Principles of Physics II (PHY112)

Lab

Experiment no: 2

Name of the experiment: Determination of the end correction of 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'.

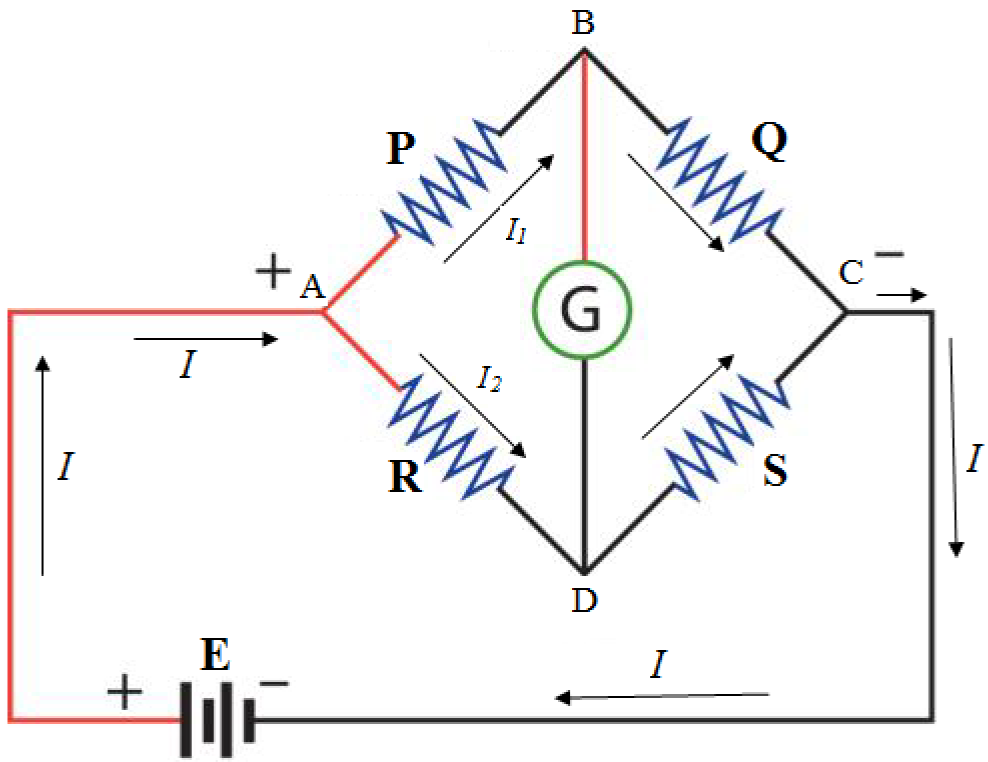


Figure 1: A Wheatstone bridge

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.

