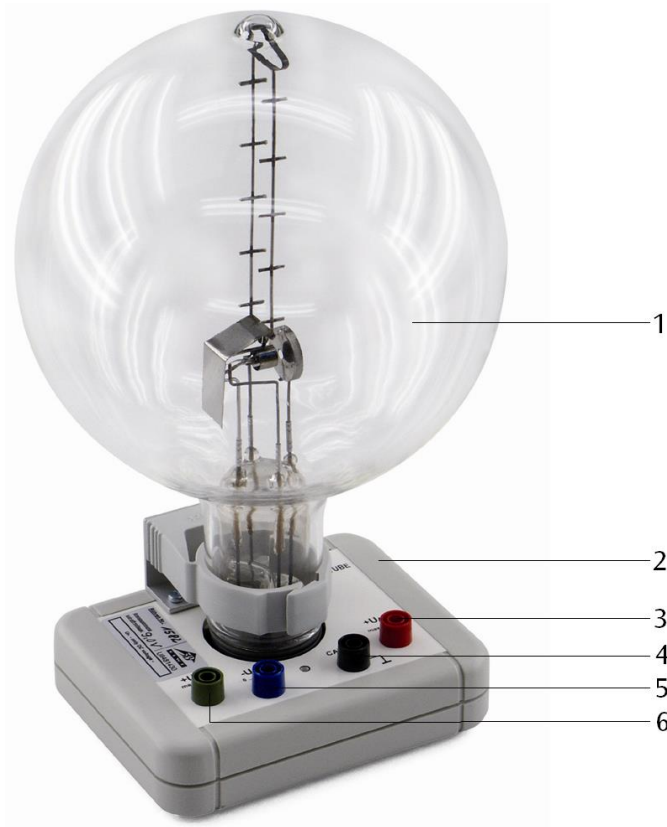# 3B SCIENTIFIC® PHYSICS

...going one step further

Fine Beam Tube on Connection Base   1000904

Instruction sheet
10/15 ALF

1 Fine beam tube
2 Connector base
3 Connection for anode
4 Connection for cathode
5 Connection for Wehnelt cylinder
6 Connection for heater

1. Safety instructions

Hot cathode tubes are thin-walled, highly evacu-ated 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 parame-ters.

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 con-necting 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 electro-magnetic compatibility is only guaranteed when using the recommended power supplies.

2. Description

The Fine Beam Tube is used for investigating the deflection of cathode rays in a uniform magnetic field produced by a pair of Helmholtz coils (1000906). 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 neon 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. Incorporated measurement marks facilitate a parallax-free determination of the diameter of the circular path of the beam deflected in the magnetic field.

The Fine Beam Tube is mounted on a base with coloured connectors. In order to protect the tube, a protective circuit is built into the base, which shuts off any voltage in excess of the base's preset cut-off voltage. The protective circuit prevents excessive voltages from damaging the heater filament and ensures a "smooth" switch-on response once the voltage is applied.

3. Technical data

Gas filling:	Neon
Gas pressure:	$1,3 \times 10^{-5}$ bar
Filament voltage:	5 to 7 V DC (see cut-off-voltage on tube socket)
Filament current:	< 150 mA
Wehnelt voltage:	0 bis -50 V
Anode voltage:	200 to 300 V
Anode current:	< 0.3 mA
Diameter of fine beam path:	20 to 120 mm
Division spacing:	20 mm
Tube diameter:	160 mm
Total height incl. base:	260 mm
Base plate:	115 x 115 x 35 mm³
Weight:	approx. 820 g

4. 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

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

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^2B^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:

$$B = k \cdot I_H \text{ where}$$

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

Thus, all parameters for the specific charge are known.

5. Additionally required equipment

1 DC power supply 300 V (@230 V) or	1001012
1 DC power supply 300 V (@2115 V) and	1001011
1 DC power supply 20 V, 5 A (@230 V) or	1003312
1 DC power supply 20 V, 5 A (@115 V) or	1003311
1 DC power supply 500 V (@230 V) or	1003308
1 DC power supply 500 V (@115 V)	1003307
1 Pair of Helmholtz coils	1000906
1 resp. 2 Analogue multimeter AM50	1003073
Safety leads	

6. Operation

6.1 Set up

- Place the fine beam tube between the Helmholtz coils.
- To get a clearer view of the electron beam, conduct the experiment in a darkened room.

6.1.1 Set up with the DC power supply unit 300 V

- Set up the tube as in fig. 1.
- Connect the voltmeter in parallel to the 300-V output.
- Connect the coils in series to the DC power supply 20 V, as shown in Fig. 2, so that equal current passes through both coils.

