Experiment 312.
Determining the internal resistance of a battery

Objects of the experiment

- Measuring the terminal voltage U as a function of the current I flowing through a load resistor.
- Determining the internal resistance R_i, the open-circuit voltage U_0 and the short-circuit current I_S.
- Calculating the power P supplied as a function of the load resistance R.
- Determining the maximum power P_{max} and the associated values $R_{\max}$, $U_{\max}$ and $I_{\max}$ for the load resistance, the open-circuit voltage and the current drawn.

Apparatus

Battery case, 1x 1,5 V	1 pts.	57689
Rheostat10 Ω	1 pts.	53732
Multimeter LD Danalog 20	2 pts.	531120
Connecting leads	5 pts.	50123

Principles

The open-circuit voltage U_0 generated in a voltage source is, in general, different from the terminal voltage U measured at the terminals when a current I is drawn from the voltage source. When the maximum current that can be drawn from the voltage source, the short-circuit current I_S, flows, the terminal voltage breaks down to become zero. That means, there must be an internal resistance R_i acting in the voltage source, where part of the voltage generated drops. This resistance is called the internal resistance of the voltage source.

In the experiment, a rheostat is connected to a battery as an ohmic load for determining the internal resistance. The terminal voltage U of the battery is measured for various loads and plotted against the current I flowing through the load resistor. Under the assumption that

the internal resistance R_i is constant, a straight line is fitted to the measured values according to

$$U = U_0 - R_i \cdot I. \tag{1}$$

From the slope of the straight line, the internal resistance is determined (fig. 1). As R_i is constant, the short-circuit current is

$$I_S = \frac{U_0}{R_i}. \tag{2}$$

In a second diagram, the power supplied,

$$P = U \cdot I, \tag{3}$$

is plotted as a function of the load resistance

$$R = \frac{U}{I}. \tag{4}$$

Because of (1), (3) and (4), the power fulfils the following relation:

$$P = U_0^2 \frac{R}{(R + R_i)^2}. \tag{5}$$

The power P supplied attains its maximum when the load resistance R is equal to the internal resistance R_i, and the maximum power is

$$P_{max} = \frac{U_0^2}{4R_i} = \frac{1}{4} \cdot U_0 \cdot I_S. \tag{6}$$

At maximum power the terminal voltage corresponds to half the open-circuit voltage, i.e.

$$U_{max} = \frac{U_0}{2}, \tag{7}$$

and the current drawn is half the short-circuit current, i.e.

$$I_{max} = \frac{U_0}{2R_i} = \frac{I_S}{2}. \tag{8}$$

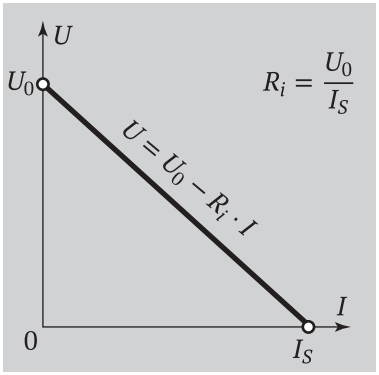

Figure 1.

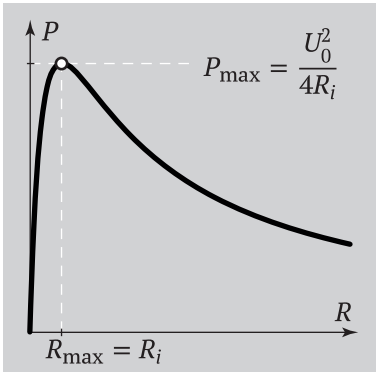

Figure 2.

Setup

The experimental setup measuring is illustrated in Fig. 3.

Note: As a voltmeter and an ammeter in the experiment should be used a ”LDanalog 20” multimeters. Type of current (AC or DC) and the operating mode (measurement of current or voltage, ranges) is selected by turning the knob switch. Before connect devices in the circuit you must select the measurement limit specified below.

Carrying out the experiment

- Disconnect the circuit (open the key).
- Assemble the circuit according to Figure 3: connect the battery case, the ammeter and the rheostat in series; however, do not close the circuit yet to spare the batteries.

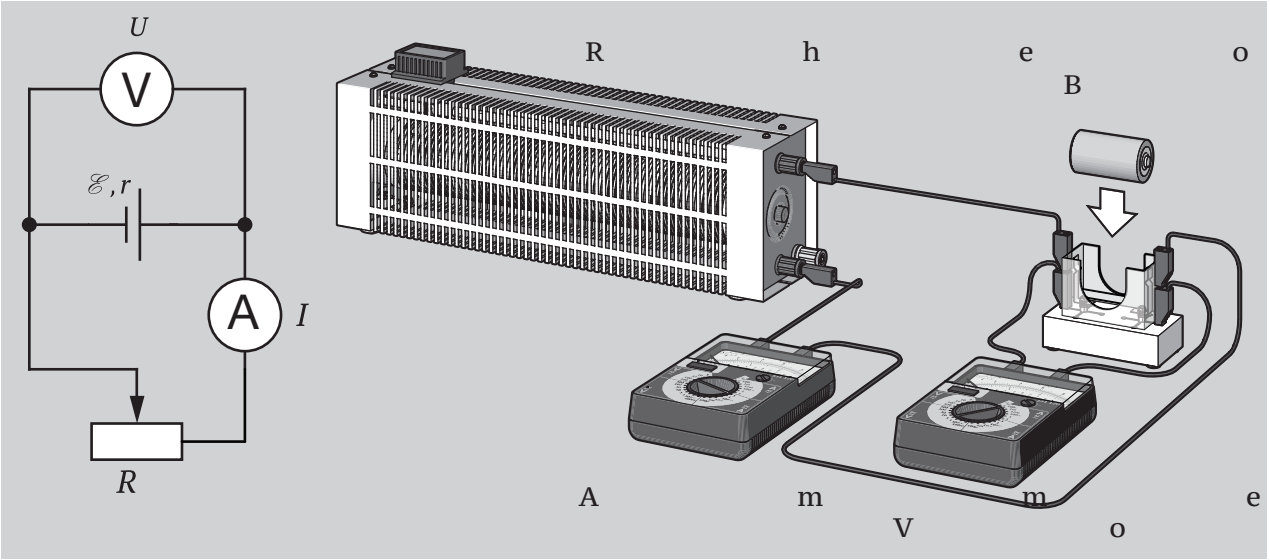

Figure 3. Experimental setup for determining the internal resistance of a battery.

- Connect the voltmeter to the sockets of the battery case (fig. 3).
- Set measurement ranges 3 V DC on voltmeter and 3 A DC on ammeter.
- Close the circuit with the key, and adjust the rheostat so that the smallest possible current flows.
- Read the current I and the voltage U, and write them down into table.

U, V	I, A	P, W	R, Ω	η
		…		

- Changing the load resistance, increase the current step by step, but quickly, up to 3 A at maximum, each time reading and taking down the current and the voltage.
- Having finished the series of measurements, interrupt the circuit.

Evaluation

1. Determining the internal resistance, the open-circuit voltage and the short-circuit current.

   Plot dependance of the voltage U from the current I. From the slope of the straight line, obtain short-circuit current I_S, open-circuit voltage U_0 and determine the internal resistance R_i.

2. Calculating the power supplied as a function of the load resistance.

   Calculate $P = U \cdot I$ supplied and the load resistance $R = U/I$ from the measured values of U and I from table. Plot dependance of the power P from the resistance R.

3. Explain your results and draw conclusions.