

## Experiment 15

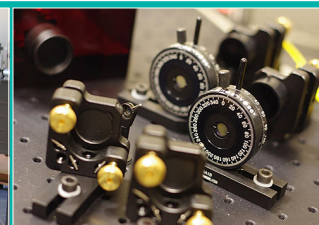
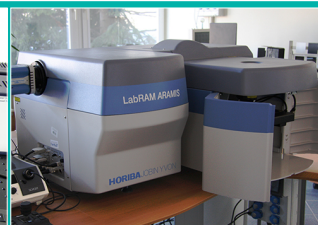
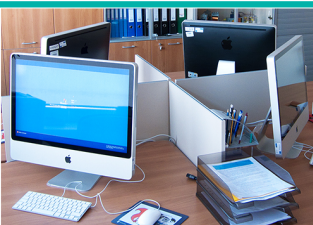
# Determining the charge to mass ratio $e/m$ of an electron



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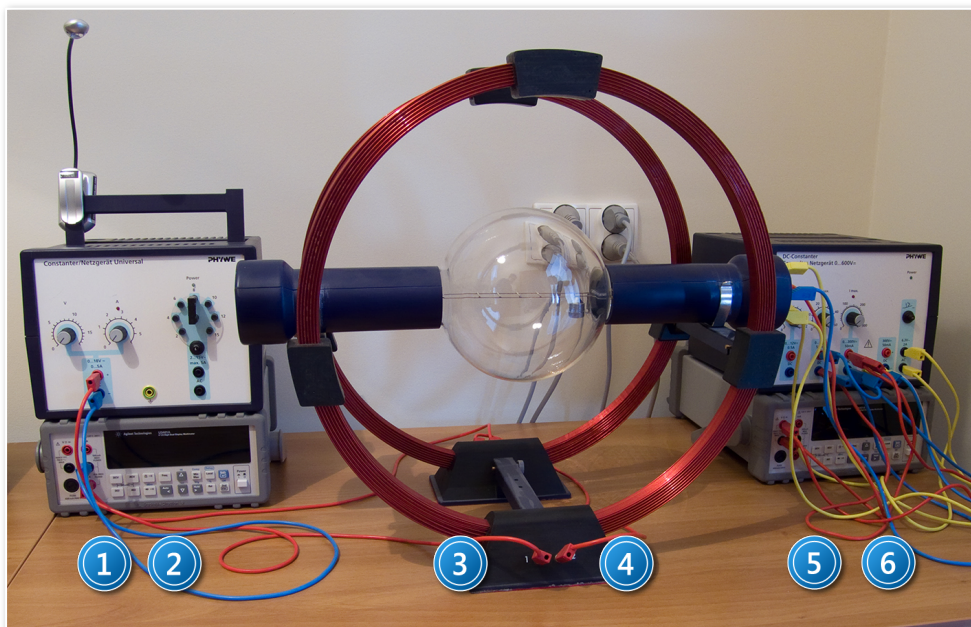


## I. Background theory.

1. Point charges in electric and magnetic fields:
  - a) characteristics of electric and magnetic fields;
  - b) motion of a charged particle in an electric and magnetic field:
    - electrostatic force,
    - potential energy of a charged particle in an electrostatic field,
    - Lorentz force;
  - c) magnetic fields induced by an electric current :
    - circular circuit,
    - solenoid,
    - Helmholtz coils;
  - d) Biot-Savart-Laplace law.
2. Methods for determining the charge to mass ratio of the electron:
  - a) focusing the electron beam in a longitudinal magnetic field;
  - b) the method of transverse fields (Thomson).
3. Construction and operation of an electron gun.
4. Experimental setup to determine the charge to mass ratio  $e/m$  by Thomson's method.
5. Argon atom:
  - a) electron configuration and energy levels;
  - b) excitation and ionisation energy;
  - c) electronic transitions in argon.
6. Elastic and inelastic collision of electrons with gas atoms.

## II. Experimental tasks.

1. Refer to the setup shown in *Picture 1*.



Picture 1. Apparatus for determining the charge to mass ratio of an electron: 1 – power supply; 2, 6 – universal multimeter; 3 – pair of Helmholtz coils; 4 – lamp with electron gun; 5 – multifunctional power unit.