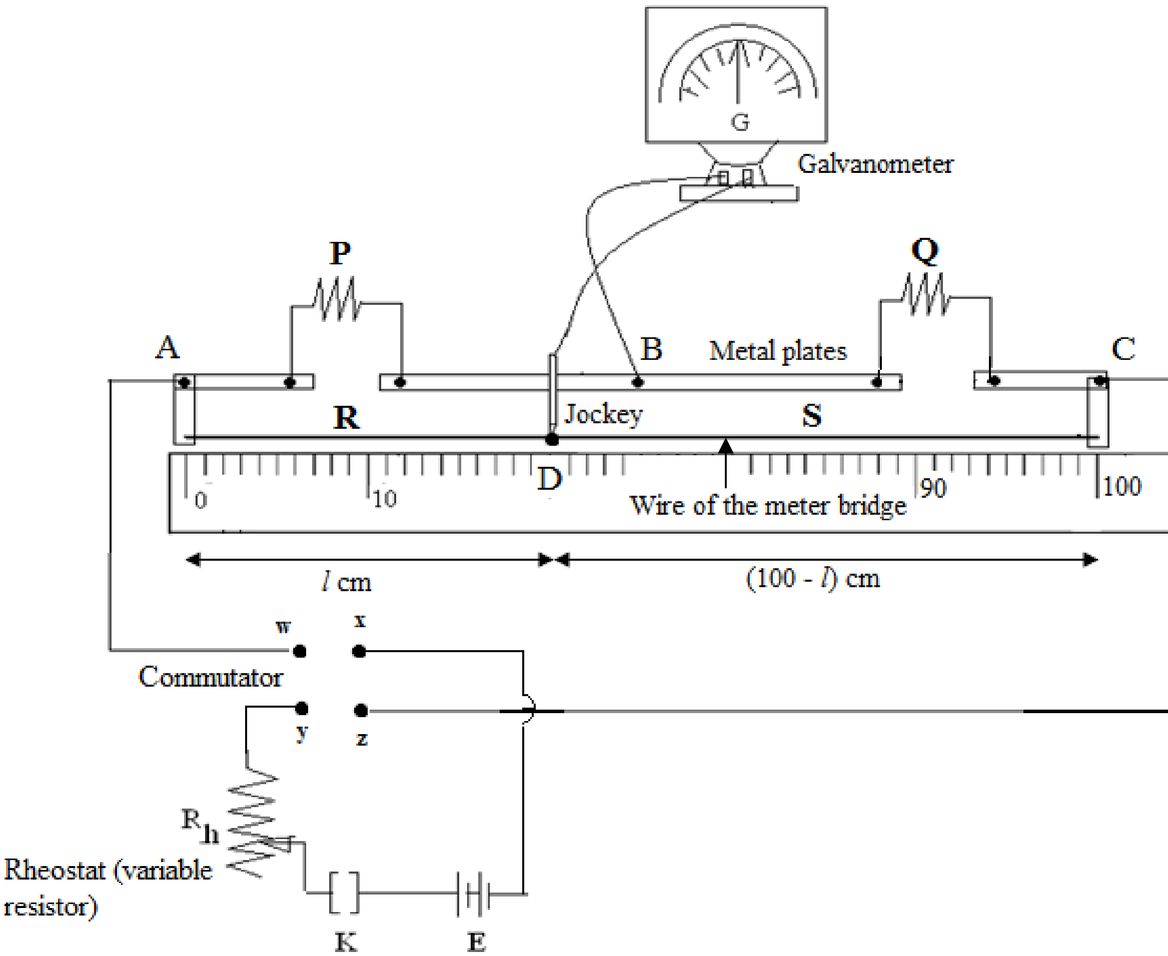


Figure 2: A meter bridge connected to the other elements to construct a Wheatstone bridge network

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:

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

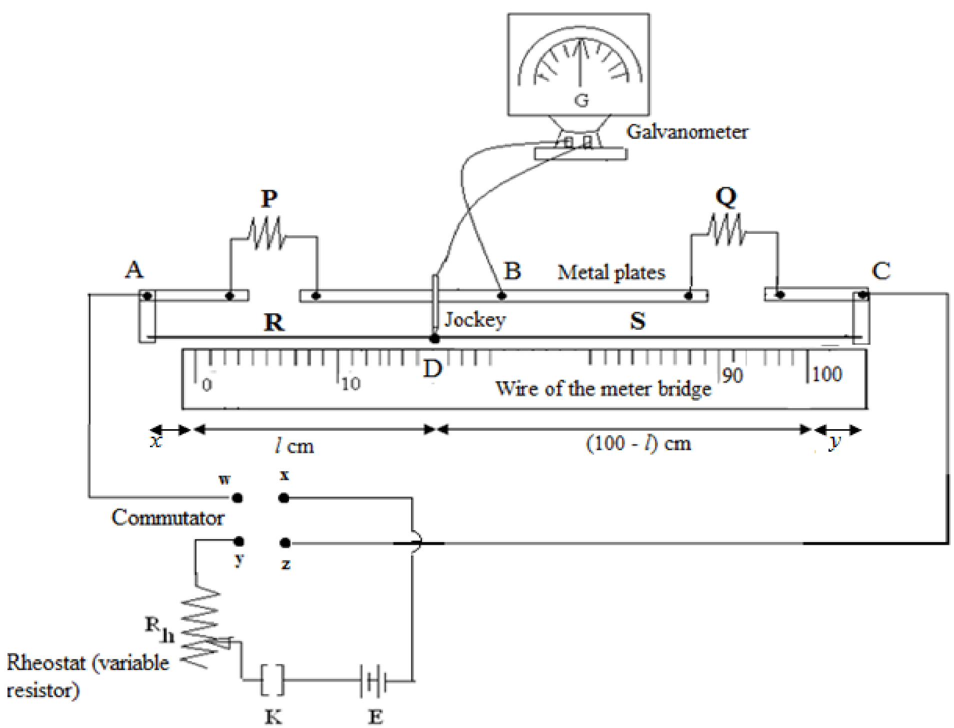
If anyone of the values of P and Q is known to us, we can find out the unknown one by using this formula.

