Principles of Physics II (PHY112)

Lab

Experiment no: 3

Name of the experiment: Determination of the resistance of a wire and the specific resistance of its material by using a meter bridge

Theory

Meter-bridge is an apparatus which consists of a wire of uniform cross-section and one meter length. The wire has significant resistance. By using this apparatus an unknown resistance can be measured by using a resistor of known resistance and applying the principle of 'Wheatstone Bridge'.

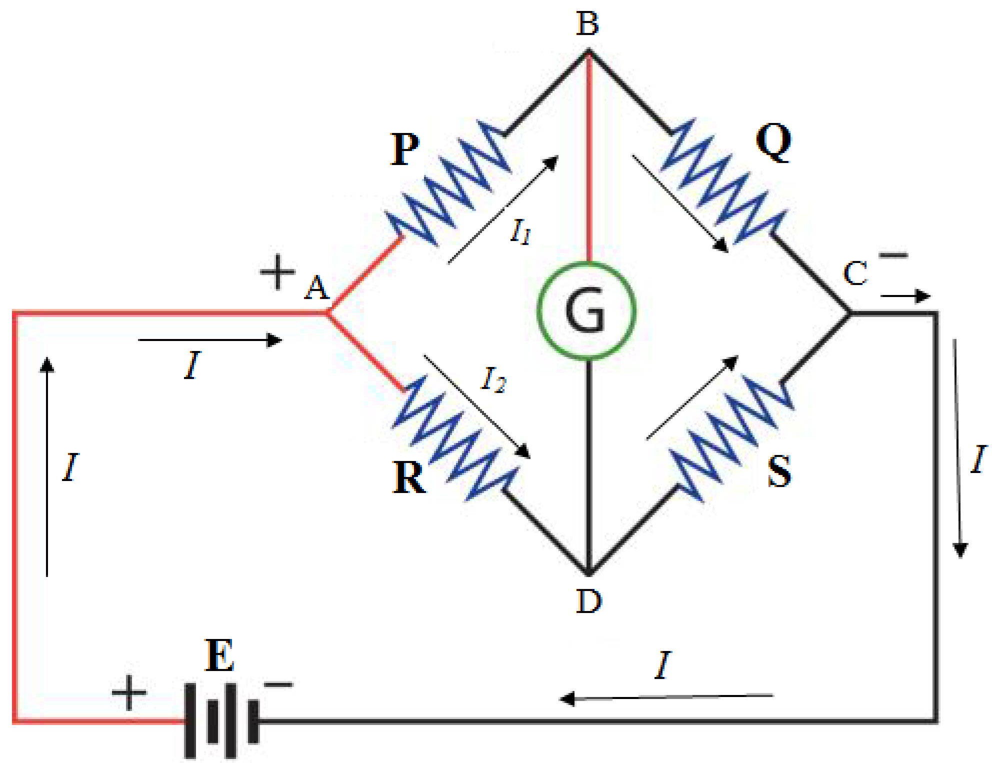

Figure 1: A Wheatstone bridge

In a Wheatstone bridge, four resistors (of resistances P, Q, S & R in Figure 1) are connected in a cyclic way. The first end of the first resistor is connected to the last end of the last one to form a closed circuit. A cell (of electromotive force E in Figure 1) is connected between two opposite junctions of the cyclic combination of the four resistors. A galvanometer (G in Figure 1) is connected between rests of its two junctions.

See Figure 1. A current I is generated by the battery. When it reaches the junction A, it gets divided into two different flows: I_1 and I_2. The magnitude and the direction of the current passing through the galvanometer (G) depend on the values of the four resistances, i.e. P, Q, R & S. If the resistances satisfy a certain condition then no current passes through the galvanometer. When it happens the Wheatstone bridge is in equilibrium condition. Now, we are going to derive the equilibrium condition of Wheatstone bridge.

Suppose, the electric potentials of the nodes A, B, C and D are V_A, V_B, V_C and V_D respectively. If there is no current passing through the galvanometer then the current I_1 will pass through Q after reaching the node B and the current I_2 will pass through S after reaching the node D.

