Manual of Operations

e/m Apparatus EM-4N

CAT. No. B10-7353-W1

Important!

Read the following before using the equipment:

1. Carefully follow all instructions and observe all precautions given in this manual.
2. Raising the B-voltage too high will shorten the operational life to the discharge tube.

NaRiKa

Feb 2013
Printed in Japan

B10-7353　e/m APPARATUS, EM-4N

1．Purpose

Used for the study and measurement of e/m by observing the circular paths of electrons under the influence of a uniform magnetic field.

2. Structure

Photo 1 shows the device.

1. The uniform magnetic field is produced by Helmholtz coil, consisting of two parallel-mounted circular coils connected in series. Since the electrical current flows in the same direction and strength both coils, the uniform magnetic field is created between the coils.

2. The discharge tube for measuring e/m is placed within the magnetic field created between Helmholtz coils. The tube, which incorporates an electron gun, is filled with a low-pressure gas. The electron beam emitted by the gun appears as an illuminated circular path which can be easily observed and measured.

3. An external power supply terminal is provided on the front panel of the device.

Coil rating：130 turns each, R (Radius) = 0.150 m	Anode 200 – 500V DC
Material：Plastics (Acrylate resin)	Heater 6.3V / 1A
Size：370(W) x 255 (D) x 388 (H)	Helmholtz coil 12V DC / 2A
Weight：ca. 7 Kg	
Rating of e/m tube,　Heater：6.3V, 0.4A,　Plate voltage：500V DC, 10mA, Life：100 hrs	

3. Features

The e/m tube incorporates the following special features :

① Helium gas sealed within the tube facilitates the production of a bright, clear view of the electron beam.

② An electrode is provided for absorbing electrons after they have been emitted from the electron gun and traced their circular path. Thus, the circular tracing of the electron path is undisturbed by previously emitted electrons, contributing to more accurate measurement and extended operating life of the discharge tube.

③ The e/m tube incorporates a built-in scale for measuring the path traced by the electron beam. The graduations and numerals of the scale are illuminated by the collision of the electrons, making observation and reading even easier.

4. Principle of operation

1. Acceleration of electrons (electron gun)
   Figure 1 illustrates how the electron gun accelerates the motion of the electrons by means of the electromagnetic field.

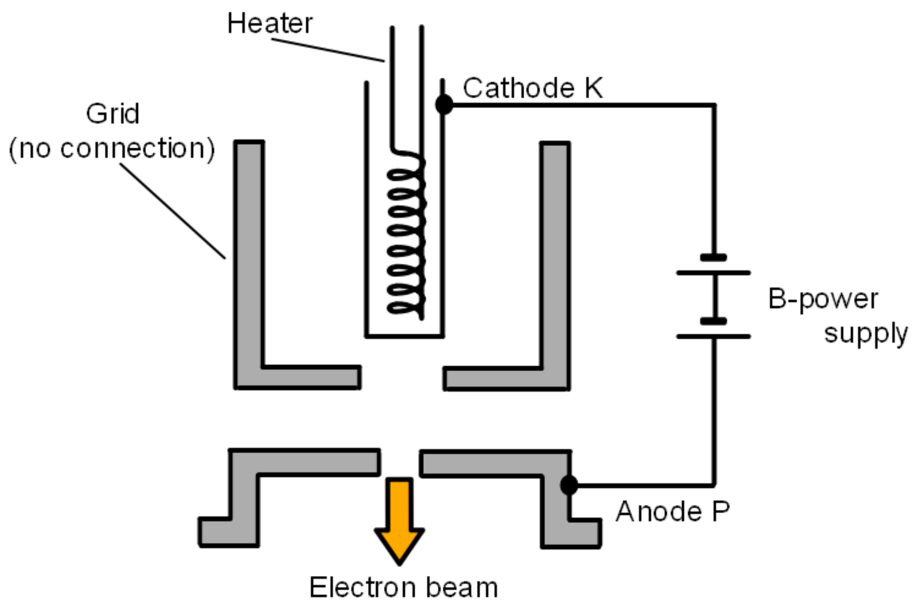


Figure 1: Electron Gun

Cathode K is heated, releasing thermions, whose motion is further accelerated by the electromagnetic field generated between Anode P and Cathode K. Under the Law of the Conservation of Energy, the velocity of the electron (m/s) when voltage V is applied at the anode can be calculated as follows (not including the initial impetus applied to the electron as it is discharged from cathode) :

