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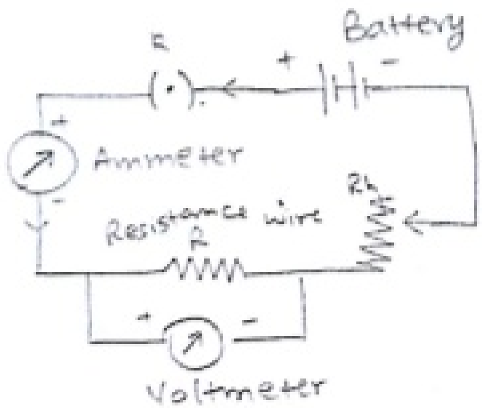
Aim :- To determine the resistance per cm of a given wire by plotting a graph of potential difference versus current



circuit to find the resistance of a wire

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Aim :- To determine the resistance per cm of a given wire by plotting a graph of potential difference versus current.

Apparatus :-

About 100 cm long resistance wire of about 10 ohm resistance in the form of coil, a battery eliminator or an accumulator or two dry cells (0 to 3V), d.c. voltmeter (range 3V), d.c. ammeter (range about 500 mA), a rheostat, one plug key, thick connecting wires, sand paper etc.

Theory

According to Ohm's law, "The current flowing through a conductor is directly proportional to the potential difference across its ends provided the physical conditions of the conductor (temperature, dimensions etc) remain the same.

Let 'I' be the current flowing through the conductor and 'V' be the potential drop across its ends,

then $I \propto V$

or $V \propto I$

or $V/I = \text{constant} = R$

or $R = V/I$ ...... working Formula

where R is a constant depending upon the dimensions (length and radius and material of the wire. R is called electrical resistance and it is expressed in ohm whereas V is measured in volt and the

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Observation Table

Variation of Potential Drop with Current

S.No.	Ammeter reading I (Ampere)		Voltmeter reading V (Volt)		Ratio V/I = R (ohm)
	observed I_0	Corrected $I = I_0 + (-e_1)$	observed V_0	Corrected $V = V_0 + (-e_1)$	
1	50	50	65	65	1.3
2	60	60	85	85	1.4
3	70	70	95	95	1.35
4	80	80	105	105	1.31
5	90	90	120	120	1.33

mean value of resistance, R = 1.33 ohm

Observation -

Ranges of instruments : Ammeter - 0-250 mA

Voltmeter - 0-500 mV

Least Counts of : Ammeter scale - 5 mA

Voltmeter scale - 20 mA

length of the resistance wire (l) - 28 cm current I in ampere.

A study of current-voltage relationship would require an arrangement in which potential drop V can be varied across the resistance wire and the corresponding current I can be measured.

With the variation of potential drop V, the variation of current I is noted. The actual I-V variation would be best depicted if a graph is plotted by taking the values of V along the abscissa (x-axis), and the corresponding values of I along the ordinate (y-axis).

Since Ohm's law requires that for a given conductor, the drop of potential 'V' across its ends is directly proportional to the current I, the (V-I) graph is expected to be a straight line. The slope (V/I) of this line is a measure of the resistance of the conductor.

Observations and Calculations

1. Ranges of instruments : Ammeter = 0-250 mA
   Voltmeter = 0-500 mV
2. least counts of :
   Ammeter scale = 5 mA
   Voltmeter scale = 20 mV
3. zero errors and zero corrections
   Zero error of the ammeter, e_1 = 0 A
   zero correction of the ammeter, $(-e_1)$ = 0 A
   zero error of the voltmeter e_2 = 0 V

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zero correction of the voltmeter $(-e_2)$ = 0 V

4. length of the resistance wire l = 38 cm

Graph -

Choose appropriate scales and plot a graph between the values of V corresponding to various values of I, taking I along the x-axis and V along the y-axis as shown.

Draw a straight line best fitting through all the points on the graph. Select two points A and B on the graph. Draw the line AC perpendicular to the x-axis and the line BC perpendicular to the y-axis through B.

Calculations :-

1. Calculate the value of slope of V-I graph.

$$\text{Slope} = \frac{\Delta V}{\Delta I} = \frac{AC}{BC} = \frac{\text{Reading (in Volt) at A} - \text{Reading at C}}{\text{Reading (in Amp) at C} - \text{Reading at B}}$$

2. Resistance per unit length $= \frac{R}{l}$ = 0.035 ohm cm^{-1}
= 3.5 ohm m^{-1}

Precautions

1. First of all, the circuit should be drawn and got checked.
2. The connecting wires used should be thick copper wire and the insulation of their ends should be removed by rubbing them with a sand paper.

