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WORK INSTRUCTION

1.0 EXPERIMENT NO: BS/PHP101/09

2.0 NAME OF EXPERIMENT: Carey Foster Bridge

3.0 0BJECTIVE: Determination of unknown resistance by Carey Foster Bridge

4.0 THEORITICAL BACKGROUND

Post Office Box:

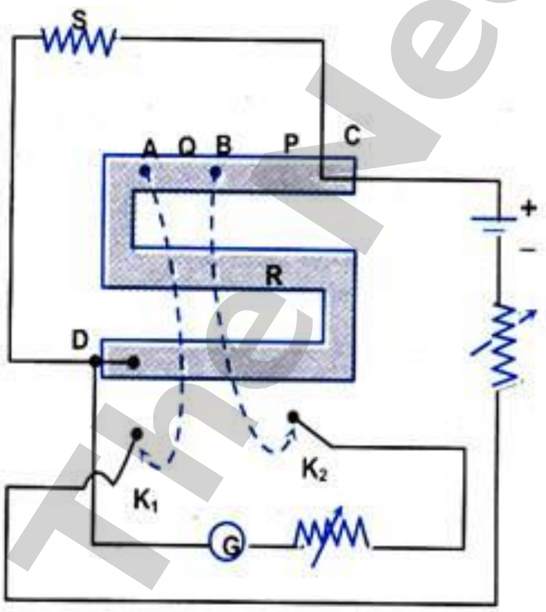
The Post Office Box was a Wheatstone bridge style testing device with pegs and spring arms to close electrical circuits and measure properties of the circuit under test. The boxes were used in the United Kingdom by engineers from the then General Post Office, who were responsible for UK telecommunications to trace electrical faults, i.e. to determine where a break occurred in a cable which could be several miles in length. It works on the principle of Wheatstone bridge to identify the resistance of wire connected and then by using wire resistivity and cross section calculating length of wire and thus determining where cable had broken.

A Post Office Box can also be used to measure an unknown resistance. It is a Wheatstone Bridge with three arms P, Q and R; while the fourth arm(s) is the unknown resistance. P and Q are known as the ratio arms while R is known as the rheostat arm.

At balance, the unknown resistance

$$S = (P/Q)\, R \qquad \ldots\ldots (1)$$

The ratio arms are first adjusted so that they carry 100 W each. The resistance in the rheostat arm is now adjusted so that the galvanometer deflection is in one direction. If $R = R_0$ (ohm) and $R = R_0 + 1$ (ohm) are the resistance in rheostat arm, for which the deflection in galvanometer is in opposite direction, then it implies that the unknown resistance ‘s’ lies between R_0 & $(R_0 + 1)$ ohm.



Resistance-using-post-office-box

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Now, the resistance in P and Q are made 100 W and 1000 W, respectively, and the process is repeated. Equation (1) is used to compute S. The ratio P/Q is progressively made 1:10, and then 1:100. Thus, the resistance S can be accurately measured.

Some points to note down:

Balance point (of a Carey Foster bridge): A point on the bridge wire that produces zero deflection in the galvanometer when the jockey knife edge is in contact with it. Also known as a **null point**.

Carey Foster Bridge: a bridge based on the principle of Wheat stone's bridge that is used to compare two nearly equal resistances and to determine values of low resistances and the specific resistance of a wire. It differs from a meter bridge because additional resistances of similar magnitudes are included at either end of the meter wire.

end correction (for a Carey Foster bridge): A small resistance that includes contributions from the finite resistance of the fixed copper strips within a Carey Foster bridge, the resistance at the junctions of the bridge wire with the copper strips and the effects of the non coincidence of the ends of the wire with the zero and one hundred division marks on the scale.

Fractional resistance box: A box containing a number of fixed small resistance coils (0.1-1.0 Ω or 0.01-0.1 Ω), so mounted that any number of these resistance coils can be connected in series.

Galvanometer: An instrument used to detect current. In the Carey Foster bridge experiments, a very sensitive galvanometer is used, with zero current corresponding to the center of the scale.

jockey: A metal knife edge mounted in plastic handle that can move along the bridge wire of a Carey Foster bridge and is used to locate the null point. Pressing on the jockey makes a point contact with the bridge wire.

low resistance: A resistance in the range of 1-5 ohm.

meter bridge: The most commonly used form of the Wheatstone's bridge. It includes a uniform 1m long wire fixed on a wooden board, and it can be used for comparison of the values of two similar resistances.

null point (of a Carey Foster bridge): A point on the bridge wire that produces zero deflection in the galvanometer when the jockey knife edge is in contact with it. Also known as a **balance point**.

post office box: A compact form of Wheatstone's bridge in which two of the arms contain resistances of 10, 100 or 1000 Ω. A third arm contains resistances from 1-5000 Ω, and an unknown resistance can be connected in the fourth arm. Tapping keys are provided for connections to a galvanometer and battery.

resistance: The opposition offered to the flow of current by an object. If a current I flows through an object when a potential difference V is connected across it, then the resistance R is given by $R = V/I$. The SI unit of resistance is the ohm, Ω.

specific resistance (of a wire): The resistance per unit length of the wire. In SI units, this is measured in Ω m-1.