However, the goal of this experiment is NOT to work out any unknown resistance. There might have been a systematic error in the meter-bridge, called 'end-error'.

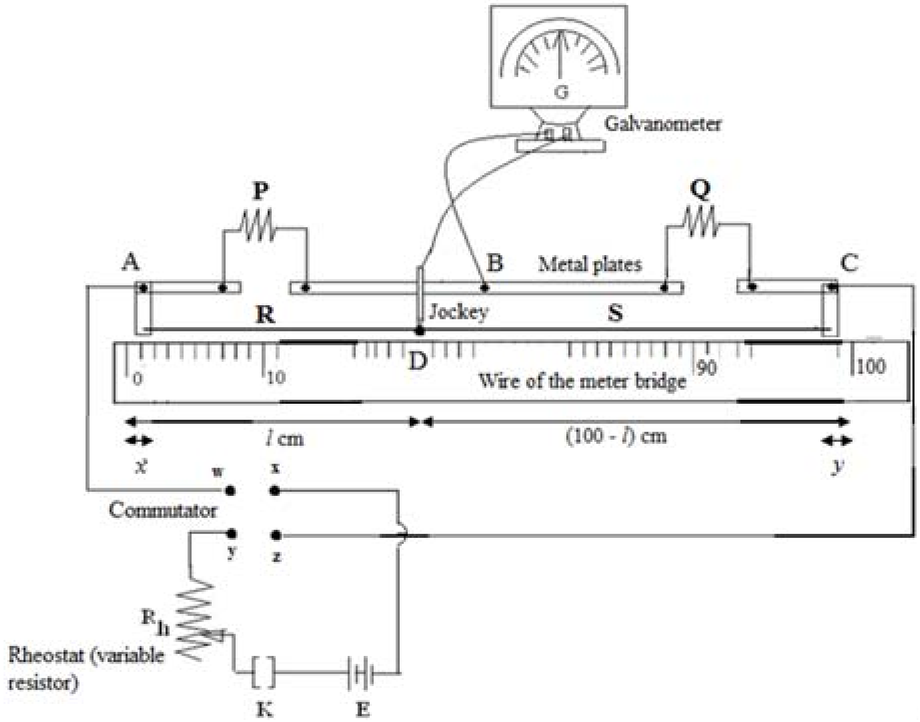
To derive equation (1) we have made the following assumptions:

1) The meter bridge's wire is perfectly of 100 cm length
2) The left end of the meter bridge's were coincides with the zero mark of the meter scale and its right end coincides with the hundred mark of the meter scale.
3) The metal plates, with which the meter bridge's wire is connected, do not have resistances.

However, in reality these assumptions may not be true. Let's see the following Figure 3 when the ends of the meter bridges wire do not coincide with the zero/hundred marks of the meter scale.



(a)



(b)

Figure 3: Meter-bridge having end errors.

In the case of Figure 3(a) we have to add an amount x with l and y with 100-l. For Figure 3(b) we will have to subtract them instead of adding. Therefore, equation (1) should be corrected in the following way

$$r = \frac{P}{Q} = \frac{l + x}{100 - l + y} \quad \text{.......(2)}$$

Here, r is the ratio of P and Q. x and y can be positive or negative.

Next, we swap P and Q, i.e., we connect P between the junctions B & C and connect Q between the junctions A & B. Suppose, now we get the null point of the galvanometer L distance away from the zero mark of the meter scale. Hence, we can write

$$\frac{1}{r} = \frac{Q}{P} = \frac{L + x}{100 - L + y} \quad \text{.......(3)}$$

r, L and l are known to us. We can solve equations (2) and (3) for x and y to get:

$$x = \frac{l - rL}{r - 1} \quad \text{.......(4)}$$

$$y = \frac{rl - L}{r - 1} - 100 \quad \text{.........(5)}$$

Apparatus

Meter-bridge, Cell (E), Resistance boxes (P & Q), Rheostat, Commutator, Galvanometer, wires.

