2.2.2. DETERMINATION OF RESISTANCE BY WHEATSTONE BRIDGE METHOD

MAIN PRINCIPLE

I. Measurement of a resistance of unknown value,

II. Determination of the resistivity of the wire.

EQUIPMENT

Galvanometer, Voltage Source, Resistance Wire, Resistors of Various Values, Resistance Junction Box, Connection Cable, Micrometer, and Ruler.

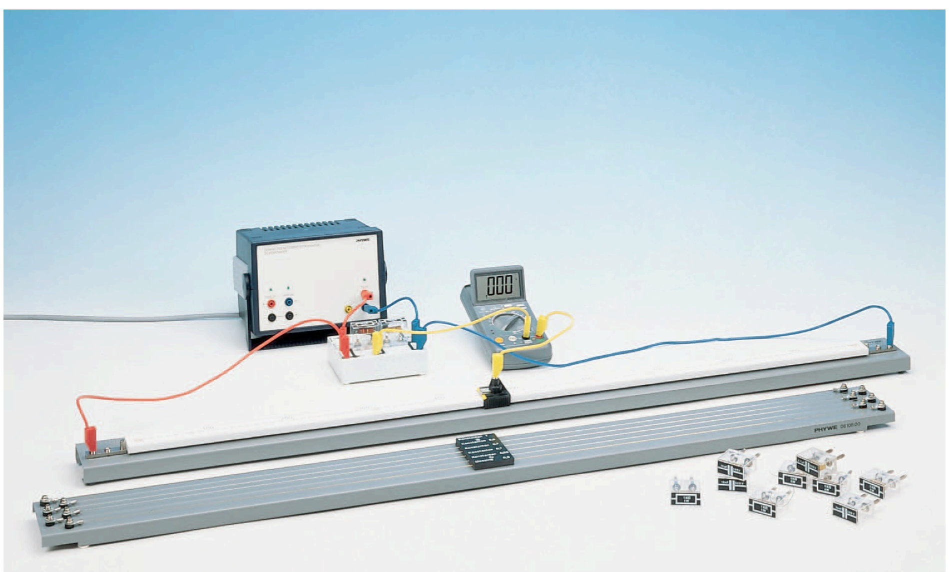

Figure 2.20: Wheatstone Bridge Experimental Setup

THEORY

OHM's LAW:

We know that when an electric potential difference is applied to the terminals of a conductor, current flows through the conductor. Now let us change the electric potential difference applied to the terminals of the same type of conductor.

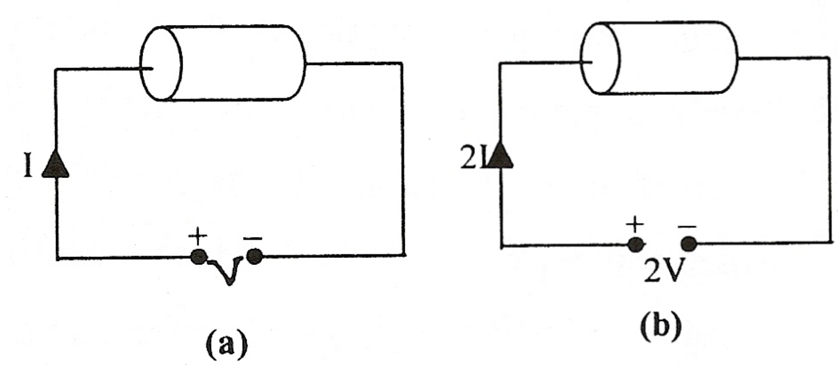

Figure 2.21: Circuits with different voltage sources a) V b) 2V

When a potential difference V is applied to the conductor in Figure 2.21-a, a current of I passes through the conductor. As seen in Figure 2.21-b, when the potential difference is made $2V$, the current intensity becomes 2I. Current changes proportionally with a potential difference. Therefore, the V/I the ratio is constant. This constant is called the resistance of the conductor and is represented by the symbol R. Therefore, the ratio between the potential difference between the terminals of a conductor and the current intensity is constant and this constant ratio is called the resistance of the conductor.

$$R = \frac{V}{I} \tag{2.17}$$

R is given by the expression. In this expression, V is $Volts$, A is $ampere$ and R is $volt/ampere$.