Wheatstone's bridge: A bridge circuit (depicted in Figure 1) that comprises four resistances P, Q, R and S joined together to form a quadrilateral, with a battery connected across terminals at two opposite corners of the quadrilateral and a galvanometer between the other two corners. When the bridge is balanced (no current through the galvanometer), then $P/Q = R/S$.

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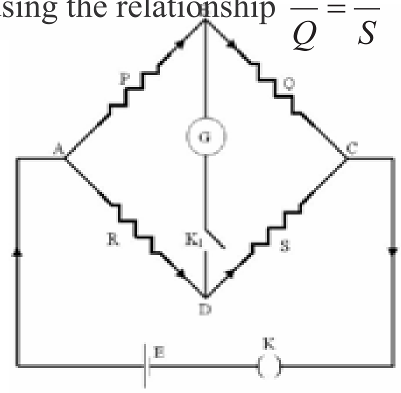
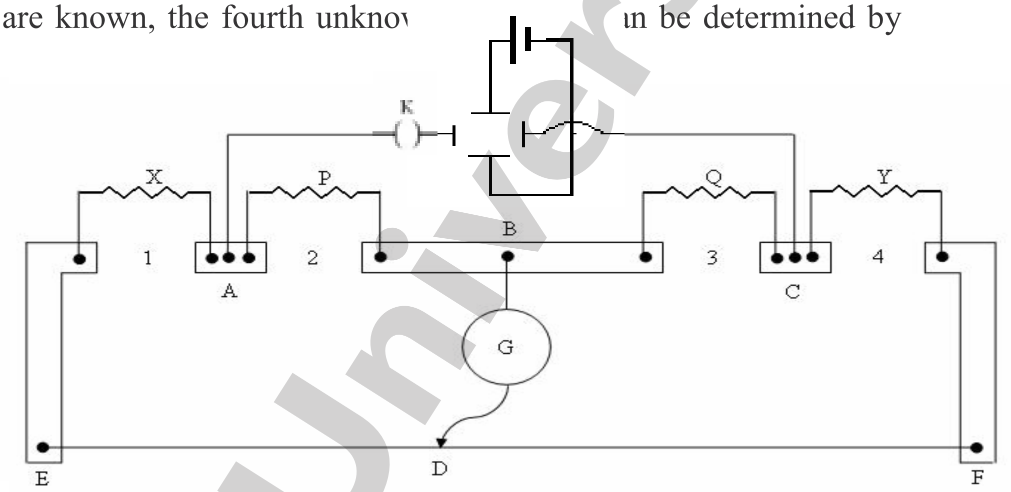
5.0 PRINCIPLE: The Carey Foster Bridge is an electrical circuit that can be used to measure very small resistances. It works on the same principle as Wheatstone's bridge works. Wheatstone's bridge consists of four resistances, P, Q, R and S that are connected to each other as shown in the circuit diagram. In this circuit, G is a galvanometer. If the values of the resistances are adjusted so that no current flows through the galvanometer, then if any three of the resistances P, Q, R and S are known, the fourth unknov ... n be determined by using the relationship $\frac{P}{Q}=\frac{R}{S}$





In the above circuit diagram the four points A, B, C and D of the Carey Foster bridge (right) exactly correspond to the points labeled A, B, C and D in the circuit diagram of Wheatstone's bridge (left). In this way the Carey Foster Bridge effectively works like a Wheatstone's bridge. If the balance point is located at a distance l_1 from E, then we can write the condition of balance as

$$\frac{P}{Q}=\frac{R}{S}=\frac{X+\alpha+l_1\rho}{Y+\beta+(100-l_1)\rho}$$

Where ρ is resistance per unit length of wire of the meter bridge and α and β are the end corrections at the left and right ends. These end corrections include the resistances of the metal strips to which the wire is soldered, the contact resistances between the wire and the strips, and they also allow for the non-coincidence of the ends of the wire with the zero and one hundred division marks on the scale.

If the positions of X and Y are interchanged, i.e., X is put in gap 4 and Y in gap 1, and the balance point is found at a distance l_2 from E, then the balance condition becomes, $\frac{P}{Q}=\frac{R}{S}=\frac{Y+\alpha+l_2\rho}{X+\beta+(100-l_2)\rho}$

Adding 1 in both sides of each equation and equating them we get-

$$\frac{P+Q}{Q}=\frac{X+Y+\alpha+\beta+100\rho}{Y+\beta+(100-l_1)\rho}=\frac{X+Y+\alpha+\beta+100\rho}{X+\beta+(100-l_2)\rho}$$

Since the numerators are equal, we can write, $Y+\beta+(100-l_1)\rho= X+\beta+(100-l_2)\rho$

So, $\rho=\frac{X-Y}{l_2-l_1}$ and $Y=X-\rho(l_2-l_1)$

Thus, $\rho=\frac{X}{l_2-l_1}$, when Y=0

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Thus if Y is short circuit (say putting a copper strip in this gap) then we can measure the value of ρ and hence any unknown resistance.

6.0 TOOLS/APPARATUS REQUIRED:

- Meter Bridge
- Two Equal Resistances Of About 2 Ohms Each
- Thick Copper Strip
- Fractional Resistance Box
- Commutator
- Galvanometer/null detector
- Unknown Low Resistance
- One Way Key
- Connecting Wires

7.0 PROCEDURE:

7.1 Determination of resistance per unit length, ρ, of the Carey Foster bridge wire:

- Make the circuit connections as shown. Place a copper strip in the gape 4

↓

- Plug in the battery key so that a current flows through the bridge. Note that you should remove the battery key and make the circuit open when you are not taking any measurements.

↓

- Press down the jockey so that the knife edge makes contact with the wire, and observe the galvanometer deflection. Release the jockey.

↓

- Move the jockey to different positions along the wire to locate the position of the null point, where there is no deflection of the galvanometer. This point should be near the middle of the bridge wire when X=0

↓

- Fix a certain resistance of the fractional resistance box (X) [say 2 Ω or 1.8 Ω] and note the balancing length l_1 for direct as well as reverse current. You can change the direct current to the reverse current by using commutator. Similarly note down the balancing length l_1 for other values of X by decreasing it in steps of 0.2 Ω. Record your observations in Table – 1.

↓

- Interchange the copper strip and X, and repeat the previous step for the same set of resistances. In this case the balancing length has to be denoted by l_2. The measurement of l_2 should be done from the same side of the meter bridge. Record the values of l_2 also in the Table – 1.

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7.2 Determination of an unknown low resistance Y:

- Remove the copper strip and insert the unknown low resistance (Y) in the gap 4 and fractional resistance box (X) in the gap 1.

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- Repeat the step 5 of previous part. Record your observation in Table -2

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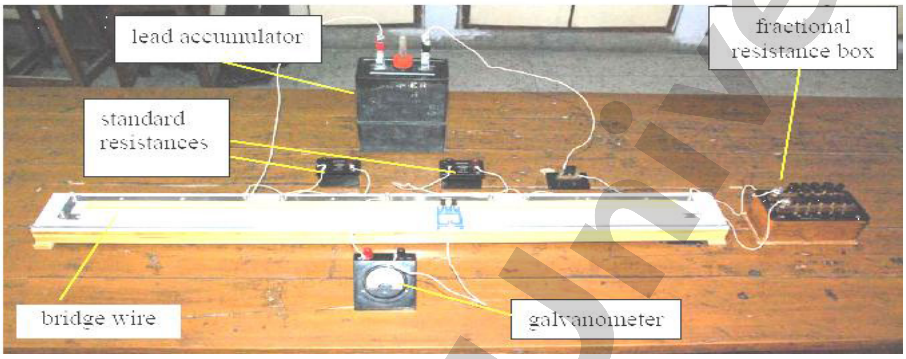
- Interchange Y and X, and repeat the step 6 of the previous part. Record your observation in Table -2.



8.0 TABULATION:

TABLE – 1

Determination of resistance per unit length, ρ, of the Carey Foster bridge wire:

Y = 0

No. of obs.	X in Ohm	Position of the null point when the copper strip is in						$(l_2 - l_1)$ (cm)	Value of X from graph Ohm	Value of $(l_2 - l_1)$ from graph (cm)	$\rho = \frac{X}{l_2 - l_1}$ Ohm/cm
		Extreme right gap 4 (l_1) (cm)			Extreme left gap 1 (l_2) (cm)						
		Direct current (cm)	Reverse current (cm)	Mean (cm) (l_1)	Direct current (cm)	Reverse current (cm)	Mean (cm) (l_2)				
1											
2											
3											
4											
5											

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Result and Graph:
Draw a graph showing the variation of X and $(l_2 - l_1)$. Plot X along the abscissa (x-axis) and $(l_2 - l_1)$ along vertices (y-axis). Determine values of X and $(l_2 - l_1)$ from the graph and therefrom determine ρ, resistance per unit length of wire of the meter bridge.

TABLE - 2

Determination of an unknown low resistance Y:

No. of obs.	X in Ohm	Position of the null point when the unknown resistance is inserted: Extreme right gap 4 (l_1) (cm)			Extreme left gap 1 (l_2) (cm)			$(l_2 - l_1)$ (cm)	Value of X from graph Ohm	Value of $(l_2 - l_1)$ from graph (cm)	Y= $X - \rho(l_2 - l_1)$ Ohm
		Direct current (cm)	Reverse current (cm)	Mean (cm) (l_1)	Direct current (cm)	Reverse current (cm)	Mean (cm) (l_2)				
1											
2											
3											
4											
5											

Result and Graph:
Draw a graph showing the variation of X and $(l_2 - l_1)$. Plot X along the abscissa (x-axis) and $(l_2 - l_1)$ along vertices (y-axis). Determine values of X and $(l_2 - l_1)$ from the graph and there from determine the unknown resistance, Y.

9.0 COMPUTATION OF PERCENTAGE ERROR:

We know, $Y = X - \rho(l_2 - l_1)$

or, $Y = X - \rho \Delta l_2$

or, $Y = X - \frac{x}{\Delta l_1} \Delta l_2$

or, $Y = X(1 - \frac{\Delta l_2}{\Delta l_1})$

or, $Y = X\,(\frac{\Delta l_1 - \Delta l_2}{\Delta l_1})$

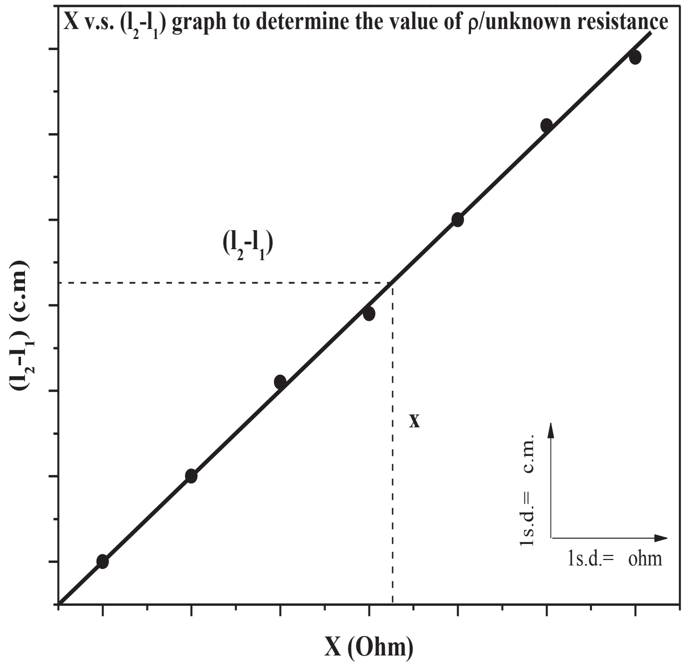
Taking logarithm on both sides

$\ln Y = \ln X + \ln(\Delta l_1 - \Delta l_2) - \ln \Delta l_1$

Differentiating both sides

$\frac{\partial Y}{Y} = \frac{\partial X}{X} + \frac{\partial(\Delta l_1 - \Delta l_2)}{\Delta l_1 - \Delta l_2} - \frac{\partial(\Delta l_1)}{\Delta l_1}$

As we are calculating maximum error so negative signs are made +ve



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$$\frac{\partial Y}{Y} = \frac{\partial X}{X} + \frac{2\partial l + 2\partial l}{\Delta l_1 - \Delta l_2} + \frac{2\partial l}{\Delta l_1}$$

$$\frac{\partial Y}{Y} = \frac{\partial X}{X} + \frac{4\partial l}{\Delta l_1 - \Delta l_2} + \frac{2\partial l}{\Delta l_1}$$

Hence, the percentage error is $\left(\frac{\partial Y}{Y} \text{ x } 100\right)\%$

(Put the value of proportional error and calculate the percentage error)

10.0 DISCUSSION:

As stated earlier.

References

1) ELECTRICITY AND MAGNETISM - Rakshit, Chatterjee
2) ADVANCED PRACTICAL PHYSICS- Ghosh & Majumdar

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