According to Ohm's law at a certain temperature the current (I) passing through a conductor is directly proportional to the potential difference (ΔV) between the two ends of the conductor, i.e. $I \propto \Delta V$. Here, the constant of proportionality is the conductance (=1/resistance) of the conductor. If R is the resistance of the conductor then $I = \Delta V / R \Rightarrow \Delta V = IR$

When no current passes through the galvanometer, then by applying Ohm's law for the four resistors of Figure 1, we find that,

$$V_A - V_B = I_1 P$$

$$V_B - V_C = I_1 Q$$

$$V_A - V_D = I_2 R$$

$$V_D - V_C = I_2 S$$

By dividing first equation by the second and the third equation by the fourth we get,

$$\frac{V_A - V_B}{V_B - V_C} = \frac{P}{Q} \text{ and } \frac{V_A - V_D}{V_D - V_C} = \frac{R}{S}$$

Since, no current passes through the Galvanometer,

$$V_B - V_D = 0 \times \text{Galvanometer's resistance} \Rightarrow V_B = V_D$$

Therefore, the two above mentioned ratios are equal.

$$\boxed{\frac{P}{Q} = \frac{R}{S}}$$

Figure 2 shows a meter bridge. Both ends of a Nichrome wire of one meter length, having uniform cross section are connected to metal plates. They represent the A and C junctions of the Wheatstone bridge of Figure 1. Metal plates are good conductors whose resistances are significantly smaller than the nichrome wire. Between the pieces of metal plates, which are connected to the nichrome wire, there is another piece metal plate separated from the previous two. It represents the junction B. The junction B is connected with a galvanometer by means of a copper wire. Another end of the Galvanometer is connected with a jockey. We can make contact between the jockey and any point on the meter bridge's nichrome wire. This point of contact represents the junction D.

