3B SCIENTIFIC® PHYSICS

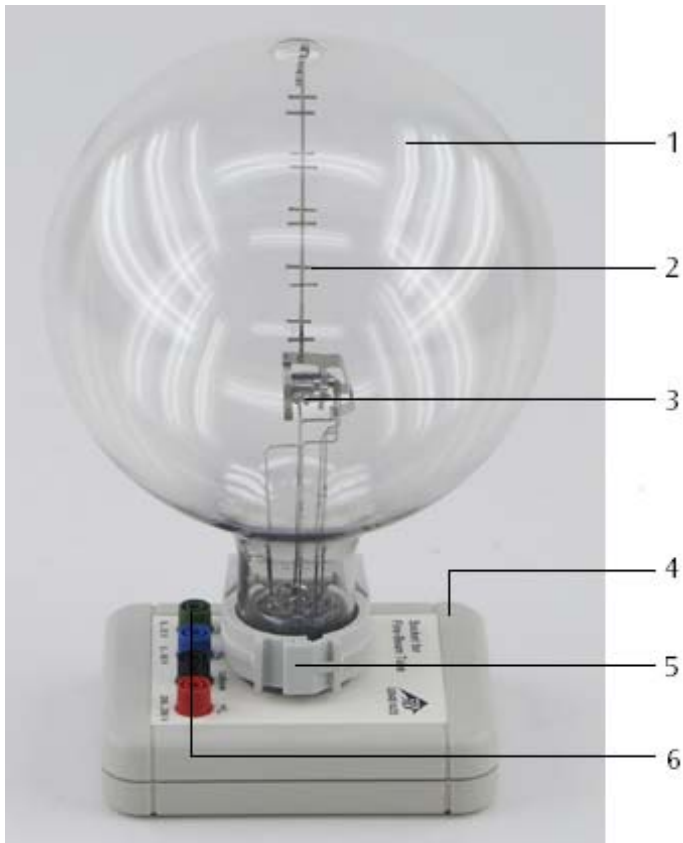## Fine Beam Tube TEL   U18575

Instruction sheet

07/11 ALF

1 Fine beam tube U18575
2 Measurement marks
3 Electron gun
4 Socket U8481435
5 Clip
6 Connectors

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.

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.
- Before switching on the anode voltage wait about 1 minute for the heater temperature to stabilise.

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.
- Do not connect up the terminals on the base until the tube is fixed into it.

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 tube may only be used with Socket for Fine Beam Tube TEL U8481435.

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

2. Description

The Fine Beam Tube TEL is used for investigating the deflection of cathode rays in a uniform magnetic field produced by a pair of Helmholtz coils (U8481500). In addition, it can also be used for quantitative determination of the specific charge of an electron e/m.

Located inside a glass bulb with a Helium residual gas atmosphere is an electron gun, which consists of an indirectly heated oxide cathode, a Wehnelt cylinder and a perforated anode. The gas atoms are ionised along the path of the electrons and a narrow, well-defined, luminescent beam is produced. Integrated measurement marks facilitate a parallax-free determination of the diameter of the circular path of the beam deflected in the magnetic field.

Socket U8481435 with coloured terminals is needed for operation of the fine-beam tube.

3. Technical data

Gas filling:	Helium
Gas pressure:	0.13 mbar
Filament voltage:	< 12.0 V DC
Anode voltage:	max. 300 V
Anode current:	typ. 20 mA
Wehnelt voltage:	0 to -50 V
Diameter of fine beam path:	20 to 100 mm
Division spacing:	20 mm
Tube diameter:	approx. 165 mm
Total height:	approx. 260 mm

4. Socket for Fine Beam Tube TEL U8481435

Fig. 1 Socket: 1 Clip, 2 Opening for guide pin, 3 connection for anode, 4 connection for cathode, 5 connection for Wehnelt cylinder, 6 connection for heater

5. Additionally required equipment

1 Socket for Fine Beam Tube TEL	U8481435
1 DC Power Supply 500 V (230 V, 50/60 Hz) or	U33000-230
1 DC Power Supply 500 V (115 V, 50/60 Hz)	U33000-115
1 Pair of Helmholtz Coils	U8481500
1 Analogue Multimeter AM50	U17450
Safety leads from	U138021

6. Basic principles

An electron moving with velocity v in a direction perpendicular to a uniform magnetic field B experiences a Lorentz force in a direction perpendicular to both the velocity and the magnetic field

$$F = e \cdot v \cdot B \tag{1}$$

e: elementary charge

This gives rise to a centripetal force on the electron in a circular path with radius r, where

$$F = \frac{m \cdot v^2}{r} \quad \text{and} \tag{2}$$

m is the mass of an electron.

Thus,

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

The velocity v depends on the accelerating voltage of the electron gun:

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

Therefore, the specific charge of an electron is given by:

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

If we measure the radius of the circular orbit in each case for different accelerating voltages U and different magnetic fields B, then, according to equation 5, the measured values can be plotted in a graph of $r^2 B^2$ against $2U$ as a straight line through the origin with slope e/m.

The magnetic field B generated in a pair of Helmholtz coils is proportional to the current I_H passing through a single coil. The constant of proportionality k can be determined from the coil radius $R = 147.5$ mm and the number of turns $N = 124$ per coil:

$$B = k \cdot I_\text{H} \quad \text{where}$$

$$k = \left(\frac{4}{5}\right)^{\frac{3}{2}} \cdot 4\pi \cdot 10^{-7} \frac{\text{Vs}}{\text{Am}} \cdot \frac{N}{R} = 0{,}756 \frac{\text{mT}}{\text{A}}$$

Thus, all parameters for the specific charge are known.