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3. connections should be tight.

Result

i) Graph between Potential drop 'V' and the current through the conductor 'I' is a straight line.

ii) The resistance of the given wire is 1.33 ohm.

iii) The resistance per cm of the given wire is 0.035 ohm per cm.

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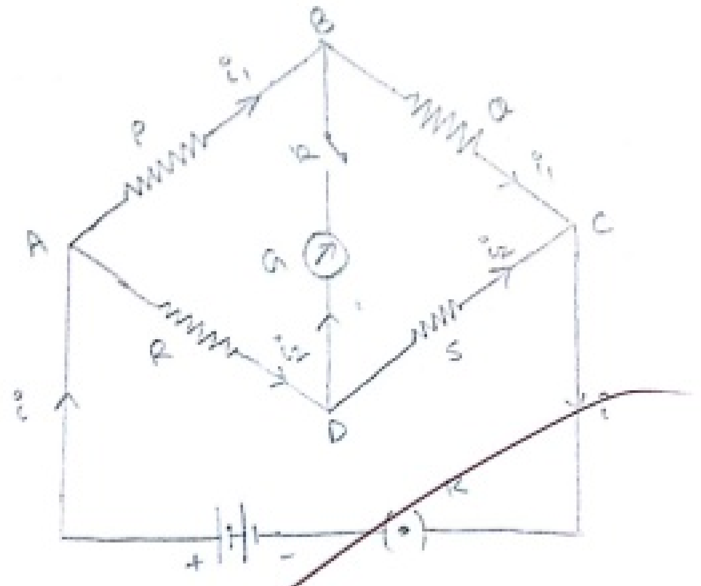
Aim :- To find the resistance of a given wire using a metre bridge and hence determine the specific resistance of its material.



Wheatstone's Bridge Network

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Aim :- To find the resistance of a given wire using a meter bridge and hence determine the specific resistance of its material.

Apparatus :-
A meter bridge, a wire about 1 metre long (of the material whose specific resistance is to be determined) a resistance box, a jockey, a key, a galvanometer a battery eliminator or a lechlanche cell, thick connecting wires, sand paper, screw gauge, S.W.G. tables etc.

Theory -
An accurate method to determine the value of a resistor is by using wheatstone's Bridge arrangement. The bridge consists of four resistor P, Q, R and S joined such that they form a quadrilateral ABCD as shown in fig. The terminals A and C are joined to two terminals of a cell. The other pair of junctions B and D are connected to a galvanometer G through a key K.
The current i drawn from the cell is divided at A into two parts. One part i_1 flows along the path ABC and the other part i_2 flows along ADC. Since the potential falls uniformly along the two conductors, it is possible to find two points B and D, such that they are at the same

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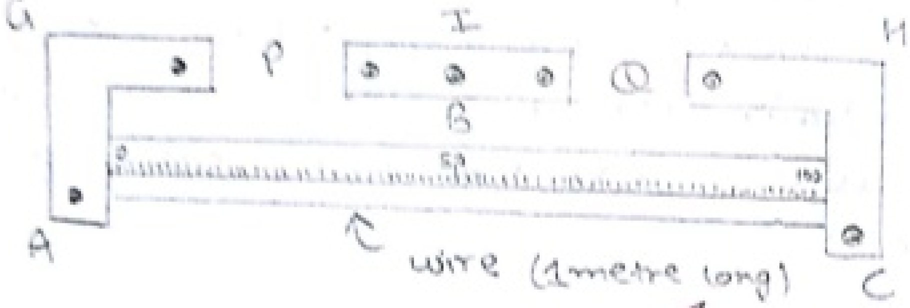

metre Bridge

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potential. If B and D are connected with a key K through a Galvanometer G, no current will flow throw G on closing key K. Hence there will be no deflection in the galvanometer and the bridge is said to be balanced. Let i_1 and i_2 be the currents in arms ABC and ADC respectively and let V_a, V_b, V_c and V_d be the potentials at the points A, B, C and D respectively in the balanced condition, then

$$V_a - V_b = V_a - V_d$$

and $$V_b - V_c = V_d - V_c$$

Applying ohm's law, we get

$$V_a - V_b = P i_1$$
$$V_b - V_c = Q i_1$$
$$V_a - V_d = R i_2$$
$$V_d - V_c = S i_2$$

