Experiment No.: 14

Title: Construction of one-ohm coil using Carey Foster bridge

Theory:

A Carey Foster bridge is an electrical circuit that can measure very small resistance. It works on the similar principle as Wheatstone's bridge.

A Wheatstone's bridge consists of four resistances *P*, *Q*, *R* and *S* that are connected as shown in the *Figure 1*.

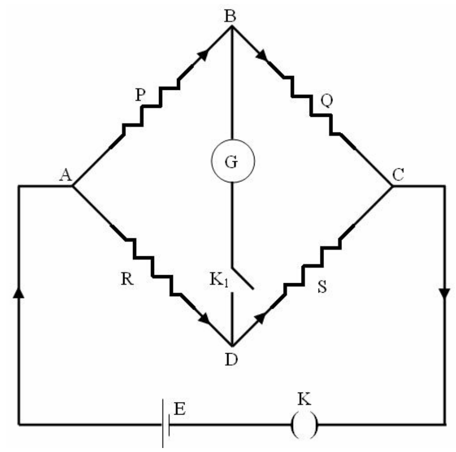

Figure 1

In this circuit, *G* is a galvanometer, *E* is a lead accumulator, and K_1 and *K* are the galvanometer and battery key, respectively. If the value of resistances are adjusted so that no current flows through the galvanometer, then if any three of the resistances are known, the forth unknown resistance can be determined by using the relationship $P/Q = R/S$.

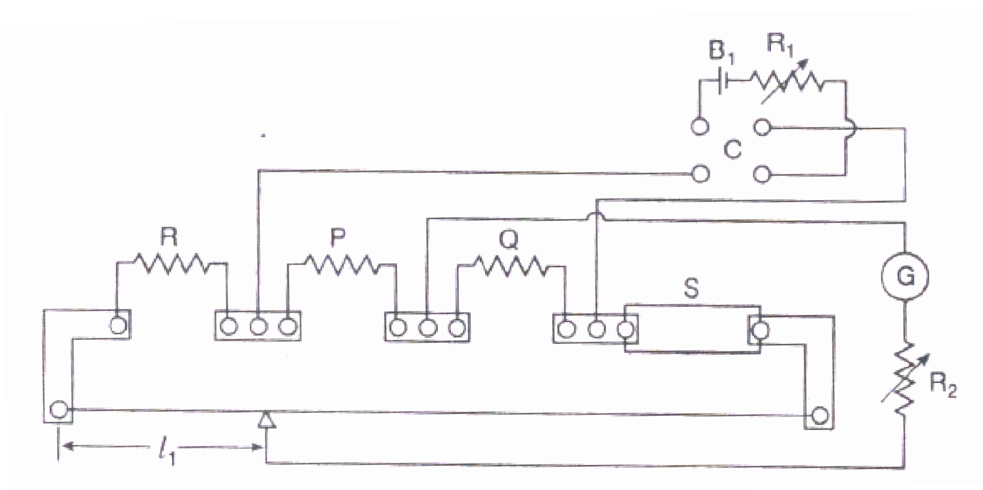

Figure 2

Note: a meter bridge also works is similar principle. In the meter bridge, two of the resistors, *R* and *S* are replaced by a one meter length of resistance wire, with uniform cross-sectional are fixed on a meter scale. Point D is an electrical contact that can be moved along the wire, thus varying the magnitudes of resistances *R* and *S*. The Carey Foster bridge is a modified form of the meter bridge in which the effective length of the wire is considerably increased by connecting a resistance in series with each end of the wire. This increases the accuracy of the bridge. *Figure 2* shows the circuit diagram of a Carey Foster bridge.

In this circuit, *P* and *Q* are two nearly equal resistances (each of 1 or 2 ohm), *R* is a known resistance, *S* is a thick metal strip having zero resistance, *G* is a galvanometer, B_1 is a storage battery, *C* is a commutator, R_1 is a rheostat in the battery circuit and R_2 is a rheostat in series with the galvanometer.

When the bridge is balanced, let the null point be l_1 cm from the left end of the bridge wire. If by interchanging *R* and *S*, the null point is obtained at l_2 cm from the same end, we have

$$R = \rho(l_2 - l_1)$$

Or,
$$\rho = \frac{R}{(l_2 - l_1)} \qquad \text{...... (i)}$$

Where ρ is the resistance per unit length (in Ω/cm) of the bridge wire.

Let the thick metal *S* be replaced by a known resistance *r*, and *R* be replaced by the given wire of length *L*. Suppose that the resistance of the given wire is R_x and that l_1' is the distance of the null point from the left end of the bridge wire obtained with this circuit. Let l_2' be the distance of the null point from the same end obtained with the circuit when *r* and R_x are interchanged.