RESISTIVITY

The resistance of a wire conductor is directly proportional to its length and inversely proportional to its cross-section.

$$R \sim \frac{L}{I} \Rightarrow R = \rho \frac{L}{A} \tag{2.18}$$

In this expression, L is the length of the wire and A is the cross-sectional area of the wire. The coefficient of proportionality ρ depends on the material the wire is made of and is called "resistivity". In other words, resistivity refers to the resistance of a material of unit length and unit cross-section.

Here $[R] = \Omega$, $[L] = m$, $[A] = m^2$ and $[\rho] = \Omega m$ units.

WHEATSTONE BRIDGE

The circuit is given in Figure 2.23, consisting of a voltage source, four resistors, and a galvanometer, is called a “Wheatstone Bridge”. By changing the values of the resistors, it can be ensured that current does not pass through the arm where the galvanometer is located. In this case, the bridge is said to be in equilibrium. The equilibrium condition of the bridge is shown in Figure 2.22. As can be seen from the result of Figure 2.22, the equilibrium condition is suitable for calculating a resistance only with the help of other resistances.

$$\frac{R_1}{R_4} = \frac{R_2}{R_3} \tag{2.19}$$

For this purpose, the bridge is formed as in Figure 2.23.

Resistance R1 of unknown resistance is found between points A - C. In the circuit, a resistance wire placed on a 1 m ruler is used as the unknown resistance. Thus, a desired length of the wire can be selected.

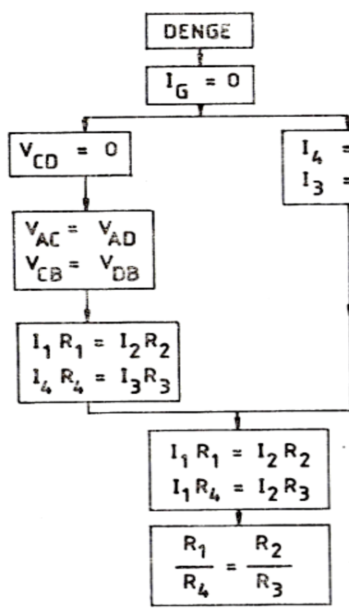

Figure 2.22

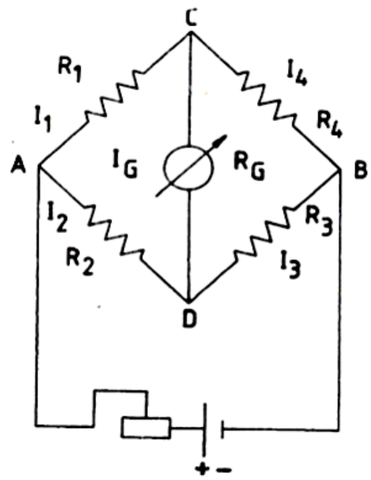

Figure 2.23

Between points A and B there is a resistance wire stretched on the ruler. By sliding the slider D on the wire, the lengths L_2 and L_3 of resistors R_2 and R_3 can be changed. The relation between these lengths and resistances is found in relation (2.18) as,

$$R_2 = \rho \frac{L_2}{A}, R_3 = \rho \frac{L_3}{A} \tag{2.20}$$

Since,

$$\frac{R_2}{R_3} = \frac{L_2}{L_3} \tag{2.21}$$

there is no need to calculate the resistances separately. It is sufficient to measure the lengths. Between points $C - B$ there is a resistor box whose value can be changed gradually. Therefore, R_4 can be read directly. From relations (2.19) and (2.21),

$$\frac{R_1}{R_4} = \frac{R_2}{R_3} = \frac{L_2}{L_3} \Rightarrow R_1 = R_4 \frac{L_2}{L_3} \tag{2.22}$$

unknown resistance R_1 is calculated with the help of lengths L_2, L_3 and resistance R_4.