2. Prepare the experimental setup for measurements.

To do this, check whether the Helmholtz coils are connected according to the diagram in *Figure 2*.

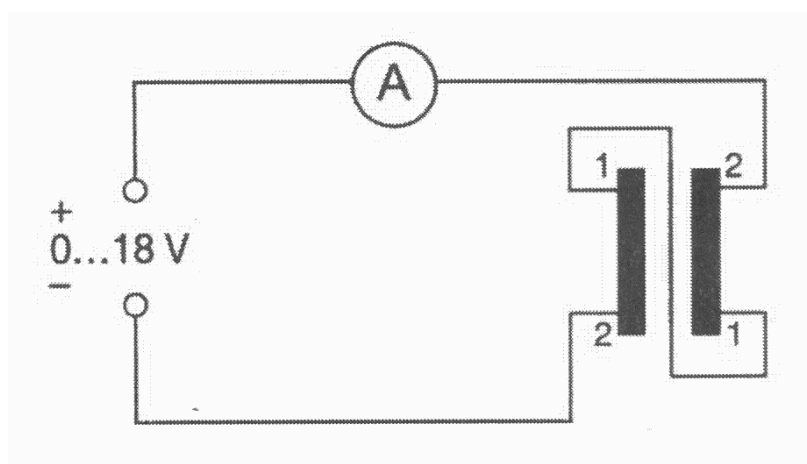


Figure 2. Helmholtz coils circuit diagram (Phywe).

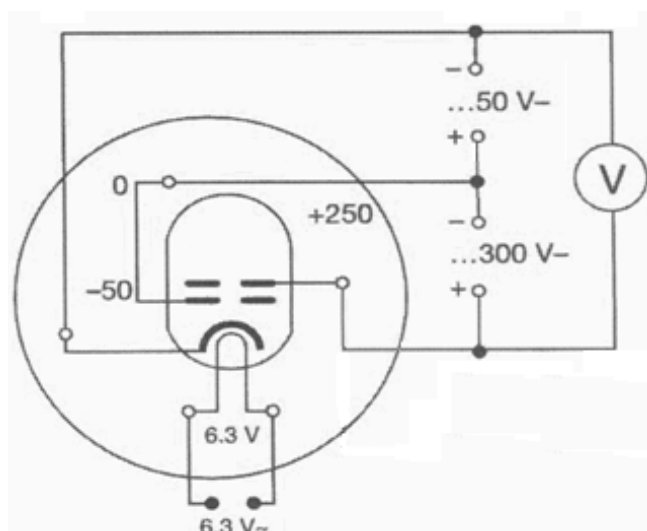


Figure 3. Electron gun circuit diagram (Phywe).

Connect the electron gun tube to the power supply according to the diagram in Figure 3.

Ensure that the voltage knobs – 50 V and 250 V Are set to position “0”.

Turn on the multifunction power unit (5 in Picture 1) and set the voltages – 50 V and 250 V respectively on the grid and anode. When you see a blue glowing electron beam appear (after a few minutes), turn on the power supply for the Helmholtz coils (1 in Picture 1).



## ATTENTION!

The maximum allowed current  $I$  through the coils is 5 A.

If the electron beam moves in a spiral rather than a circle, set the lamp to the correct position by gently turning the handle.

- Take readings of anode voltage  $U$  and current  $I$  in the Helmholtz coils to calculate the  $e/m$  ratio with the following formula:

$$\frac{e}{m} = \frac{2U}{(Br)^2} \quad .$$

To do this, adjust the voltage  $U$  in the range 100 V to 300 V in steps of 20 V. Record the Helmholtz coil current  $I$  for each voltage such that the electron beam intersects with each of the “ladder rungs” inside the lamp.

The radii of each rung successively are  $r = 0,02, 0,03, 0,04, 0,05$  m ( $\Delta r = 0,001$  m).

- Calculate the magnitude of the magnetic field induced in the coils for step II.3. for the value of the current  $I$ .

The radius of the coils is  $R = 0,02 \pm 0,002$  m; the number of turns per coil is 154.

5. Calculate the  $e/m$  ratio including uncertainties.
6. Compare the obtained value with the tabulated data.
7. Explain the blue glow of the electron beam in the lamp.