6.1.2 Set up with the DC power supply unit 500 V

- Set up the tube as in fig. 4.

6.2 Adjusting the electron beam

- Apply a heater voltage of say 7.5 V. (the heater voltage must be below the cut-off voltage).
- 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.

7. 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^2B^2 against $2U$ (see Fig. 3).

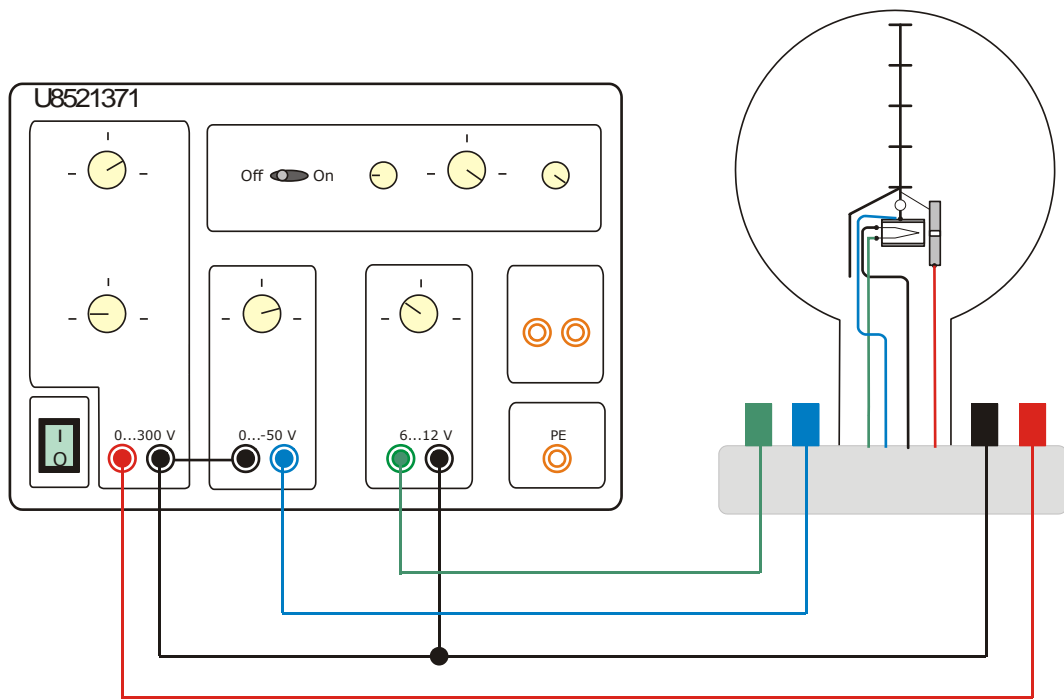The slope of the line through the origin corresponds to e/m.

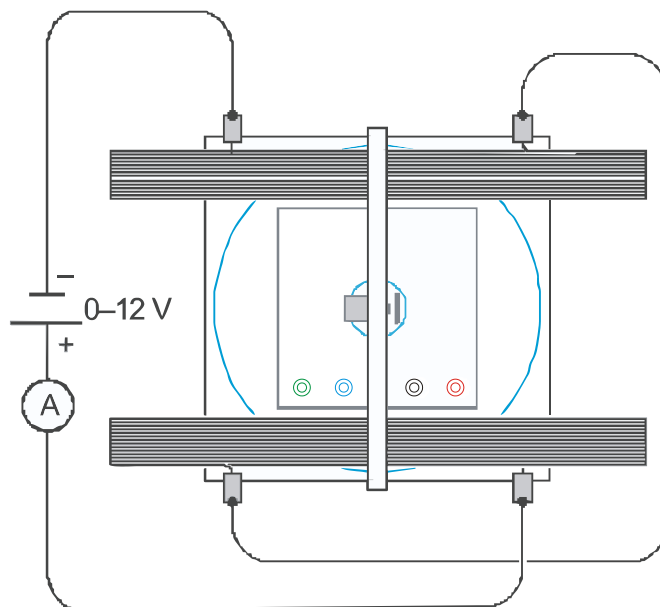Fig. 1 Electrical connections from the fine beam tube to the DC power supply unit 300 V