SETUP AND PROCEDURE

1. Take R_1, R_4 as ($82\ k\Omega, 100\ k\Omega$); ($4.7\ k\Omega, 10\ k\Omega$); ($330\ \Omega, 150\ \Omega$) and find the values of L_2, L_3 at the point where the current is zero with the slider D and write them to Table 2.6.

Table 2.6

$R_1\ (k\Omega)$	$R_4\ (k\Omega)$	$L_2\ (cm)$	$L_3\ (cm)$	$\frac{R_1}{R_4}$	$\frac{L_2}{L_3}$

2. The circuit in Figure 2.24 is established. Set up the circuit with CuNi (constantan) resistance wires with diameters $d_1 = 1\ mm$, $d_2 = 0.7\ mm$, $d_3 = 0.5\ mm$, $d_4 = 0.35\ mm$ respectively as R_1 wire in the circuit diagram.

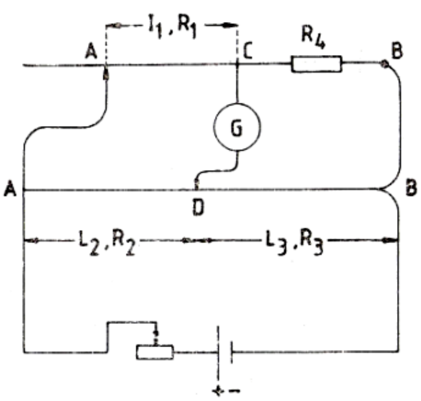

Figure 2.24

3. With the help of the D slider, the ammeter is adjusted until zero current passes through it. This condition is called a system in equilibrium. After equilibrium is achieved for various diameters, the lengths L_2, L_3 are read and processed in Table 2.6.

4. Draw the graph of $R(d)$ with the help of Table 2.6. Take a point of the line you found on the graph.

$R =$ .... Ω , $d =$ .... mm

Using the R, d values you found, find the resistivity ρ from the formula below.

$$\rho = \frac{RA}{L} = \frac{R\pi d^2}{4L} = \ldots\ldots\ldots\ldots\ldots\ldots \, \Omega cm$$

Table 2.7

$d\ (mm)$	$L_1\ (cm)$	$L_2\ (cm)$	$R_3\ (\Omega)$	$R_3\ (\Omega)$
1				
0.7				
0.5				
0.35				

For $d_1 \rightarrow R_1 = R_4 \frac{L_2}{L_3} = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots \, \Omega$

For $d_2 \rightarrow R_1 = R_4 \frac{L_2}{L_3} = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots \, \Omega$

For $d_3 \rightarrow R_1 = R_4 \frac{L_2}{L_3} = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots \, \Omega$

For $d_4 \rightarrow R_1 = R_4 \frac{L_2}{L_3} = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots \, \Omega$

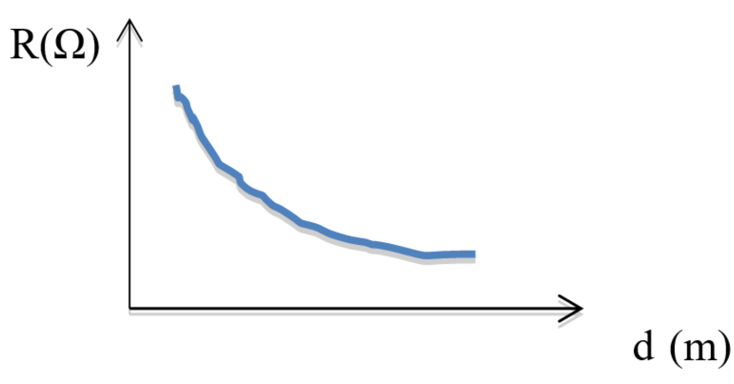

Figure 2.25

5. Take a brass wire with a diameter of $d = 0.5\ mm$ as resistance R_1 and use the slider D in the circuit to make the current zero. Calculate the resistance and resistivity of the brass wire.

$R = \ldots\ldots\ldots\ldots\ldots\ldots \, \Omega,\ \rho \ldots\ldots\ldots\ldots\ldots\ldots \, \Omega cm$