Student's name ____

Experiment E2

DETERMINATION OF SCALE GRADUATION MARK AND INTERNAL RESISTANCE OF GALVANOMETER

Objective: determination of scale graduation mark and internal resistance of galvanometer by shunt method.

1 EQUIPMENT

1) Galvanometer of magneto-electric system;
2) shunt P34 (0-900 Ω);
3) resistor bank MCP-60 M (0,01 Ω – 10000 Ω);
4) current source of known *emf* (accumulator or electrical element);
5) switches

2 THEORY

A voltmeter is an instrument for measuring the voltage between two points in an electric circuit. Since one is interested in measuring the voltage between two points, a voltmeter must be connected in parallel with the portion of the circuit on which the measurement is made. An ammeter is an instrument used to measure the flow of electric current in a circuit. Since one is interested in measuring the current flowing through a circuit component, the ammeter must be connected in series with the measured circuit component. Ideally, an ammeter should have zero resistance so that the current being measured is not altered. In real circuits the resistance of the ammeter should be much less than total resistance of the circuit. An ideal voltmeter has infinite resistance so that no current exists in it. In practice, this condition requires that the voltmeter have a resistance much greater than the resistance to which the voltmeter is connected in parallel.

A galvanometer can also be used as a voltmeter by adding an external resistor (shunt) in series with it. In this case, the external resistor must have a value much greater than the resistance of the galvanometer to ensure that the galvanometer does not significantly alter the voltage being measured.

Galvanometer is a sensitive measuring instrument without graduated scale. To measure current (or voltage) one has to know the graduation mark for the scale of the instrument. This value can be found either experimentally or from certificate of the instrument.

A graduation mark, denoted as C_a, is measured in amperes per graduation mark and is used to calibrate ammeters. A graduation mark for voltmeter C_v is measured in volts per graduation mark. These coefficients are related by Ohm's law

$$C_v = C_a R_g, \qquad (2.1)$$

where R_g is an internal resistance of galvanometer.

A quantity inverse to coefficient C is known as sensitivity S of a galvanometer. The less is C, the more sensitive instrument is, and vice versa. Sensitivity of galvanometer can be changed by adding an external resistance (shunt). When a galvanometer is to be used as an ammeter, the shunt resistor R_s is connected in parallel to the galvanometer.

When one is going to measure voltage, the shunt is connected in series to the galvanometer. Shunting make it possible to broaden the limits of a measurement for a given galvanometer.

The goal of this experiment is to determine the internal resistance and conversion coefficients for galvanometer by shunt method.

Since in measuring devices of magneto-electric system the pointer deviation in directly proportional to current passing through galvanometer, the coefficient C_a has constant value as well, so the current intensity I at deviation to n'th scale mark is

$$I = C_a \cdot n . \tag{2.2}$$

A diagram of the circuit designed for determination of graduation mark C_a and galvanometer's internal resistance R_g is given in Fig. 2.1. Here **G** denotes a galvanometer, E is *emf* source, R_s is shunt resistance, **R** is a set of resistors. Let us use the following notations: at the value of load resistance $R=R_1$ and shunt disconnected the value of current is I_1, at $R=R_2$ and shunt connected the value of current is I_2. By using Kirchhoff's first rule (or Ohm's law for a closed circuit) in both of cases mentioned one obtains:

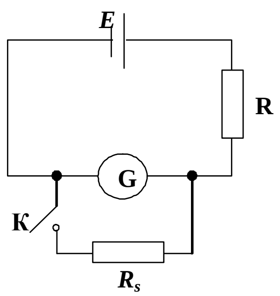

Figure 2.1

$$E = I_1\left(R_g + R_1\right) = C_a n_1\left(R_g + R_1\right), \tag{2.3}$$

$$E = I_2\left(R' + R_2\right). \tag{2.4}$$

Here resistance of connecting wires and internal resistence of *emf* source are neglected. Equivalent resistance R' of galvanometer-shunt parallel connection equals

$$R' = \frac{R_s R_g}{R_s + R_g} .$$

By Kirchhoff's first rule $I_2 = I_g + I_s$, where I_g is the current flowing through galvanometer, and I_s is that, for shunt. The ration of current values in each branch is inversely proportional to the branch's resistances, thus

$$\frac{I_g}{I_s} = \frac{R_s}{R_g} ,$$

hence

$$I_s = I_g \frac{R_g}{R_s};$$

$$I_2 = I_g + I_s = I_g\left(1 + \frac{R_g}{R_s}\right).$$

Substituting I_2 and R' in formula (2.4), we obtain ($I_2 = C_a \cdot n_2$)

$$E = C_a n_2\left(1 + \frac{R_g}{R_s}\right)\left(R_2 + \frac{R_s R_g}{R_s + R_g}\right). \tag{2.5}$$

Solving the system of equations (2.3) and (2.5) with respect to R_g and C_a, one obtains

$$R_g = \frac{R_s\left(n_1 R_1 - n_2 R_2\right)}{n_2\left(R_2 + R_s\right) - n_1 R_s}, \tag{2.6}$$

$$C_a = \frac{E}{n_1\left(R_g + R_1\right)}. \tag{2.7}$$

4 PROCEDURE AND ANALYSIS

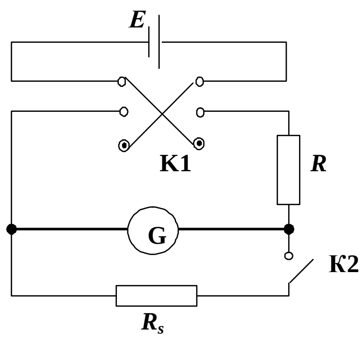

Figure 3.1 Electric diagram for galvanometer characterization

3.1 Assemble electric circuit according to diagram shown in Fig. 3.1 without connecting *emf* source. All switches must be off.

3.2 Set resistance **R** to have maximum value. Check the pointer of galvanometer matching zero of scale and tune it, if necessary.

3.3 After verification of circuit by lab assistant, connect *emf* source and start measurements.

3.4 Set switch **K1** on, then find a value R_1 of load resistance, at which galvanometer gives a 2/3-scale deflection. Note number n_1 of scale marks and value R_1 of resistance.

3.5 Using the switch **K1** change direction of current and note scale reading n'_1 for deflection in opposite side. Set switch **K1** off and maximum resistance **R**.

3.6 Connect shunt R_s by setting switch **K2** on and find a value R_2 of the load resistor at which full-scale deflection is observed on galvanometer. Note the number n_2 of scale marks in this case.

3.7 Change the current direction for the opposite by switch **K1** and note the deflection n'_2. Determine the value of shunt resistance R_s used.

3.8 Repeat the experiment two times more for any other values of shunt resistance. Fill the table 3.1 with results of measurements and calculations:

Table 3.1

	Galvanometer scale deflection at shunt disconnected			Resistances			Galvanometer scale deflection at shunt connected		
	n_1	n'_1	$n_0 = \frac{n_1 + n'_1}{2}$	R_1	R_2	R_s	n_2	n'_2	$n = \frac{n_2 + n'_2}{2}$
1.									
2.									
3.									
Mean value									

3.9 Calculate the internal resistance and graduation marks by formulae (2.6), (2.7), (2.1).

3.10 Calculate absolute and relative errors and mean values of R_g, C_a and C_v.