"Carey-Foster Bridge"

Objective :-
To determine the specific resistance of the material of a given unknown wire using 'Carey-Foster Bridge'.

Apparatus :- Carey-Foster bridge, power supply, resistance box, wire of Unknown resistance, a thick copper strip, a plug key, two equal resistances, a galvanometer.

Theory :-
The specific resistance is defined as resistance of wire of unit length and unit Cross-section area. Since, Resistance is proportional to the length and inversely proportional to the Cross-section area, the specific resistance is defined as,

$$\boxed{\rho = R\left(\frac{A}{l}\right) \Omega m = R\left(\frac{\pi r^2}{l}\right) \Omega m}$$

where l = length of given wire.
r = radius of Cross section of given wire.
R = Resistance of given wire.
ρ = specific resistance.

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The specific resistance (ρ) depends only on the material and is independent of shape of wire.

In order to determine specific resistance, we need to find resistance, length and radius of a given wire. The length and radius can be calculated using Vernier caliper and screw-gauge.
The mesurement of resistance is carried out with this experiment.

Why Carey - Foster Bridge :- An easier Method to determine resistance is as follow:
Attach a battery across the wire,
Note the voltage across the wire and current flowing through it.
Apply Ohm's law, $\boxed{R = V/I}$

you may have other simple techniques but
This method is not suitable for mesuring low resistances because of the following reason :

When we join two conducting wires or two resistances by clamping or by twisting (and not by soldering), we actually bring two layers of molecules close to each other. The sheets of molecules have gap of few angstroms. The electrons in a conductor are assumed to move freely without loosing any energy. When these electrons pass through the junction, they have to jump from one layer to other and they lose some energy in this process.
The energy loss is, equivalent to resistance, called 'Contact resistance'.
The value of contact resistance is small and can be safely neglected when we mesure resistance of higher order. But for small resistance we can't neglect contact Resistance.
So, we have to look for a method which eliminate or bypass the error in mesurements due to contact resistance.
'Carey-Foster bridge' is one such device which is highly sensitive and can mesure low resistance which avoid this error in mesurements.

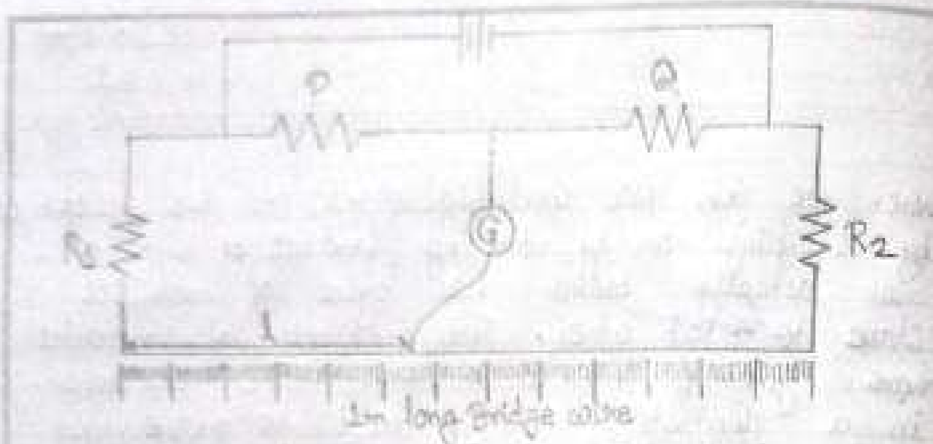

Figure 1: A schematic of Carey-Foster Bridge.

