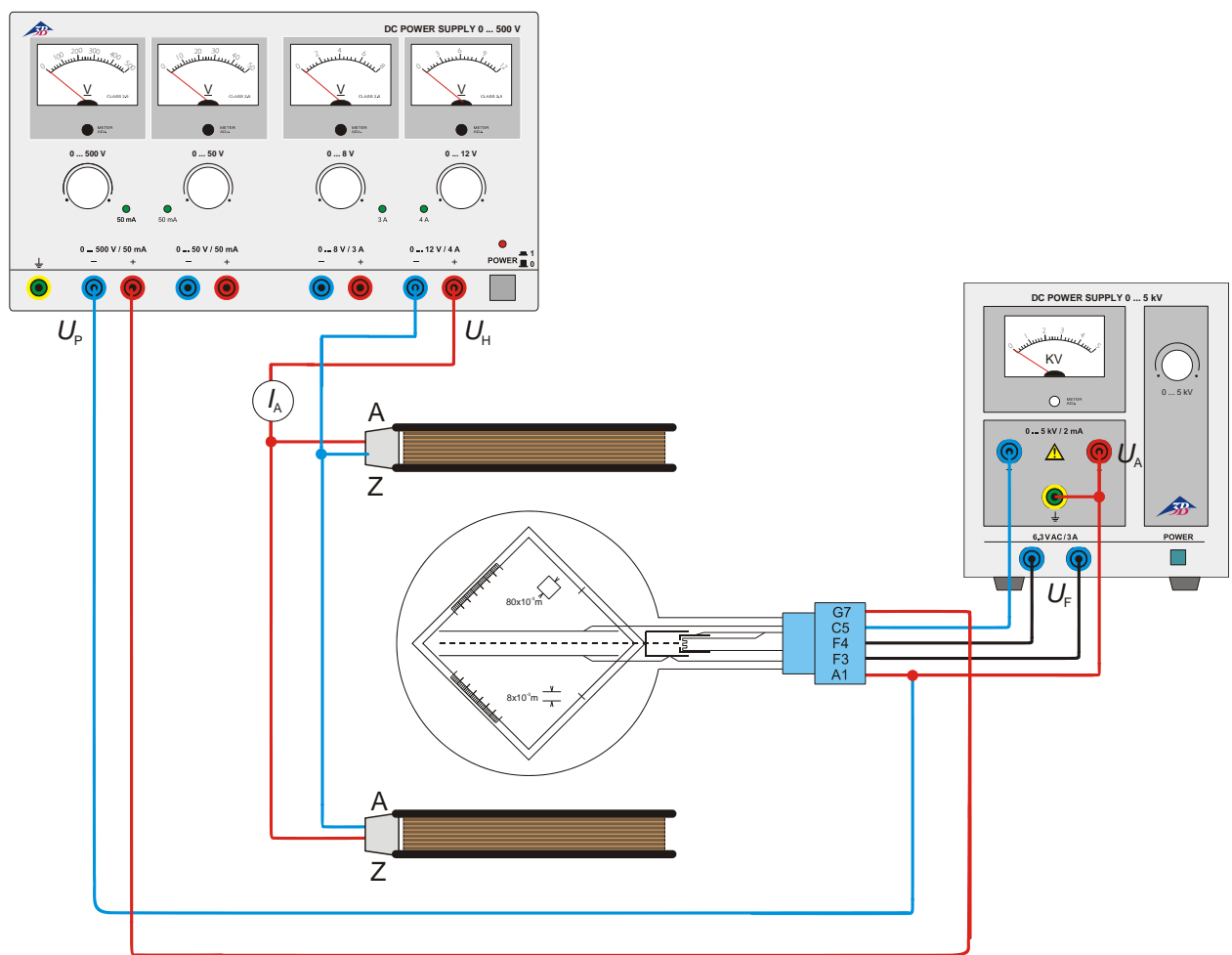


Fig. 4 Determining  $e/m$  by means of field compensation