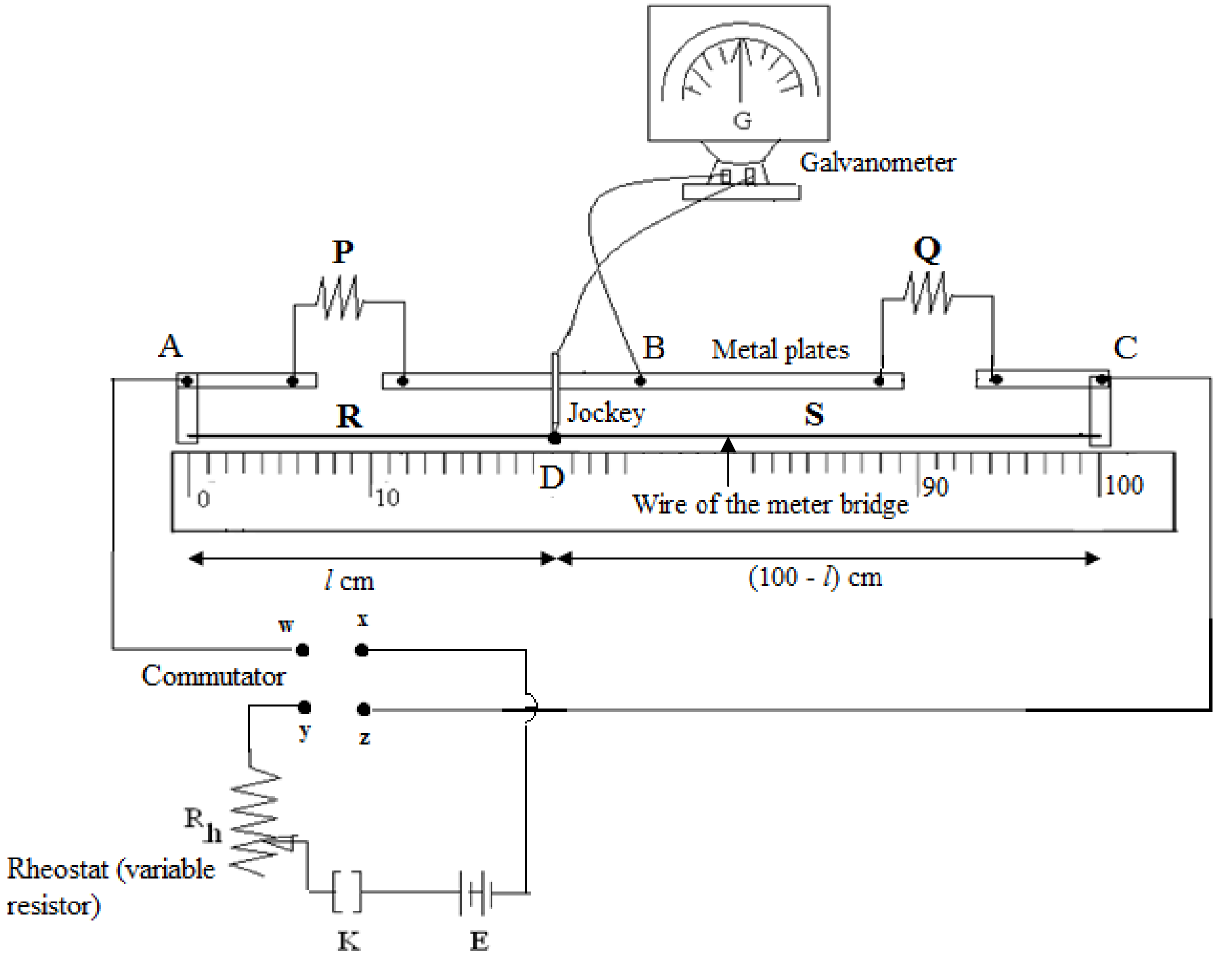

Figure 2: A meter bridge connected to the other elements to construct a Wheatstone bridge network

Two resistors, which may be resistance boxes and/or wires, P and Q fill the gap between (A, B) and (B, C). Resistance of the segment of nichrome wire between point D and the junction A represents the resistance R and the resistance of the segment of nichrome wire between D and the junction C represents the resistance S. A and C are connected with two diagonal terminals (w & x in Figure 2) of a commutator. The other two diagonal terminals (x & y in Figure 2) of the commutator are connected with a series combination of a voltage source of electromotive force E, a key (K) and a rheostat (R_h) to complete the Wheatstone network. Rheostat is a resistor of variable resistance. We can change its resistance, hence the amount of the current through the circuit. By using the commutator we can change the direction of the current. Left and right ends of the nichrome wire coincide with the zero and hundred marks of a meter scale respectively.

We can vary the values of R and S by making contact between the jockey and the meter bridge's nichrome wire on different points. We have to find out a point where the deflection of the galvanometer is zero to make sure that no current passes through the galvanometer. Then the equilibrium condition of the Wheatstone bridge is established. We call that point on the meter bridge's wire is null point. If D is such a null point, distances of D from the left and right ends of the wire are *l* cm and (100 -*l*) cm respectively. Let the resistance per unit length of the meter bridge's nichrome wire is σ Ohm/cm. Therefore, $R = l\sigma$ Ohm and $S = (100 - l)\sigma$ Ohm.

According to the equilibrium condition of the Wheatstone bridge we can write:

$$\frac{P}{Q} = \frac{l\sigma}{(100 - l)\sigma} = \frac{l}{100 - l} \quad \ldots\ldots\ldots\ldots \quad (1)$$

If anyone of the values of P and Q is known to us we can find out the unknown one by using this formula. If you have already performed experiment 2, you know that due to a special type of systematic error, called 'end error', the above mentioned equation should be modified. However, in this experiment we are assuming that our meter bridge is free from end-errors.

In this experiment we are given a piece of wire of unknown resistance *X*. We have to determine *X* by using a resistance box, whose resistance, *R* is known to us.