$$\frac{1}{2}mv^2 = eV$$

$$v = \sqrt{\frac{2eV}{m}} \qquad \text{———— ①}$$

m [kg]: Mass of electron
e [C]: Elementary electrical charge

2. Electron motion in the magnetic field

Electrons which enter the magnetic field at a perpendicular angle move in a circular pattern with equal velocity on each side of the perpendicular plane against the magnetic field. Given the magnetic field with magnetic flux B [b/m^2], the following formula is obtained, where the velocity (v, m/s of circular motion, the radius (r) of the circular motion, and the Lorentz force becomes centripetal force :

$$evB = \frac{mv^2}{r}$$

$$eB = \frac{mv}{r} \qquad \text{———— ②}$$

In formulas ① and ② above, e/m is expressed as follows:

$$e/m = \frac{2V}{R^2B^2} \qquad \text{———— ③}$$

3. Helmholtz coil

Two circular coils of equal radius are mounted in parallel on a common axis. When an electrical current is applied to the coils, so that it flows in the same direction and strength, the uniform magnetic field is formed around the common axis between the coils. This is the underlying principle applied to the operation of this device.

According to Bio-Savart's Law, given intensity H (A/m) of magnetic field between the two coils, radius r, and current intensity I (A), the following formula is obtained:

$$H = \frac{8}{5\sqrt{5}}\,\frac{I}{R} = 0.7155 \text{ X } \frac{I}{R}$$

Accordingly, when there are N turns of wire in each coil, the intensity of the magnetic field is multiplied N times. With permeability in a vacuum, $4\pi/10^7$, intra-coil magnetic flux density is as follows:

$$B = 0.7155 \text{ X } \frac{4\pi}{10^7}$$

$$= 8.99 \text{ X } 10^{-7}\frac{NI}{R} \quad [\text{Wb/m}^2]$$

Thus, since the coils in this apparatus are constructed with 130 turns and a radius of 0.150 m, the following formula can be applied to determine B:

$$B = 7.79 \times 10^{-4} I \quad [\mathrm{Wb/m^2}]$$

5. Setting Procedures

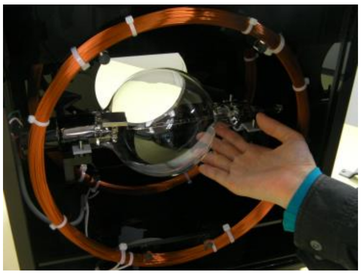
1. e/m tube setting

a) The apparatus has a back cover. Remove the back cover in order to set e/m tube. The back cover shall be put on a table beside the apparatus.

b) Connect a socket of the apparatus inside to a plug of the e/m tube carefully, notice the socket and plug connecting position.

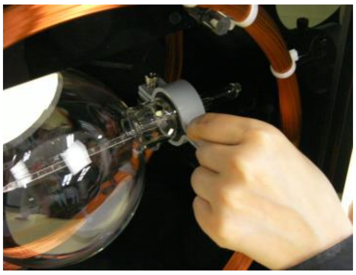
c) After connected each other, bring them back inside a body of the apparatus carefully, not to wreck the flame.

d) Put the e/m tube connected the socket on tube holder arms and set the sphere of e/m tube in the middle of arms. And turn around the e/m tube in order to adjust the correct position of plate inside which shall be upside (see photo).



e) Hold the e/m tube slightly for adjustment position in experimentation and measurement process.

f) Close the back cover.



2. Preparation

(1) Configuration

① Power supply unit, PS-2 for e/m tubes (B)

② Regulated DC power supply unit, RPS-1000N or 6 – 12V storage battery

③ DC voltmeter (500V)

④ DC ammeter, measurements up to 2A

⑤ Magnetic needle

③ and ④ above are not required when only observation is to be performed.

(2) Connecting the power supply system

① Connect a 6.3V power supply to the power terminal of the heater on the main body of the unit (either AC or DC can be used).

② Connect a 0 – 500V DC power supply to the B- power terminal of the main unit (Red terminal P is +, Black terminal is −).

<u>Note: The power supply requirements for both ＋ and − can be met by the power supply unit for e/m tubes.</u>

③ Connect the DC power supply to the coil power supply terminal on the main unit (Red terminal is ＋, Black terminal is −).

