

## LAWS OR EQUALITY

Mukhiti Idayatolla Mukhituly

*Kazakh National Technical University, Almaty, Kazakhstan*

Email: [mukhiti\\_i@mail.ru](mailto:mukhiti_i@mail.ru)

**Abstract** There evidence which is based on the fundamental principles of the law of Kirchhoff taken as experimental. Definitions and mathematical formulas of named laws correspond to theory and practice of their application. It's offered to name Kirchhoff laws as the first and second equations.

**Keywords** circuit, voltage, potential, equality, laws

The study of any subject or discipline is based on fundamental principles: the axioms, laws and theorems that not require proof or has been reliable proved in theoretically and practically. Fundamental principles must not allow other thoughts or ambiguity except of categorically put into them. In particular, laws should be primary in consistent mental activity. Is there really question of primacy with laws of Kirchhoff in studying electrical engineering?

More than a hundred years have passed since these principles were taken as the fundamental laws of electrical circuits. May it be considered not on time to discuss? But, for any truth, especially for scientific judgment the anachronism should not be.

The first Kirchhoff's law can be proved on the basis of the Gauss theorem. This theorem is more fundamental, and has the character of universality.

By Gauss' theorem, if in node of electric-circuit there is no source of circuit charges, that means that the quantity of charges incoming in the node is equal to the number of charges out coming from the node ( Fig. 1):

$$\int_{S_{i,i}} (\bar{j} d\bar{s})_{i,i} = \int_{S_{l,k}} (\bar{j} d\bar{s})_{l,k} , \tag{1}$$

$j$  – means density of incoming charges into the node and out coming charges from the node;

$s$  – surface areas, limiting the volume of the node through which the flow of charges were made.

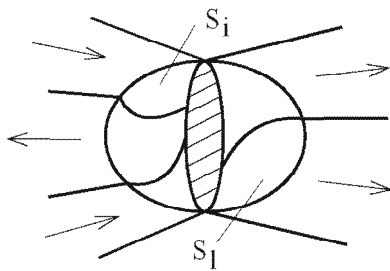


Fig.1 Conceptual illustration of a node circuit

The current (charge) density

$$\bar{j} = nq\bar{v},$$

(2)

$n$  – the concentration of the charge;

$q$  – the charge;

$v$  – charge movement rate in an electric field.

If the values of the current densities substitute into equation (1), then

$$\int_{S_{i,i}} (nq\bar{v}d\bar{s})_{i,i} = \int_{S_{l,k}} (nq\bar{v}d\bar{s})_{l,k} \tag{3}$$

Equation (3), indicating the equal number of charges incoming in the node to the quantity charge out coming from the node, is substantially the charge conservation equation.

If in equation (3) to replace the integrals by sums

$$\sum_{1}^n I_{i,i} = \sum_{1}^m I_{l,k} , \tag{4}$$

or

$$\sum_{i=1}^n I_{i,i} - \sum_{k=1}^m I_{l,k} = 0 \quad (5)$$

Hence as in many textbooks and manuals for electrical engineering (Example: [1], page 48, Formula 2.9) the formula of the first law of Kirchhoff is given

$$\sum I = 0.$$

(6)

The first law of Kirchhoff is decided to formulate as "algebraic sum of currents converging in the node of electric circuit is equal to zero", and written as formula (6). Practice shows that students often find it difficult to write the formula for a particular current, and sometimes even say that there is no current electricity in the node. This makes sense, because in formula (6) is written that the current is equal to zero and also there are no limits for sum. As a rule the sum in low limit must be specified as 0 or 1, which would mean the sum of universality. But the record of zero does not make sense and record of unit will lead to the absurd, i.e. "there is one current, but it is equal to zero." Therefore, the formula (6) of the first Kirchhoff's law in such recording is not quite mathematically and implicitly rigorous.

Taking into consideration all this, we believe that from a methodological point of view, *the first Kirchhoff's law must be recorded in the form (5) and formulated as "algebraic sum of currents directed to the node and from the node is equal to zero."*

The second law of Kirchhoff as experimentally was made, in most cases can be recorded as

$$\sum RI = \sum E \quad (7)$$

(Ex. [1], page 50, the formula 2.10) and formulating as " the algebraic sum of the voltage drops in closed loop of electrical circuit is equal to the algebraic sum of the EMF loop."

Formula (6) and (7) are logical, rather than mathematical.

Formula (7) of the second Kirchhoff's law is valid only for a closed loop with a current different from zero, i.e.,  $I \neq 0$ , which does not allow to set a lower limit sum. According to the formula (7) we can be assumed that the voltage drop across the circuit elements create only EMF of this loop, which is a wrong conclusion. Besides there are can be the following voltage sources in the loop: for example, the joint trolley line and battery energization; or parallel network and generator operation, etc.