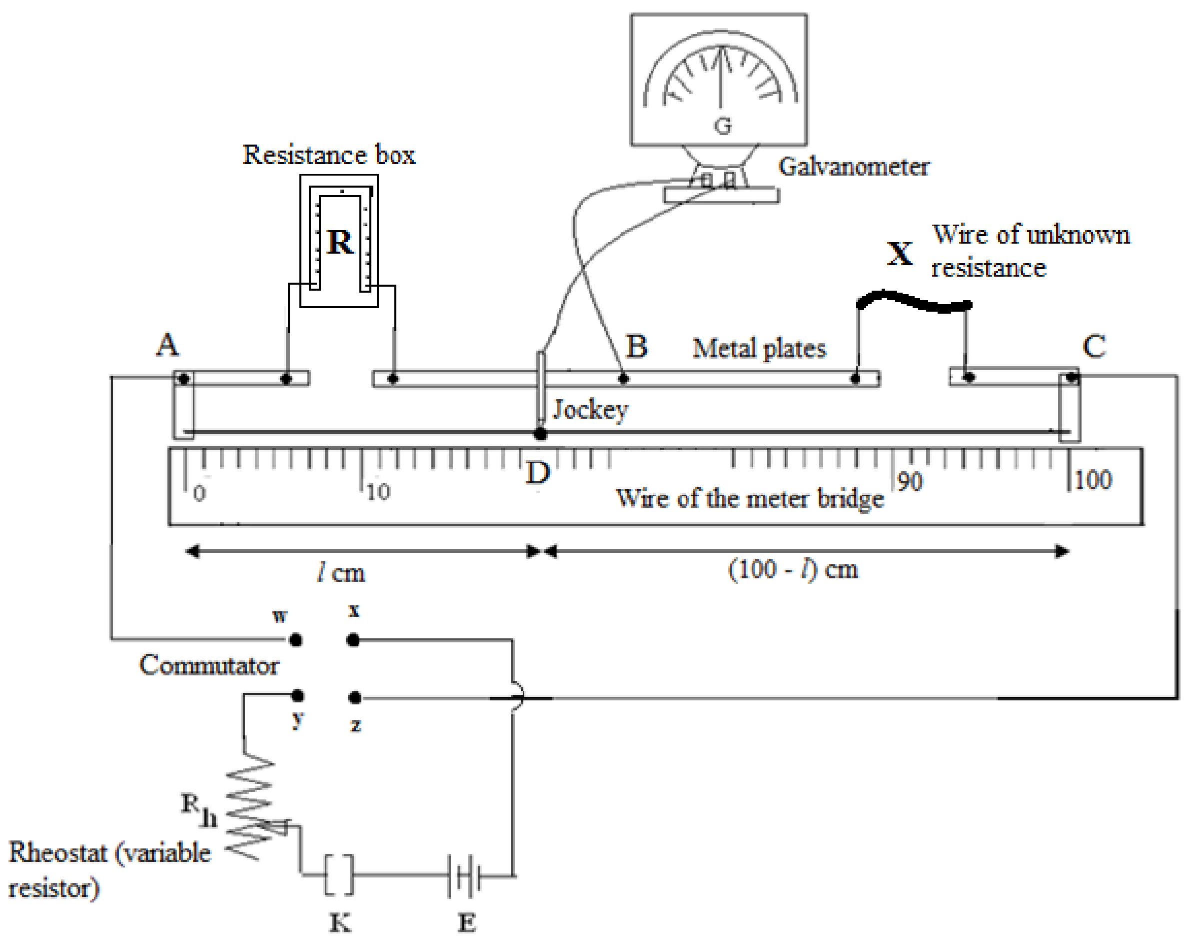

Figure 3: Arrangement of the experiment.

See Figure 3. Say, the resistance of the resistance box is *R*. I would like to remind you that we are redefining *R*. So do not get confused with the *R* shown in Figure 2. The resistance box is connected in the left gap of the meter bridge connecting the junctions A & B. The wire of unknown resistance is connected in the right gap of the meter bridge connecting the junctions B & C. If D is the null point of the galvanometer found *l* cm away from the left end of the meter bridge's wire then we can write:

$$\frac{R}{X} = \frac{l}{100-l} \Rightarrow \boxed{X = \frac{(100-l)}{l}R} \qquad (5)$$

Later, we swap R and X, i.e., X is connected in the left gap and the R is connected in the right gap of the meter bridge. Suppose, now the null point is found at a l' distance away from the left end of the meter bridge's wire. Hence we can write:

$$\frac{X}{R} = \frac{l'}{100-l'} \Rightarrow \boxed{X = \frac{l'}{100-l'}R} \qquad (6)$$

We know that, at a certain temperature the resistance of a conductor is directly proportional to its length and inversely proportional to its area of cross-section. If *L* is the length of the wire and *A* is the area of its cross-section, then at a certain temperature its resistance, $X \propto \frac{L}{A} \Rightarrow X = \rho\frac{L}{A}$

Here, ρ is the constant of proportionality which depends on the material- the wire consists of and the temperature. It is called to be the 'specific resistance' of the material-the wire consists of.

$$\boxed{\rho = \frac{AX}{L} = \frac{\pi d^2 X}{4L}} \qquad (7)$$

Here, *d* is the diameter of the cross-section of the wire.

At a certain temperature the resistance of a piece of a body of 1 unit area of cross-section and 1 unit length is called to be the resistance of the material of that body at that temperature.

Apparatus

Meter-bridge, DC power source, a Resistance box (*R*), Rheostat, Commutator, Galvanometer, copper wires, wire of unknown resistance (*X*).