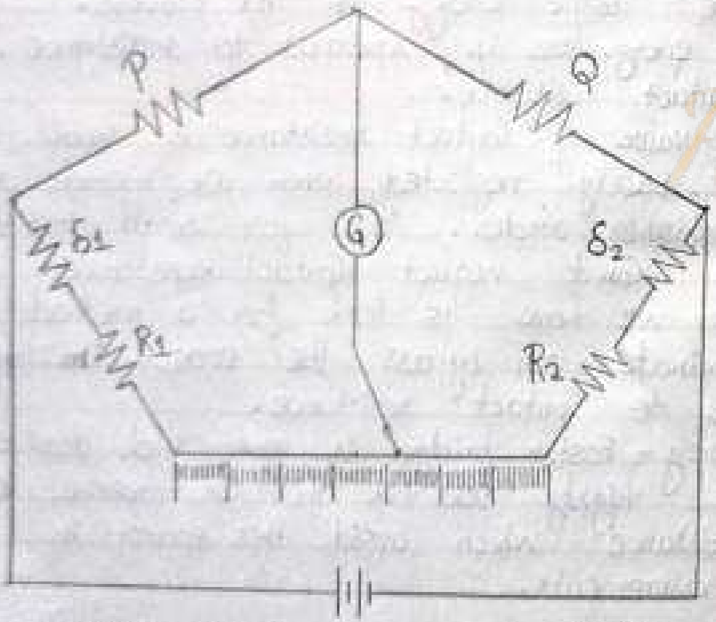

Figure 2: Another Schematic of Carey-Foster Bridge. This figure show the Contact resistance through δ1 and δ2.

Working Principle :-

The apparatus works on the principle of wheat-stone bridge.

Let's assume that the Contact resistance on the left and right hand side are equivalent to the resistance δ_1 and δ_2 respectively.
The Contact resistances δ_1 and δ_2 are unknown, small in value and there exist no way to mesure them.
Our goal is to mesure unknown resistance without evaluating δ_1 and δ_2.

If we get null point, i.e. no current through galvanometer, at a distance l_1 from left, then we can write,

$$\boxed{\frac{P}{Q} = \frac{R_1 + \delta_1 + R_w l_1}{R_2 + \delta_2 + R_w (1 - l_1)}} \quad --- (1)$$

or

$$\boxed{\frac{P}{Q} + 1 = \frac{R_1 + R_2 + \delta_1 + \delta_2 + R_w}{R_2 + \delta_2 + R_w (1 - l_1)}} \quad --- (2)$$

where R_w is the resistance per unit length of bridge wire.
The bridge wire is 1m long.

If we interchange R_1 and R_2, we get new position of null point at $l = l_2$, so we now have.

$$\boxed{\frac{P}{Q} = \frac{R_2 + \delta_1 + R_w l_2}{R_1 + \delta_2 + R_w(1 - l_2)}} \quad --- \quad (3)$$

or

$$\boxed{\frac{P}{Q} + 1 = \frac{R_1 + R_2 + \delta_1 + \delta_2 + R_w}{R_1 + \delta_2 + R_w(1 - l_2)}} \quad --- \quad (4)$$

from equ^n (2, 4) we get.

$$\boxed{R_1 - R_2 = R_w(l_2 - l_1)} \quad --- \quad (5)$$

Thus we have a relation independent of δ_1 and δ_2. we shall use this expression to determine unknown resistance.

Procedure :-

we have Eq. (5) two times to determine unknown resistance.
First we evaluate R_w. we set following values for different resistances.

$P = 1\Omega$
$Q = 1\Omega$
$R_1 =$ Resistance box
$R_2 =$ Copper strip $= 0\Omega$

we can find null point. Let's assume that null point is found at $l = l_1$.
Now we interchange R_1 and R_2, let's assume that new position of null point is $l = l_2$.
from eq. (5), we get,

$$\boxed{R_1 - 0 = R_w (l_2 - l_1)} \quad \text{--- (6)}$$

or

$$\boxed{R_w = \frac{R_1}{(l_2 - l_1)} \ \Omega/m} \quad \text{--- (7)}$$

Once R_w is evaluated, we use Eq. (5) again to determine unknown resistance.
Now we set following values for resistances:

$P = 1\,\Omega$ (same as before)
$Q = 1\,\Omega$ (same as before)
$R_1 =$ Resistance box (same as before)
$R_2 =$ Unknown resistance $= R\,\Omega$

we again find null point. Let's assume that null point is found at $l = l_1'$.
After Interchanging R_1 and R_2, i.e.
$R_1 =$ Unknown resistance $= R$
$R_2 =$ Resistance box.
if new position of null point is $l = l_2'$ then from eq. (5), we get,

$$\boxed{R_1 - R = R_w\,(l_2' - l_1')}$$

or

$$\boxed{R = R_1 - R_w\,(l_2' - l_1')}$$

The Unknown resistance can be calculated from above expression after substituting R_w from Eq. (7).