7. Operation

7.1 Mounting the tube onto the socket

- Use gentle pressure to push the tube into the socket on the base until the pin contacts are fully inside the socket. Check that the guide pin is in its proper, unique position (see Fig. 2).

- Turn the tube to align it such that the electron gun is parallel to the lengthways edge of the socket.

- Use gentle pressure to shut the clip. The clip is shut when you hear a click.

Fig. 2 Position of guide pin

7.2 Set up

- Place the fine beam tube between the Helmholtz coils.

- Set up the tube as in fig. 3.

- Connect the coils in series to the power supply unit, so that equal current passes through both coils.

- To get a clearer view of the electron beam, conduct the experiment in a darkened room.

7.3 Adjusting the electron beam

- Apply a heater voltage of say 10 V.

- Wait about 1 minute for the heater temperature to stabilise.

- Slowly increase the anode voltage to 300 V (the electron beam is initially horizontal and is visible as a weak, bluish ray).

- Select the Wehnelt voltage so that a very clear and narrow electron beam is visible.

- Optimise the focus and brightness of the electron beam by varying the heater voltage.

- Increase the current I_H passing through the Helmholtz coils and check that the electron beam curves upwards.

If the electron beam is not deflected at all:

- Reverse the polarity of one of the coils so that current passes in the same direction through both coils.

If the electron beam does not curve upwards:

- Swap the connections on the power supply unit to reverse the polarity of the magnetic field.

- Continue increasing the current passing through the coils watch until the electron beam forms a closed circle.

If the path does not form a closed circle:

- Slightly turn the fine beam tube, along with its base, around its vertical axis.

8. Sample experiment

Determination of the specific charge of an electron e/m

- Select the current passing through the coils so that the radius of the circular path is for example 5 cm. Note the set current value.

- Decrease the anode voltage in steps of 20 V to 200 V. In each case, set the coil current I_H so that the radius remains constant. Take down these values.

- Record other series of measured values for radii of 4 cm and 3 cm.

- For further evaluation, plot the measured values in a graph of $r^2 B^2$ against $2U$.
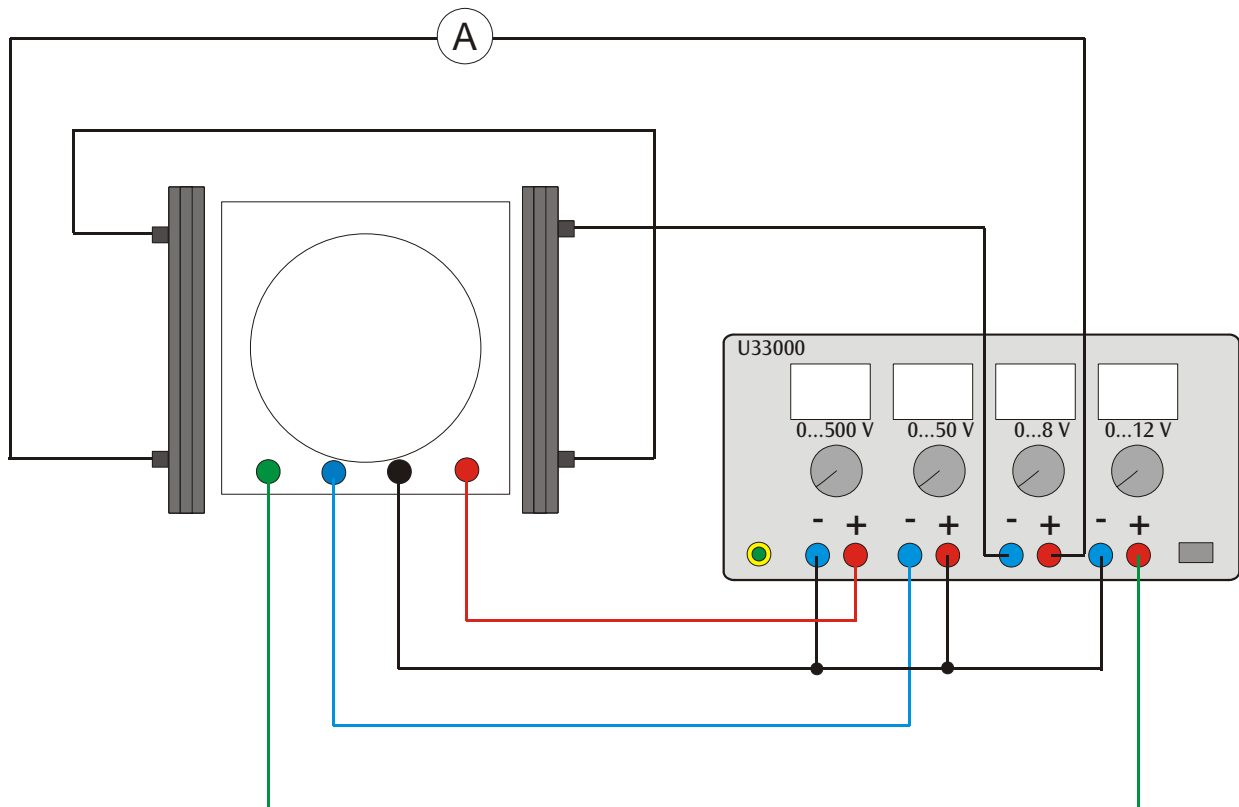
The slope of the line through the origin corresponds to e/m.

Fig. 3   Experimental set up