Procedure

1) Construct the circuit as shown in the Figure 3.
2) Put the plugs in the commutator connecting (w, y) and (x, z). Turn on the key, *K* and allow a small amount of current to flow through the rheostat. You will see the applied voltage and current in the display box of the DC voltage source.
3) Make a contact between the jockey and the meter bridge's wire near the zero mark of the meter scale and notice the deflection of the galvanometer's pointer. Make another contact between the jockey and the meter bridge's wire near the hundred mark of the scale. If you find that the

deflection of the galvanometer's pointer is now to the opposite direction of the previous one then the system is ready to perform the experiment.

4) Choose a value of R. Find out the null point of the galvanometer. Take the reading of the length between the left end of the meter-bridge's wire and the null point. This is the value of l corresponding to the chosen value of R for direct current when (w, y) and (x, z) are connected. Repeat it again for the indirect current when (w, x) and (y, z) are connected and find the value of l corresponding to R for reverse current. Take their average and write down it in the data table as l which corresponds to R.
5) Repeat step 4 for different values of R and find the corresponding l.
6) Find out the value of the resistance of the wire, X for every record by using the equation (5).
7) Swap R and X, i.e., connect the resistance box in the right gap and the wire of unknown resistance in the left gap of the meter bridge.
8) Repeat step 4 and 5. Now, you will find l' instead of l.
9) Find out the value of the resistance of the wire, X for every record by using the equation (6).
10) Workout the average value of X.
11) Measure the length of the wire.
12) Measure the diameter, d of the wire using a screw gauge.
13) Calculate the specific resistance of the material of the wire at the room temperature.

Read carefully and follow the following instructions:

- **Please READ the theory carefully, TAKE printout of the 'Questions on Theory' and ANSWER the questions in the specified space BEFORE you go to the lab class.**

- **To get full marks for the 'Questions on Theory' portion, you must answer ALL of these questions CORRECTLY and with PROPER UNDERSTANDING, BEFORE you go to the lab class. However, to ATTEND the lab class you are REQUIRED to answer AT LEAST the questions with asterisk mark.**

- **Write down your NAME, ID, THEORY SECTION, GROUP, DATE, EXPERIMENT NO AND NAME OF THE EXPERIMENT on the top of the first paper.**

- **If you face difficulties to understand the theory, please meet us BEFORE the lab class. However, you must read the theory first.**

- **DO NOT PLAGIARIZE. Plagiarism will bring ZERO marks in this WHOLE EXPERIMENT. Be sure that you have understood the questions and the answers what you have written, and all of these are your own works. You WILL BE asked questions on these tasks in the class. If you plagiarize for more than once, WHOLE lab marks will be ZERO.**

- **After entering the class, please submit this portion before you start the experiment.**

Name: ______________________ ID: ______________ Sec: ___ Group: __ Date: __________

Experiment no: ___

Name of the Experiment: ____

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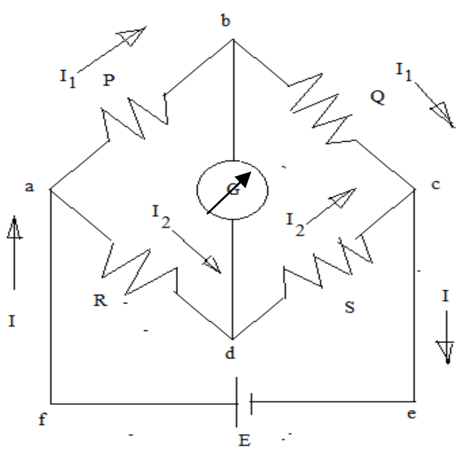
Questions on theory (all diagrams should be drawn by using a pencil and a scale)

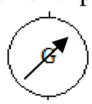
*1) Draw Wheatstone bridge diagram. [0.5]

Ans:



2) See the figure shown above. Derive the equilibrium condition of Wheatstone bridge by applying Kirchhoff's loop-voltage law around the loops abda and bcdb. [1]

Ans:

*3) Draw the arrangement of this experiment. You may denote the galvanometer, resistances of the resistance box and the wire by 

and  symbols. You can omit the meter scale but make it neat and clean and use a pencil and a scale. [0.5]

Ans:

*4) When the resistance box is in the left gap and the wire of unknown resistance is on the right gap derive the equation for the equilibrium condition for Meter Bridge. [0.5]

Ans:

*5) What will be the equilibrium condition of the meter bridge, when the resistance box is on the right side and the wire is on the left side? [0.5]