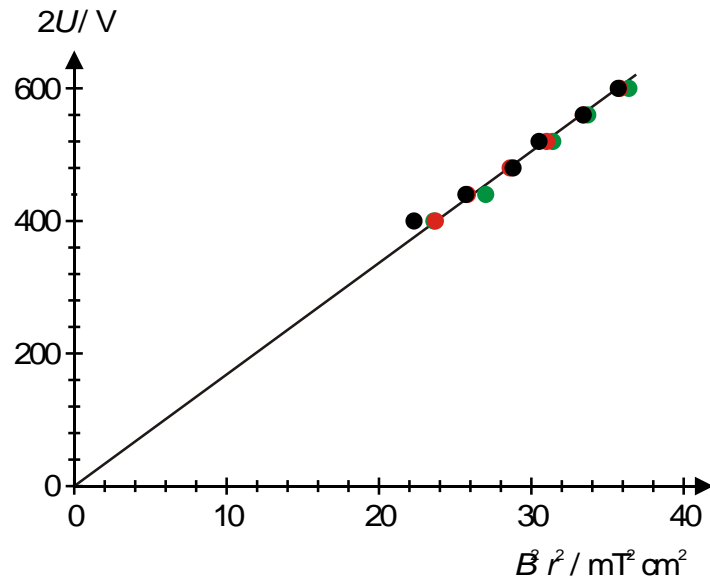Fig. 2 Electrical connections to the pair of Helmholtz coils

Fig. 3 Graph of $r^2 B^2$ against $2U$ for values as measured (black: $r = 5$ cm, red: $r = 4$ cm, green: $r = 3$ cm)
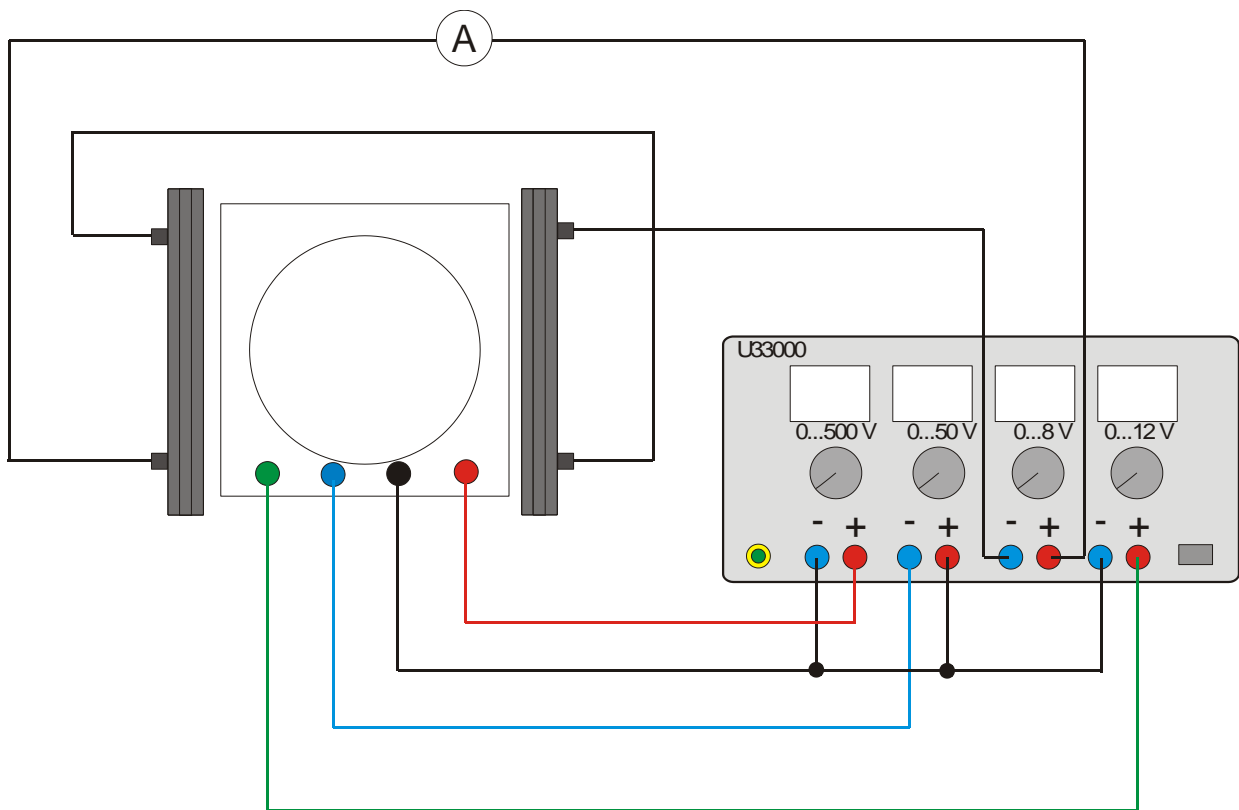

Fig. 4 Electrical connections from the fine beam tube to the DC power supply 500 V