### III. Apparatus.

1. Helmholtz coil power supply.
2. Universal multimeter (ammeter).
3. A pair of Helmholtz coils.
4. Lamp with electron gun.
5. Regulated voltage power supply: 6,3 VAC; 0 – 50 VDC; 0 – 600 VDC.
6. Universal multimeter (voltmeter).

**The electron gun meets the German safety regulations of 8 January 1987 (§5(2) - RöV) on the allowed X-ray dose in an electron beam.**

### IV. Literature.

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## Appendix A

## Energy levels and transitions in argon

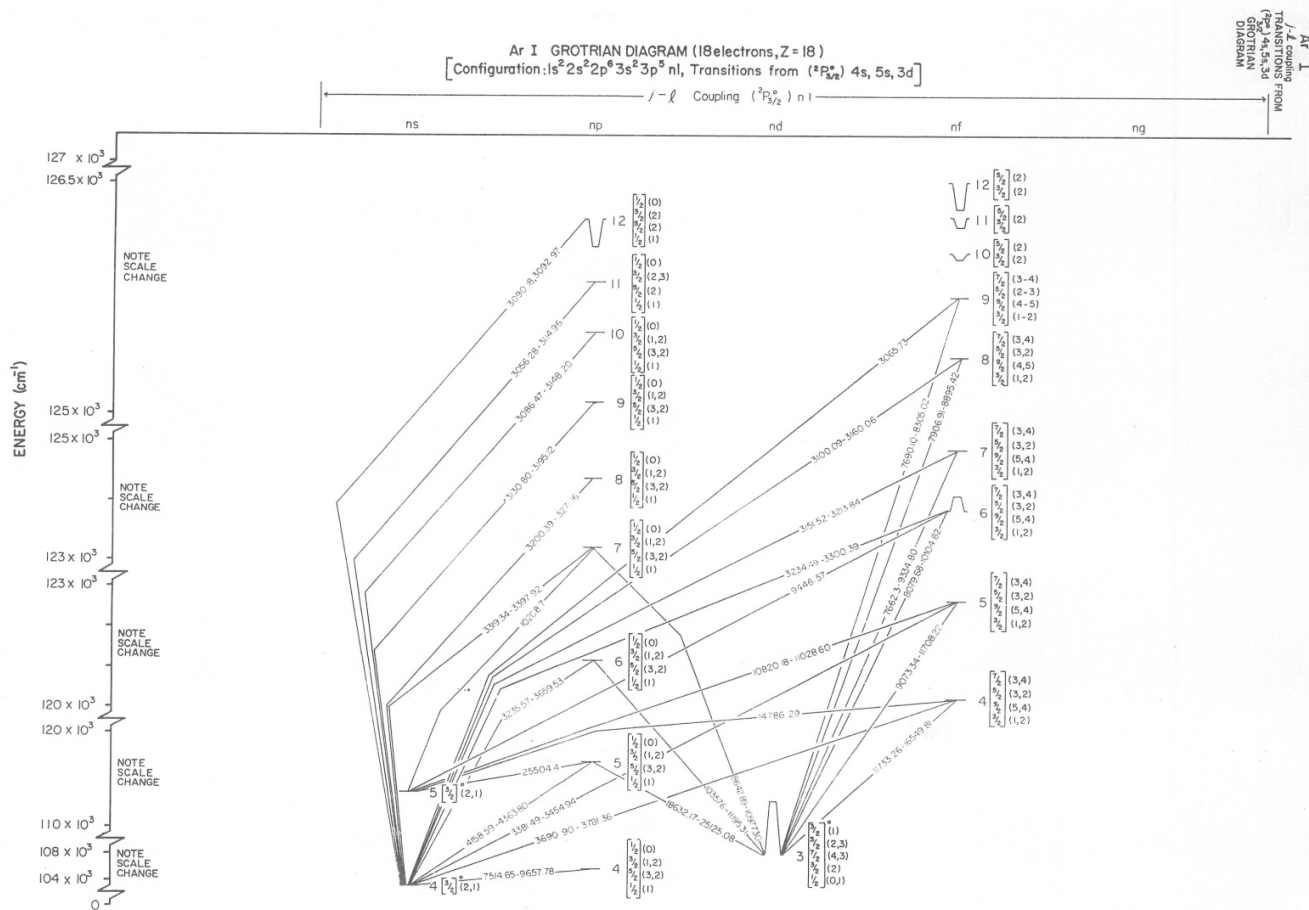


Figure 4. Energy level diagram with allowed transitions in argon.