6. Experimental Procedures

1. Observation and Experimentation

(1) Circular motion of electron beam

① First, set the voltage for B-power supply and coil to the minimum level and then turn on the main power switch of the unit.

② When the cathode glows red hot, gradually raise the voltage of the B-power supply as you observe the e/m tube. The illuminated electron beam will gradually appear at just under 200V.

③ Gradually increase the voltage of the coil power supply.

The increased voltage in the coils will raise the intensity of the magnetic field until the electron beam is bent into a circular pattern.

When the path of the beam becomes circular, use a magnetic needle to check the polarity of the magnetic field formed between Helmholtz coils. This will make it possible to confirm the relation of the magnetic field with the direction of Lorentz force.

<u>Note: If the electron gun is not pointed downward, a spiral motion of the beam will be observed (see (2) below). In this case, loosen the mounting screw of the e/m tube and adjust the position of the tube unit the electron gun is in the proper orientation.</u>

(2) Spiral motion

Loosen the mounting screw of the e/m tube and slightly readjust the position of the tube. The electron beam should then assume a spiral motion. The shape of the spiral can be changed by varying the intensity of the coil current, the voltage level of the B-power supply, or the position of the e/m tube.

(3) Affect of bringing a magnet near the e/m tube

The magnetic field of a magnet is brought near the e/m tube will generate complicated patterns in the motion of the electron beam.

Caution
If the B-voltage is raised too high, the operational life of the e/m tube will be shortened. Consequently, be careful when raising the B-voltage.

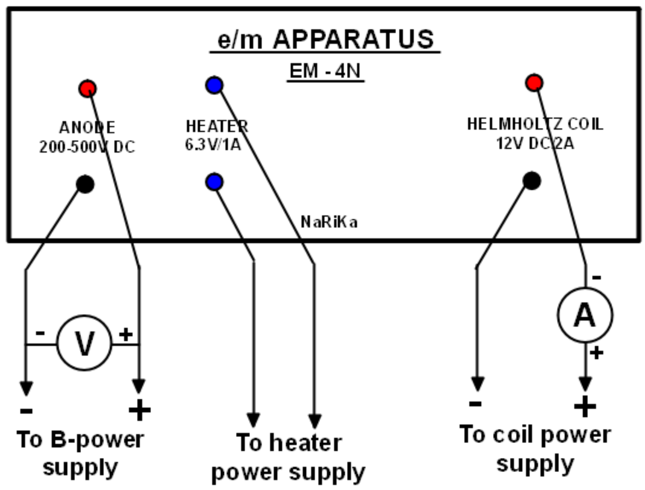
2. Measurement

(1) Setting up testing device and instruments

① Use the voltmeter and ammeter which are not connected to the power supply system and which meet the required level of accuracy for measurement.

② In order to minimize the influence of geomagnetism, use a magnetic needle to locate magnetic North and align the main unit of the device so that the face of the Helmholtz coils are parallel to the needle. This will have the effect of reducing the influence of geomagnetism on the magnetic field parallel to the coil axis.

③ Connect the power supply, voltmeter, and ammeter to the appropriate terminals of the main unit, as shown in Figure 2.



Note: The influence of geomagnetism or other sources of magnetic fields can be observed by the deflection of the circular motion of the electron beam while the main unit is rotated. The magnitude of this deflection is greater when a small current is flowing through the coils.

(2) Measurement

Set up the device as in ① to ③ above to produce a circular motion and calculate e/m by measuring the voltage (V) applied to the B-power supply, current (I) flowing through the coils, and diameter (2r) of the circle traced by the electron beam.

Example of measurement:

With B-voltage set at 300V, adjust the coil current to produce a circular path of 100mm in diameter. These values and the obtained measurement of 1.48A are applied in the following formula.

[V = 300V, I = 1.48A, r = 0.00500m]

$$e/m = \frac{2V}{r^2B^2} = \frac{2V}{(r \times 7.79 \times 10^{-4} \times I)}$$

$$= \frac{2 \times 300}{(0.05 \times 7.79 \times 10^{-4} \times 1.48)} = 1.81 \times 10^{11} \quad [C/kg]$$

[Reference] $e/m = 1.7588 \times 10^{11}$ [C/kg]

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