Observations :-

T-1 Determination of resistance per unit length of bridge wire, R_W Ω/cm :

$P = 1\Omega$, $Q = 1\Omega$, R_1 = Resistance box , R_2 = copper strip = 0Ω

S.No.	R_1 (Ω)	l_1 (cm)	l_2 (cm)	$(l_2 - l_1)$ (in cm)	$R_W = \frac{R_1}{(l_2 - l_1)}$ (Ω/cm)	Mean value of R_W
1	0.2	41.8	60.1	18.3	0.011	
2	0.5	33.9	66.1	32.2	0.015	0.0164 Ω/cm
3	1.0	20.5	77.9	57.4	0.017	
4	1.2	20.2	80.4	60.2	0.019	
5	1.5	15.0	85.6	70.6	0.021	

T-2 Determination of Unknown resistance, R :

$P = 1\Omega$, $Q = 1\Omega$, R_1 = Resistance box , R_2 = Unknown Resistance = R Ω

S.No	R_1 (Ω)	l_1' (cm)	l_2' (cm)	$(l_2' - l_1')$ (cm)	$R = R_1 - R_W(l_2' - l_1')$ (Ω)	Mean value of R
1	0.5	53.0	58.5	5.5	0.410	
2	0.7	47.3	52.4	5.1	0.618	

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S.No	$R_1(\Omega)$	l_1'(cm)	l_2'(cm)	$(l_2'-l_1')$	$R = R_1 - R_W(l_2'-l_1')$	Mean value of R
3	1.0	35.7	61.8	26.1	0.572	
4	1.2	35.0	64.3	29.3	0.720	0.642Ω
5	1.5	32.7	69.8	37.1	0.892	

T-3 Measurement of the radius of the cross-section of unknown resistance wire:

zero error = −20   least count of screw gauge = 0.001 cm

S.No	Mesurement along any direction.			Mesurement along prependicular direction.			Diameter	Mean diameter	Mean radius
	MS (cm)	CS (cm)	Total a (cm)	MS (cm)	CS (cm)	Total b(cm)	$d = \frac{a+b}{2}$	(d) (in cm)	$\left(r = \frac{d}{2}\right)$ (in cm)
1	0	34	0.054	0	29	0.049	0.0515	0.051	0.026 cm
2	0	32	0.052	0	30	0.050	0.051		
3	0	35	0.055	0	28	0.048	0.051		

zero error correction = 20 × 0.001 cm

= 0.02 cm

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Date 17-12-2021

Expt. No.

Zero error correction = 0.02cm
that is already applied in T-3.

T-4 Length of wire = 19.3cm

Calculations :-

From observation, we have

Unknown resistance R = 0.642 Ω

radius of the wire = 0.026 cm = 0.026×10^{-2} m

length of the wire = 19.3 cm = 19.3×10^{-2} m

$$\rho = R\left(\frac{A}{l}\right) = R\left(\frac{\pi r^2}{l}\right) = \frac{0.642 \times 3.14 \times (0.026 \times 10^{-2})^2}{19.3 \times 10^{-2}}$$

$$\boxed{\rho = 6.86 \times 10^{-7} \ \Omega m}$$

Results :-

The specific Resistance of the material of given wire is 6.86×10^{-7} Ωm.

Precautions :-

1) All the connections are to be made tightly.
2) Allow the current to flow when the readings are to be taken.
3) Jockey shouldnot dragged on wire, it should be lifted and made in contact with the wire.

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