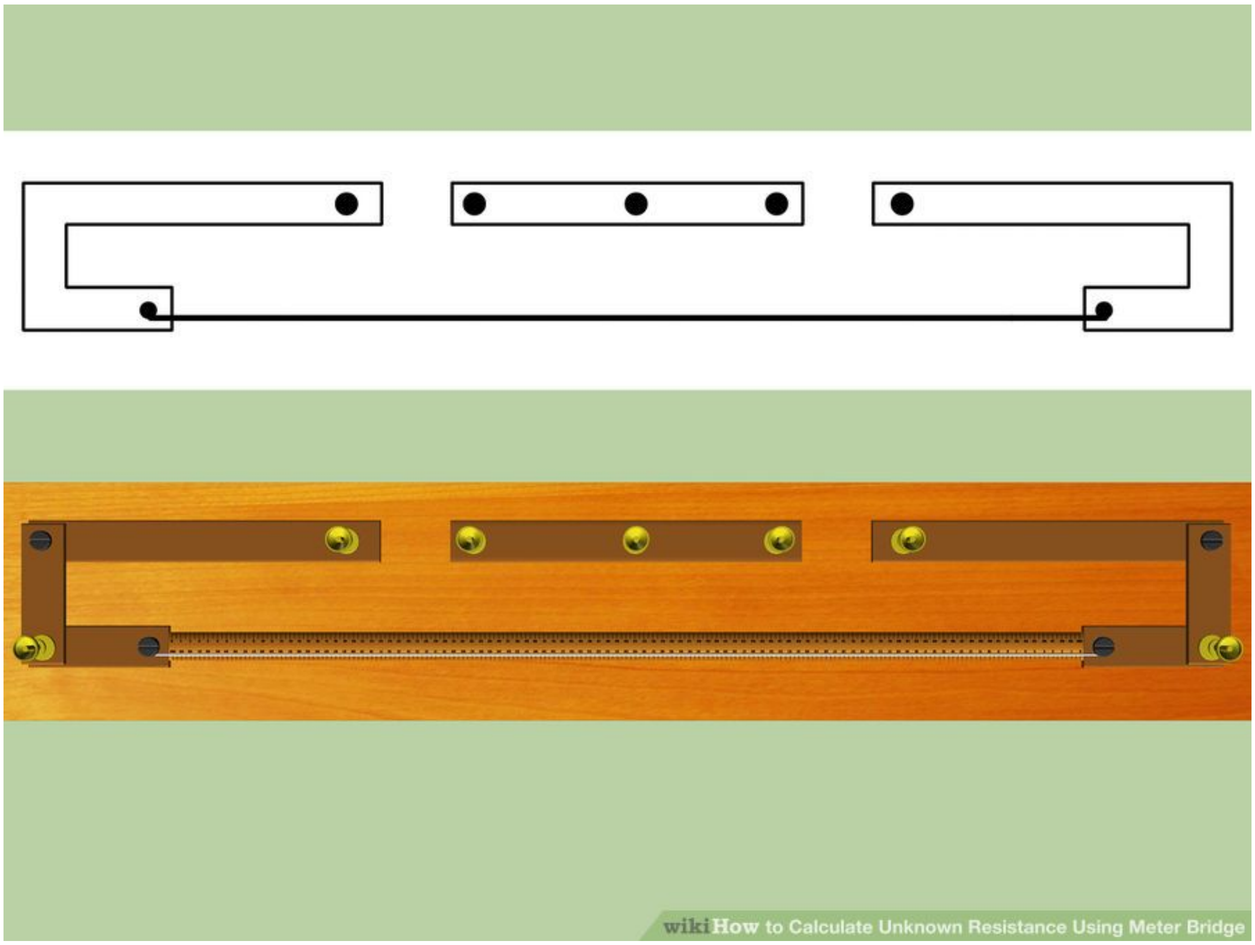


Figure 4: A meter-bridge (Courtesy: wikiHow)

Procedure

1) Construct the circuit as shown in Figure 2. Make sure that the pointer of the galvanometer deflects towards opposite directions when you make the contact between the jockey and the meter bridge's wire near end-A and end-B.
2) Choose the values of P and Q, and make sure that they are not equal. Calculate r = P/Q.
3) Put the plugs in the commutator to connect (w, y) and (x, z) terminals. Close the key K. Find out the null point. Open K. Measure the length between the zero mark of the scale and the null point. This is l for direct current.
4) To reverse the direction of the current, now connect (w, x) and (y, z) terminals of the commutator. In the same way of step 3, find l for this reverse current.