## Appendix B

Emission spectrum of argon

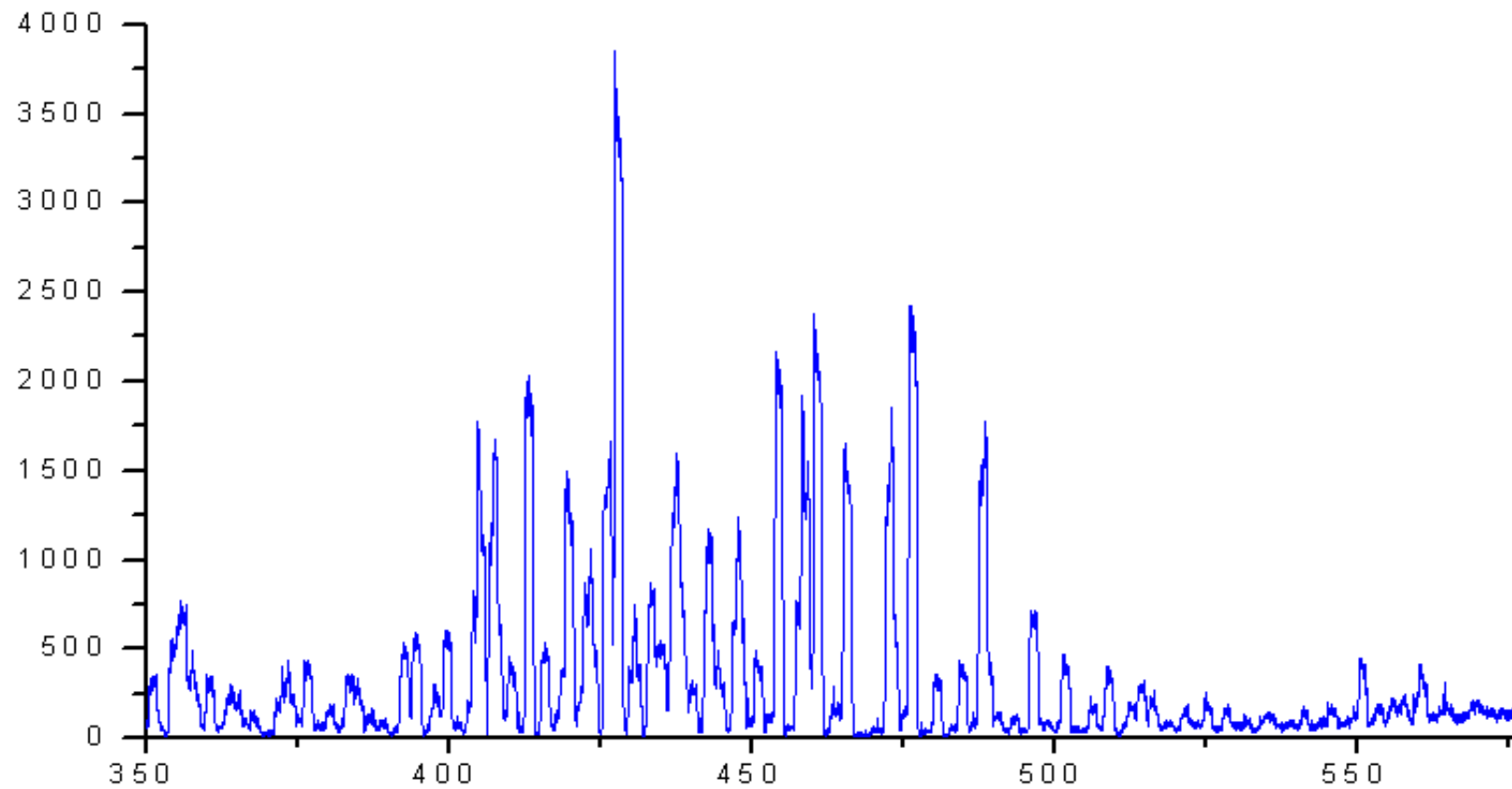


Figure 5. Emission spectrum of argon.