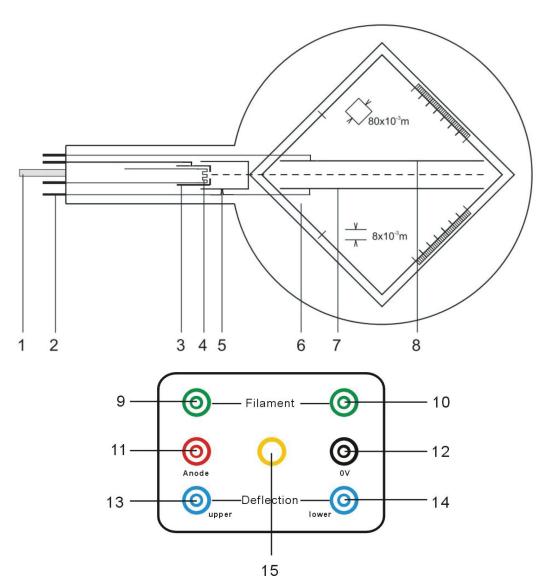


**Bringing You Science Since 1955** 

# **KSCI-TTUBE Thomson Tube / KSCI-TTBASE**

- 1 Guide pin
- 2 Connection pins
- 3 Cathode
- 4 Heater filament
- 5 Anode

- 6 Fluorescent screen
- 7 Lower deflection plate
- 8 Upper deflection plate
- 9 Connector for filament
- 10 Connector for filament
- 11 Connector for anode
- 12 Connector for cathode 0V
- 13 Connector for Upper deflection plate
- 14 Connector for lower deflection plate
- 15 Guide hole





#### 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 P348001.

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 circuits with power supply switched off.
- Set up or dismantle the tubes only when the power supply unit is switched off.

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

Allow the tube to cool before putting away the apparatus.

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, focused 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 P338002 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 millimeter graticule so that the path of the electrons can be easily traced. The mica sheet is held at 10° to the axis of the tube by the two deflecting plates.

#### 3. Technical data

Filament voltage: 6.3 V AC/DC Max. anode voltage: 5000 V DC

Anode current: 0.1 mA approx. at 4000 V Deflector plate voltage: 500 V max. Distance between plates: 8 mm approx. Fluorescent screen: 90 mm x 60 mm Glass bulb: 130 mm diam. approx. Total length: 245 mm approx.

Weight: 0.3kg



# 4. Basic principles

# 4.1 Magnetic deflection

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 B e v onto a circular path of radius r.

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

## 4.2 Electric deflection

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:

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

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

# 4.3 Calculating e/m and v

# 4.3.1 Means of magnetic deflection

The velocity is dependent on the anode voltage U<sub>A</sub> such that:

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

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

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

U<sub>A</sub> can be measured directly, B and r can be determined experimentally.

#### 4.3.1.1 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:

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

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

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

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

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

$$\Rightarrow r = \frac{\left(80^2 mm^2 + e^2\right)}{\sqrt{2}\left(80mm - e\right)} \tag{6}$$

where e can be read directly from the scale.

# 4.3.1.2 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:



$$B = \left(\frac{4}{5}\right)^{\frac{3}{2}} \cdot \frac{u_0 \cdot n}{R} \cdot I = k \cdot I \tag{7}$$

where k = in good approximation 4,2 mT/A with n = 320 (windings) and R = 68 mm (coil radius). 4.3.2 Means of field compensation

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:

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

where  $E = \frac{U_p}{d}$  . For the calculation of B refer to point 4.3.1.2.

The specific charge e/m can be calculated:

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

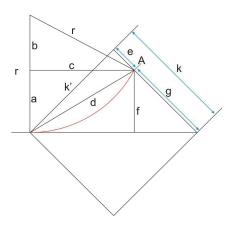


Fig.1 Determining r

# 5. Additionally required equipment

1 DC power supply
1 DC power supply
1 Pair of Helmholtz coils
1 Tube holder

KSCI-QP500E
KSCI-HV5000A
KSCI-HCL
KSCI-THDR

# 6. Operation

# 6.1 Setting up the tube in the tube holder

- The tube should not be mounted or removed unless all power supplies are disconnected.
- Insert the tube stock into the boss head of the tube holder P348001, and let the tube in an appropriate position. Screw the boss head tightly.
- Insert the tube pins into the tube base P328003.
- · Plug in all leads correctly.

# 6.2 Removing the tube from the tube holder

- Disconnect all leads, remove the tube base.
- Unscrew the boss head and take the tube out.



# 6.3Magnetic deflection steps

- Set up the tube as in Fig. 2.
- •Insert the Helmholtz coils into the holes of the tube holder and screw tight the heads to set up the coils in Helmholtz geometry.
- Turn on the high voltage power supply.
- Energize the Helmholtz coils and observe the path of the beam.

#### 6.4 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.

# 6.5 Calculate e/m and v

6.5.1 By means of magnetic deflection

- · Set up the experiment as in Fig 2.
- Measure UA, B and r, and then calculate e/m and v.

6.5.1.1 Calculate r

• Read out e from the scale and calculate r with equation 6.

6.5.1.2 Calculate B

- Calculate B with equation 7
- 6.5.2 By means of field compensation
- Set up the experiment as in Fig 4.
- Turn on the high voltage power supply unit and deflect the beam electrically.
- Energize 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.
- Calculate B as 6.5.1.2 and calculate E as  $E = \frac{U_p}{d}$
- Calculate v with equation 8
- Measure U<sub>A</sub>, and then calculate e/m with equation 9.

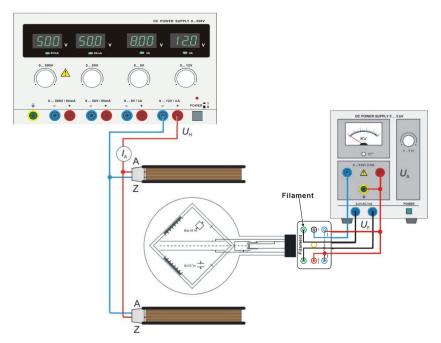


Fig.2 Magnetic deflection

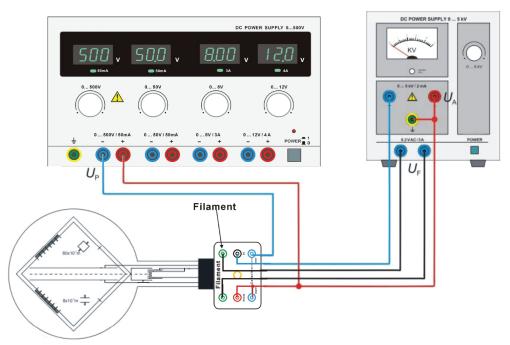


Fig.3 Electric deflection

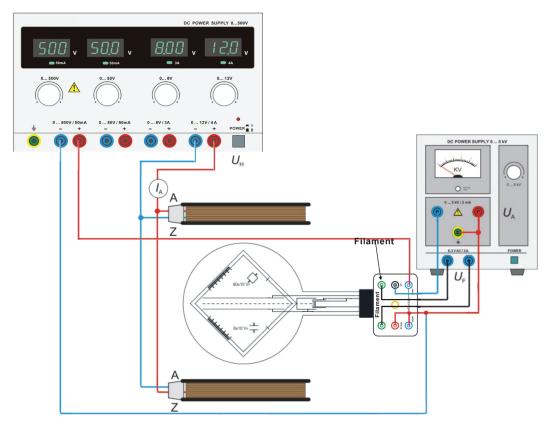


Fig.4 Determine e/m by means of field compensation