5) Take the average of the values of *l* and record it as the distance between the null point and the zero mark of the meter scale when P is in the left gap and Q is in the right gap between metal plates of the meter bridge.
6) Now, swap Q and P. To do so you do not need to swap the two whole resistance boxes. Just pluck the plug(s) correspond(s) to the resistance equal to Q from the resistance box of left gap and the plug(s) correspond(s) to the resistance equal to P from the resistance box of the right gap between the metal plates of the meter bridge.
7) Repeat step 3 to 5 but now you are calculating *L* instead of *l*. *L* is the distance between the null point and the zero mark of the meter scale when P is in the right gap and Q is in the left gap between metal plates of the meter bridge.
8) Calculate *x* and *y* which correspond to this *r*.
9) Choose another combination of P and Q. Repeat the steps from 2 to 8. Do it for 5 different combinations of P and Q.
10) Calculate the average of *x* and *y*.

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 the Wheatstone bridge diagram. [0.5]

Ans:

*2) Derive the equilibrium condition of Wheatstone bridge applying Ohm's law. [1]

Ans:

*3) Draw the meter bridge associated with other elements to construct the Wheatstone bridge. Which components of this diagram represent which part of the Wheatstone bridge? [0.5]

Ans:

*4) If we find the null point *l* distance away from the left end of the meter bridge's wire, then derive the equation for the equilibrium condition for Meter Bridge in an ideal case. [0.5]

Ans:

*5) Why do end errors happen? How should the equation of question 4 be corrected? [0.5]

Ans:

*6) If we interchange the position of the two resistances and find the null point L distance away from the zero mark, write down the equation for equilibrium condition of the Meter-bridge having end errors. [0.5]

Ans:

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

8) Solve the two equations which you have written in the answers of 6) and 7) by making the end corrections terms as subjects. [1]

- **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 End Corrections of a meter bridge

Resistance in Ohms	Ratio	Balance points in cm (P in the left)			Balance points in cm (P in the right)			x in cm	y in cm
	r = P/Q	Direct	Reverse	Mean (l)	Direct	Reverse	Mean (L)		
P = Q =									
P = Q =									
P = Q =									
P = Q =									
P = Q =									

- **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) If you find positive values of *x* and *y*, what can be the possible implications? [What does it imply about the connecting points between the wire of the meter bridge and the metal plates and/or the resistance of the metal plates?] [0. 5]

Ans:

2) If you find negative values of x and y, what can be the possible implications? [What does it imply about the connecting points between the wire of the meter bridge and the metal plates?] If you have found spurious values like -50, -80, etc, what can be the other systematic errors which may cause it? [0. 5]

Ans:

3) Why is it advantageous to use the rheostat, R_h, specially when the value of E is fixed?[0. 5]

Ans:

4) See the following figure

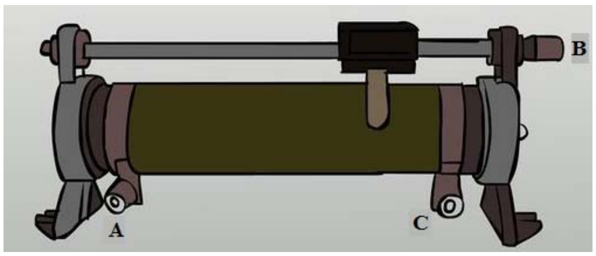

Figure 5: A rheostat (courtesy: WikiHow)

Suppose, the terminal A and the terminal B are connected with the circuit. If you move the slider rightward, will it increase or decrease the resistance of the rheostat? If the terminal B and C are connected and you move the slider rightward, would it increase or decrease the resistance of the rheostat? What would happen if A and C were connected? [0.5] (Use additional paper to answer)

Ans:

NOTE: Some of the major figures shown in this lab manual are collected from internet. They are free from copyright or the copyright holders grant permission to use them.

http://www.wikihow.com/Calculate-Unknown-Resistance-Using-Meter-Bridge

http://www.wikihow.com/Create-a-Corn-Snake-Vivarium