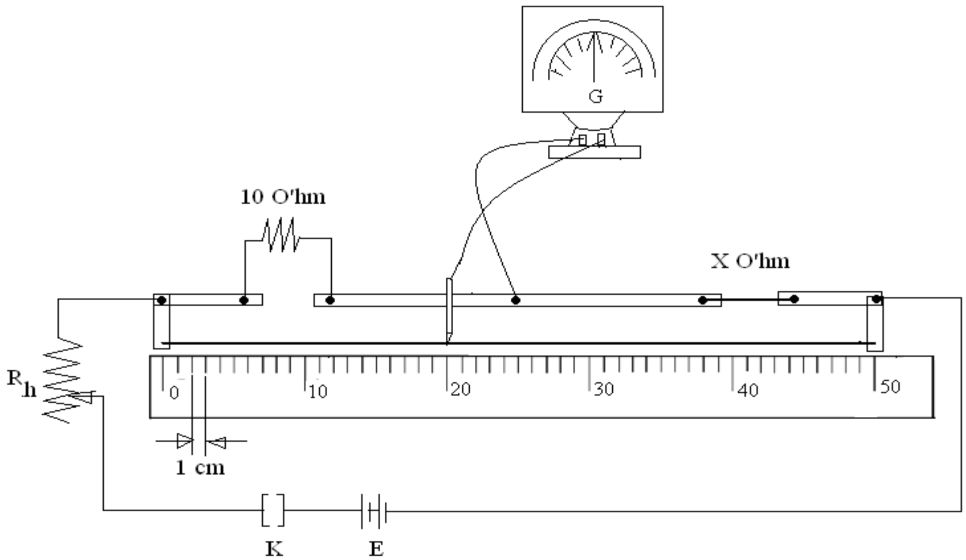
Ans:

*6) Define the specific resistance of the material of a body. [0.5]

Ans:

7) See Figure 3. Which will direction the current flow, if (w, x) & (y, z) are connected? Which direction will it flow, if (w, y) & (z, x) are connected? [0.5]

Ans:



8) In the above figure you see a semi-meter bridge (the length of the wire of this bridge is 50 cm). The arrangement of the system is almost same (only commutator is not used here) as that of the experiment what you are going to do. Now find out the value of *X*. [1]

Ans:

- **Draw the data table(s) and write down the variables to be measured shown below (in the 'Data' section), using pencil and ruler BEFORE you go to the lab class.**

- **Write down your NAME and ID on the top of the page.**
- **This part should be separated from your Answers of "Questions on Theory" part.**
- **Keep it with yourself after coming to the lab.**

Data

Table: Data for the calculations of the resistance

Known resistance R in Ω	Balance points in cm (X on the right)				Balance points in cm (X on the left)			
	Direct	Reverse	Mean (l)	**X in Ω**	Direct	Reverse	Mean (l')	**X in Ω**

Length of the wire, *L*:

Diameter of the wire, *d*:

$d_1 =$ $d_2 =$ $d_3 =$

Temperature =

- **READ the PROCEDURE carefully and perform the experiment by YOURSELVES. If you need help to understand any specific point draw attention of the instructors.**
- **DO NOT PLAGIARIZE data from other group and/or DO NOT hand in your data to other group. It will bring ZERO mark in this experiment. Repetition of such activities will bring zero mark for the whole lab.**
- **Perform calculations by following the PROCEDURE . Show every step in the Calculations section.**
- **Write down the final result(s)**

Calculations

Results:

- **TAKE printout of the ‘Questions for Discussions’ BEFORE you go to the lab class. Keep this printout with you during the experiment. ANSWER the questions in the specified space AFTER you have performed the experiment.**
- **Attach Data, Calculations, Results and the Answers of ‘Questions for Discussions’ parts to your previously submitted Answers of ‘Questions on Theory’ part to make the whole lab report.**
- **Finally, submit the lab report before you leave the lab.**

Name: ___________________________ ID: ___________________

Questions for Discussions

1) Had you made the end corrections of the meter bridge before you performed the experiment? How should the equation (1) be modified to make end corrections? [0.5]

Ans:

2) On what factors does the specific resistance depend? [0.5]

Ans:

3) Why is it advantageous to use the key K? Why should it be kept open while taking the measurements and performing other calculations, after you detect the null point? [0.5]

Ans:

4) The meter bridge's wire should be made of a material of low thermal coefficient of resistivity. It means that the specific resistance of the wire's material should not vary much with temperature. Explain why. [0.5]

Ans: