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Carey Foster Bridge
Lab Report 4

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Aim

- To find the value of an unknown low resistance S using the Carey Foster bridge.
- To determine the correction factor in the resistance measured by the Carey Foster bridge.

Experimental Setup

- A low voltage DC power supply
- A Carey Foster bridge
- Two fixed standard 1 Ω resistances
- A fractional resistance box
- A thick copper strip
- An unknown low resistance (S)
- A galvanometer
- A null detector jockey
- Connecting wires
- Sandpaper

Least count of galvanometer = 10 μA
Least count of Carey Foster bridge = 0.1 cm

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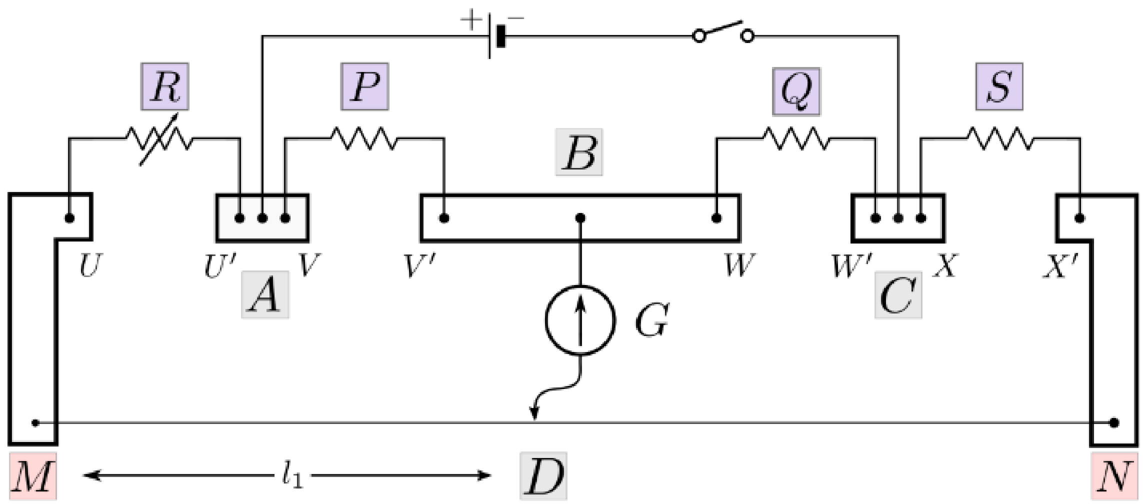

Figure 1: Experimental setup of the Carey Foster bridge

Theoretical Background

The Carey Foster bridge uses a modified Wheatstone bridge configuration to determine small unknown resistances. In a Wheatstone bridge, there are 2 pairs of resistors in parallel with a galvanometer connecting the middle of the two arms (as seen in Figure 2).

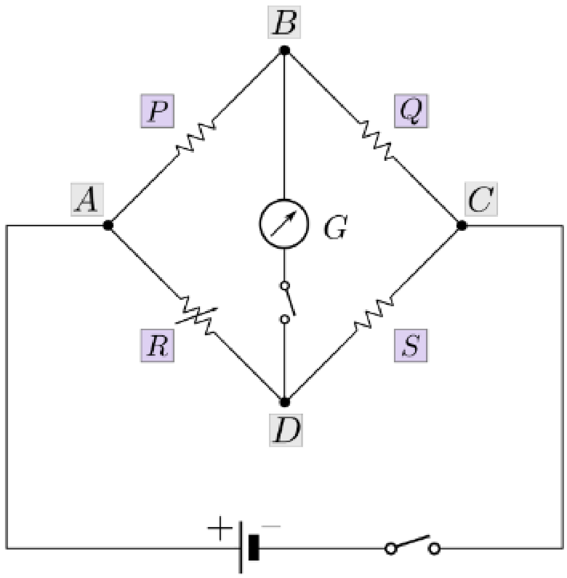

Figure 2: Schematic diagram of a Wheatstone bridge

When a current is passed through the circuit, the variable resistor R is varied until the galvanometer shows no deflection (i.e. there is no current passing through the central arm). At this point the following relation holds true:

$$\frac{P}{Q} = \frac{R}{S} \tag{1}$$

The Carey Foster bridge uses this same principle, but rather than using a variable resistance, it makes use of a null detector moving across a long wire of constant resistance per unit length (r). The known resistors P and Q are small and equal. The point on the bridge at length l_1 which gives zero deflection in the galvanometer creates a Wheatstone configuration with the formula:

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$$\frac{P}{Q} = \frac{R + \delta_1 + l_1 r}{S + \delta_2 + (100 - l_1)r} \tag{2}$$

Where δ_1 is the resistance of the junction M and δ_2 is the resistance of junction N. We can eliminate these unknown resistances by swapping R and S to give the equation:

$$\frac{P}{Q} = \frac{S + \delta_1 + l_2 r}{R + \delta_2 + (100 - l_2)r} \tag{3}$$

By combining Equation 2 and 3, we get the following relation:

$$R = (l_2 - l_1)r + S \tag{4}$$

Hence, by plotting R vs $(l_2 - l_1)$ we should get a straight line with slope r and y-intercept S.

However, since the experimental setup has some degree of systemic error, we must measure the resistance for a copper strip (whose true resistance is negligible) in order to determine the system's inherent resistance. This must be subtracted from the value of S found in the first part to determine the true value of the unknown resistor.

Procedure

Part A

1. Sandpaper the ends of wires to clean the contacts in the circuit.
2. Make the connections as shown in Figure 1 and connect the DC source.
   [Precaution: Make sure that enough wire is exposed while making connections, so that insulation does not come in between.]
3. Check each contact by tugging on the wire and ensuring that it does not loosen or come undone.
4. Start with a small resistance (R) in the resistance box and note down the balance length l_1 when the galvanometer shows null deflection.
   [Precaution: Make sure there is a finite resistance in the circuit, before the key is closed. Measure all balance lengths from the same side and on same scale.]
5. Repeat this with increasing resistances until the null reading can no longer be found on the meter bridge.
6. Switch the positions of R and S in the circuit and repeat steps 4 and 5 to and note the balance points l_2.
7. Tabulate l_1 and l_2 and plot a graph between and R and $(l_2 - l_1)$ to determine the resistance per unit length of the wire (r = slope) and the unknown resistance (S = y-intercept).

Part B

1. Switch S with a thick copper strips.
2. Repeat the steps 2-7 from Part A.
3. Find the apparent resistance of the copper strip (S) is and the unknown resistance in Part A will be the difference between intercepts of plots in Part A and Part B.

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Observations

Fixed resistances (P and Q) = 1 Ω

The table below is the data collected from Part A of the experiment where l_1 and l_2 are the null balance points.

R (Ω)	l_1 (cm)	l_2 (cm)	$l_2 - l_1$ (cm)	$l_1 + l_2$ (cm)
0.5	95.5	5.5	-90.0	101.0
1.0	88.4	15.4	-73.0	103.8
1.5	78.9	27.5	-51.4	106.4
2.0	68.7	40.1	-28.6	108.8
2.5	60.2	46.0	-14.2	106.2
3.0	68.7	40.1	11.6	108.8
3.5	41.3	65.9	24.6	107.2
4.0	30.1	78.7	48.6	106.8
4.5	22.4	85.8	63.4	108.2
5.0	12.4	92.9	80.5	105.3

Table 1: $l_2 - l_1$ for an unknown resistance

The table below is the data collected from Part B of the experiment where l_1 and l_2 are the null balance points.

R (Ω)	l_1 (cm)	l_2 (cm)	$l_2 - l_1$ (cm)	$l_1 + l_2$ (cm)
0.2	47.0	46.3	0.7	93.3
0.5	52.1	40.7	11.4	92.8
0.7	56.5	36.7	19.8	93.2
1.0	63.3	29.9	33.4	93.2
1.2	66.0	26.7	39.3	92.7
1.5	71.8	20.5	51.3	92.3
1.7	77.5	15.8	61.7	93.3
2.0	81.1	12.2	68.9	93.3
2.2	84.9	8.4	76.5	93.3
2.5	90.8	2.9	87.9	93.7

Table 2: $l_2 - l_1$ for a copper strip

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Analysis

Below is a scatter plot of the data sets shown above. If a best fit straight line is plotted over the data we can find the slope and intercepts of both lines and giving us the values of r and S.

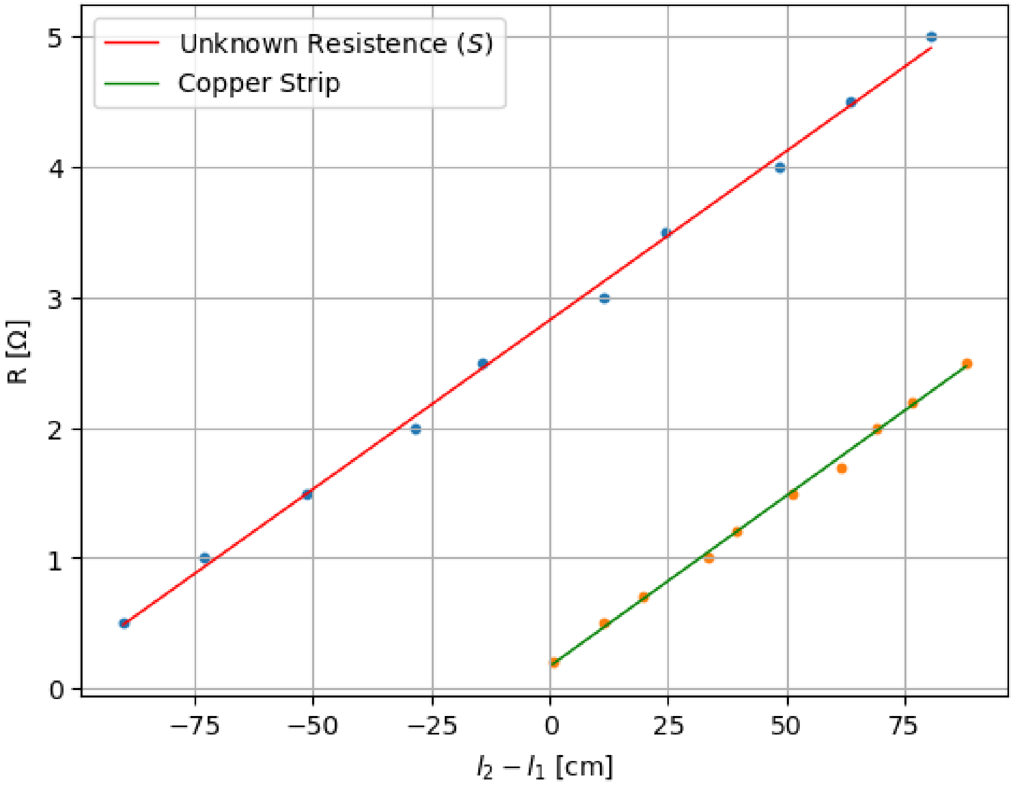

Figure 3: The slope of both data sets are parallel since the resistance per unit length of the meter bridge is the same for both parts

Slope of unknown resistance data = 0.026 Ω/cm
Slope of copper strip data = 0.026 Ω/cm
y-intercept of unknown resistance data = 2.823 Ω
y-intercept of copper strip data = 0.170 Ω

From this data we can determine the resistance per unit length of the Carey Foster bridge and the unknown resistance S using Equation 4:

Resistance per unit length (r) = 0.026 Ω/cm
Unknown resistance (S) = 2.823 − 0.170 = 2.653 Ω

The value of $l_1 + l_2$ is noticed to be roughly constant in Tables 1 and 2. This is because of the following relation derived from Equation 3 and 4 assuming that $P = Q$:

$$\frac{P}{Q} = \frac{S + \delta_1 + l_2 r}{R + \delta_2 + (100 - l_2)r}$$

$$R + \delta_2 + (100 - l_2)r = S + \delta_1 + l_2 r$$

$$\delta_1 - \delta_2 = (l_2 - l_1)r + 100r - 2l_2 r$$

$$\delta_1 - \delta_2 = r(100 - (l_1 + l_2))$$

$$l_1 + l_2 = 100 - \frac{\delta_1 - \delta_2}{r}$$

Since δ_1, δ_2 and r are all constant, $(l_1 + l_2)$ must also be constant.

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Error Analysis

Since the least count of the meter bridge is 0.1 cm, the net error in the term $l_2 - l_1 = \pm 0.2$ cm. This gives us a range of values between $l_2 - l_1(max)$ and $l_2 - l_1(min)$, which when plotted give us a range for the y-intercept.

Error margin for y-intercept of unknown resistance data = $2.829 - 2.819 = 0.01\ \Omega$
Error margin for y-intercept of copper strip data = $0.175 - 0.165 = 0.01\ \Omega$

This means that there is a $\pm 0.005\ \Omega$ error in each reading, which gives us a net error of $\pm 0.010\ \Omega$ in the value of unknown resistance S after we subtract systemic error from apparent resistance.

Other sources of error include:

- The unstable wavering of the galvanometer while trying to find the balance point makes it hard to pinpoint the true value of l_1 and l_2.
- Lose or improper connections in the circuit.
- Lose zero resistance keys in the fractional resistance box could potentially alter the results.
- The amount the wire is stretched while tapping the jockey on it alters the position of the balance point with each reading.

Results

- The unknown resistance S was found to be $\boxed{2.653 \pm 0.010\ \Omega}$
- The correction factor in the resistance due to systemic error was found to be $\boxed{0.170 \pm 0.005\ \Omega}$
- The quantity $l_1 + l_2$ was derived to be a constant that depends on the resistance of the junctions and meter bridge in the Carey Foster bridge.

Discussion

The apparent resistance of the copper strip found to be $0.17\ \Omega$ is not likely to be the true resistance of the copper strip. This value indicates the resistance measured when the circuit essentially has no significant resistance attached in place of S, which indicates the inherent resistance of the circuit or the systemic error which needs to be removed from any reading taken from the setup.

This experiment can be improved by the following measures:

- Attach a small resistor between the galvanometer and null point detection jockey. This will slightly reduce the sensitivity of the galvanometer allowing one to find the balance point with ease. Since the amount the galvanometer deflects does not matter while finding the null point, this will not adversely affect the results.
- Use a longer bridge that has a lower resistance per unit length. This will allow one to collect a larger data set with higher resolution which will likely yield more accurate results.
- Use a variable resistor rather than a fractional resistance box to bypass the possibility of lose resistor pins interfering with the results.