It is possible to eliminate these logical and mathematical errors and make the formula of the second Kirchhoff's law more universal, if rely on the potential of the field circuit.

*Axiom. The circuit potentials points in the steady-state are constant and have values resulting by this state of the circuit only.*

If the potentials of the points are constant, "the potential at the point  $y$  of circuit (Fig. 2) does not depend on which way the current was moving charge from point  $x$  to point  $y$ ":

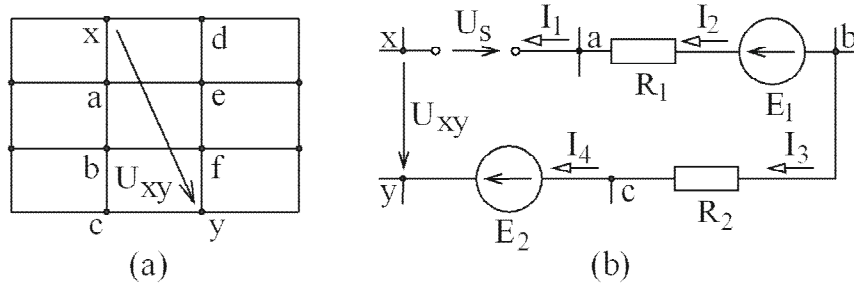


Fig.2 Topographic scheme (a) and electrical circuit section *xabcy* (b)

$$\begin{aligned}
 U_{xy} &= (\varphi_x - \varphi_a) + (\varphi_a - \varphi_b) + (\varphi_b - \varphi_c) + (\varphi_c - \varphi_y) = \\
 &= (\varphi_x - \varphi_a) + (\varphi_a - \varphi_e) + (\varphi_e - \varphi_f) + (\varphi_f - \varphi_y) = \\
 &= (\varphi_x - \varphi_d) + (\varphi_d - \varphi_e) + (\varphi_e - \varphi_a) + (\varphi_a - \varphi_b) + \\
 &+ (\varphi_b - \varphi_f) + (\varphi_f - \varphi_y) = \dots
 \end{aligned}$$

(8)

If instead of potential differences in the first equality substitute their values in accordance with Fig. 2 (b) in section circuit *xabcy*, then

$$U_{xy} = U_s - R_1 I_2 + E_1 + R_2 I_3 - E_2 \quad , \quad (9)$$

dividing and grouping of such equalities (9), bearing in mind that for the remaining sections of the connecting point *x* and point *y*, you could write the same equation, different only in the number of addends that can be written in general form as

$$U_{xy} + \sum_0^l (U_s)_i + \sum_0^m (RI)_j = \sum_0^n E_k \cdot$$

(10)

If we consider the closed loop the  $U_{xy}$  concept loses its meaning, i.e.,  $U_{xy} = 0$ , as point  $x$  and point  $y$  are merged, and the formula (10) is written as

$$\sum_0^l (U_s)_i + \sum_0^m (RI)_j = \sum_0^n E_k . \quad (11)$$

If in the loop or area there is no source voltage  $U_s$ , then formula (10) will be like this

$$U_{xy} + \sum_0^m (RI)_j = \sum_0^n E_k . \quad (12)$$

If in this area there is no current, then in the left side of formula (10) will remained  $U_{xy}$ , both float current voltage generated by EMF sources:

$$U_{xy} = \sum_0^n E_k . \quad (13)$$

If we consider a closed loop with no source of voltage, the equation (10) becomes equation (7).

All this shows that the equation (10) is more universal and rigorous than the equation (7) expressed mathematically by the second law of Kirchhoff.

On this basis we suppose that to record "*the formula for the second Kirchhoff's law as form (10)*" and formulate as "*a formula for the second Kirchhoff's law as form (10)*" and formulate as "*algebraic sum of the voltage between two points of the circuit and branch element voltage connecting these points is will be equal to the algebraic sum of EMF under review area.*"

As Kirchhoff laws are derived from the more fundamental laws [2], there is no reason to name them laws. In fact the first Kirchhoff's law establishes the quantitative ratio between the currents in the node and the second Kirchhoff's law - the quantitative ratio between the voltages and EMF voltage in the loop or on the area circuit. Therefore, we

consider that is correctly to name these principles as *"the first and second equations of Kirchhoff and mathematically express them in the form of formulas, respectively (5) and (10)."*

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## ABOUT THE AUTHOR

**Last name, first name and patronymic:** Mukhiti Idayatolla Mukhituly.

**Date of birth:** January 25, 1938.

**Place of work:** Kazakh National Technical University.

**Title:** dotsent.

**Academic degree:** candidate of technical science.

**Academic title:** dotsent.

**Address:** Apt. 28, 11, Toraigyrov Street, Almaty, Kazakhstan.

**Phone numbers:**

Home 8 (727) 265-23-26

Mobile 8 705 965 33 46

Office 8 (727) 257-70-78

**E-mail:** mukhiti\_j@mail.ru