Then,
$$R_x = r + \rho(l_2' - l_1') \qquad \text{...... (ii)}$$

The length of the wire required for one ohm is therefore given by,

$$L' = \frac{L}{R_x} \qquad \text{...... (iii)}$$

To compare the prepared ohm (say, P_1 Ω) with a standard ohm (say, S_1 Ω), equation (ii) is used and the final correct value of the prepared ohm is obtained from

$$P_1 = S_1 + \rho\,(l_2'' - l_1'') \qquad \text{...... (iv)}$$

where l_2'' and l_1'' are the final positions of the null points from the left end of the bridge wire. In the experiment l_2'' and l_1'' are made as close as possible.

Equations (i) to (iv) are the working formulas of the experiment.

Apparatus:

- Carey Foster bridge
- Two equal resistances (each about 1 Ω or 2 Ω)
- Two thick metal strips
- Fractional (variable) resistance box

- A standard one ohm
- A storage cell
- A commutator
- A galvanometer
- Two rheostats for the battery and galvanometer circuits
- Connecting wires

Procedure:

1. Make the circuit as in *Figure 2*. Note that S is a metal strip. Connect a resistance box in place of R. Observe the null point. Insert a small resistance in the circuit from the box. Note the null point readings for both direct and reverse currents. Increase gradually the resistance R (say, in steps of 0.1 Ω) and each time record the null points (l_1) for both direct and reverse currents till the end of the bridge wire is approached.
2. Interchange the metal strip S and the resistance box R. Repeat the process as in step 1 and record the null points (l_2).
3. Find the value of ρ of the bridge wire from each set of readings using equation (i) and obtain the mean ρ.
4. Take the sample wire and bend its two ends over 1 cm length for insertions in the binding screws of the bridge. Measure the length L of the wire between the two bends and record this length.
5. Put the sample wire in the extreme left gap and a resistance box r in the extreme right gap of the bridge. Insert a resistance (say, 1.6 Ω) from the resistance box r and record the null points ($l_1^{'}$) for direct and reverse currents. Increase gradually the value of the resistance r (say, in steps of 0.1 Ω or 0.2 Ω) from the box and each time record the null points for direct and reverse currents.
6. Interchange the positions of the sample wire and the resistance box r and repeat step 5. Find the null points ($l_2^{'}$).
7. Knowing the value of r and the positions of the null points in steps 5 and 6, calculate the value of the resistance R_x of the sample wire by using equation (ii).
8. Calculate the length $L^{'}$ of the wire required for 1 ohm from R_x and L by using equation (iii).
9. Cut off a length which is slightly less than $L^{'}$ from the sample wire and solder its two ends to two metal strips.
10. Connect metal strips to the two outer gaps of the bridge so that $R = 0$ Ω and $S = 0$ Ω. Obtain the null points (l_0) for both direct and reverse currents.
11. Connect the wire in place of metal strip at the left and the standard ohm in place of the right metal strip of the bridge. Obtain the null points for direct and reverse currents and find the mean value ($l_1^{''}$).
12. Rub a little the wire by a fine grained sand paper and obtain the null point again. In this case, the difference ($l_1^{''} - l_0$) will be reduced from the previous value. The process of rubbing is repeated several times until the value of ($l_2^{''} - l_0$) becomes approximately equal to zero.

13. Interchange the position of the wire and the standard ohm and record the null point reading (l_2''). Calculate the correct value of the resistance of the wire by using equation (iv) with last value of l_1'' obtained in step 12.
14. Fold the prepared one ohm wire on itself and wind round a bobbin non-conductively.

Experimental Results: Make the table according to your requirements. One example of the tables is given below.

Table

Determination of ρ of the bridge wire

No. of sets	Resistance in the extreme		Position of null point for			$(l_2 - l_1)$ (cm)	$\rho = \frac{R}{(l_2 - l_1)}$ (Ω/cm)	Mean ρ (Ω/cm)
	Left gap (Ω)	Right gap (Ω)	Direct current (cm)	Reverse current (cm)	Mean (cm)			
1	R(~ 1Ω)	0	…	…	… (l_1)			
	0	R	…	…	… (l_2)			

You will have several other tables for

(ii) Determination of the resistance (R_x) of the sample wire

(iii) Determination of the length of the wire corresponding to 1 ohm

(iv) Determination of null points (l_0)

(v) Comparison of the prepared ohm with standard ohm

(vi) Determination of the true value of prepared ohm

Calculate/estimate an error in your measurements

Discussion/conclusion