Therefore, for the balanced bridge

$$P i_1 = R i_2$$
$$Q i_1 = S i_2$$

or $$\frac{P}{Q} = \frac{R}{S}$$

If three resistances Q, R and S are known the value of the fourth resistance P can be calculated

$$P = \frac{R}{S} \times Q$$

Metre Bridge ie Slide Wire Bridge

It is a simple apparatus based on the principle of Wheatstone's bridge. It consists of a metre long

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wire AC of uniform area of cross-section and stretched on a wooden board. A metre scale is fixed along it. The ends A and C are attached to two thick copper strips G and H. Another copper strip I is fixed between G and H to form two gaps for introducing resistance at P and Q. Screw terminals are attached at the ends of the copper strips and also in the middle of strip I at B for making connections.

Measuring an Unknown Resistance

Resistance X of unknown value under observation is inserted in the gap P and a resistance box RB is placed in gap Q. The terminal B is joined to one end of the galvanometer G whose other end is joined to a jockey J which slides along the wire AC. A known resistance Q is inserted in the resistance box by taking out the plug corresponding to it and the jockey is moved to a point, such that on pressing it on the wire AC at point D there is no deflection in the galvanometer. In this position, points B and D are at the same potential. Since the wire AC is of uniform area of cross section, the ratio of the resistance of arm AD to the resistance of arm DC is the same as the ratio of the length AD to the length DC.

Therefore, $\frac{X}{Q} = \frac{R}{S} = \frac{\text{Resistance of length AD}}{\text{Resistance of length DC}}$

$= \frac{k \times \text{length AD}}{k \times \text{length DC}}$

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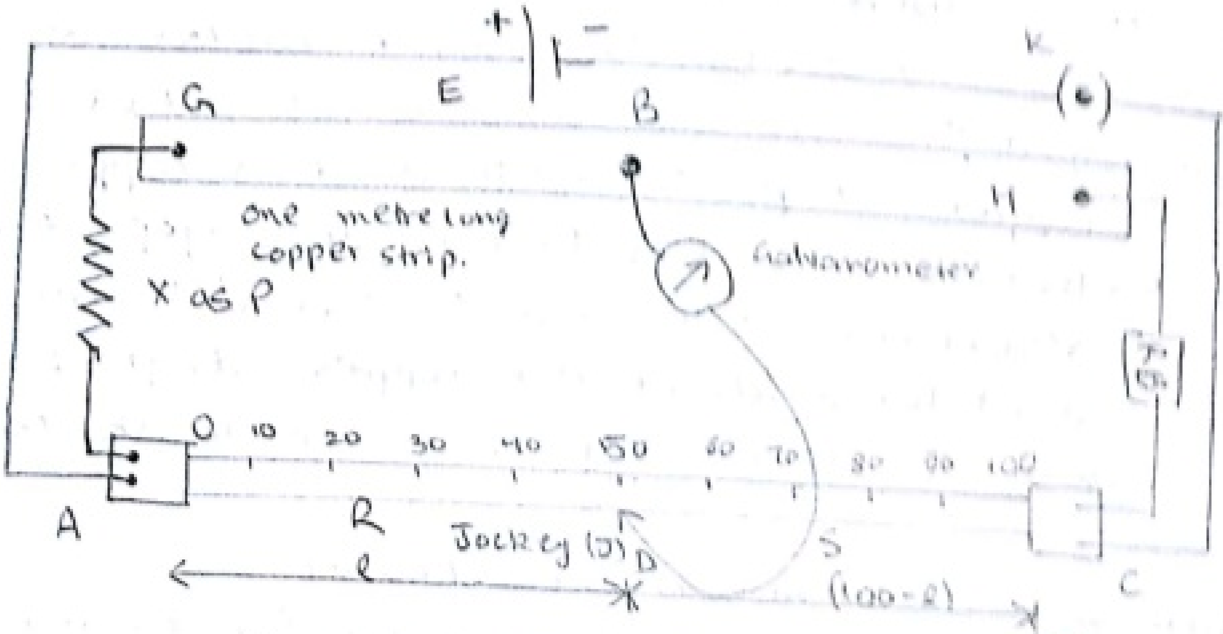
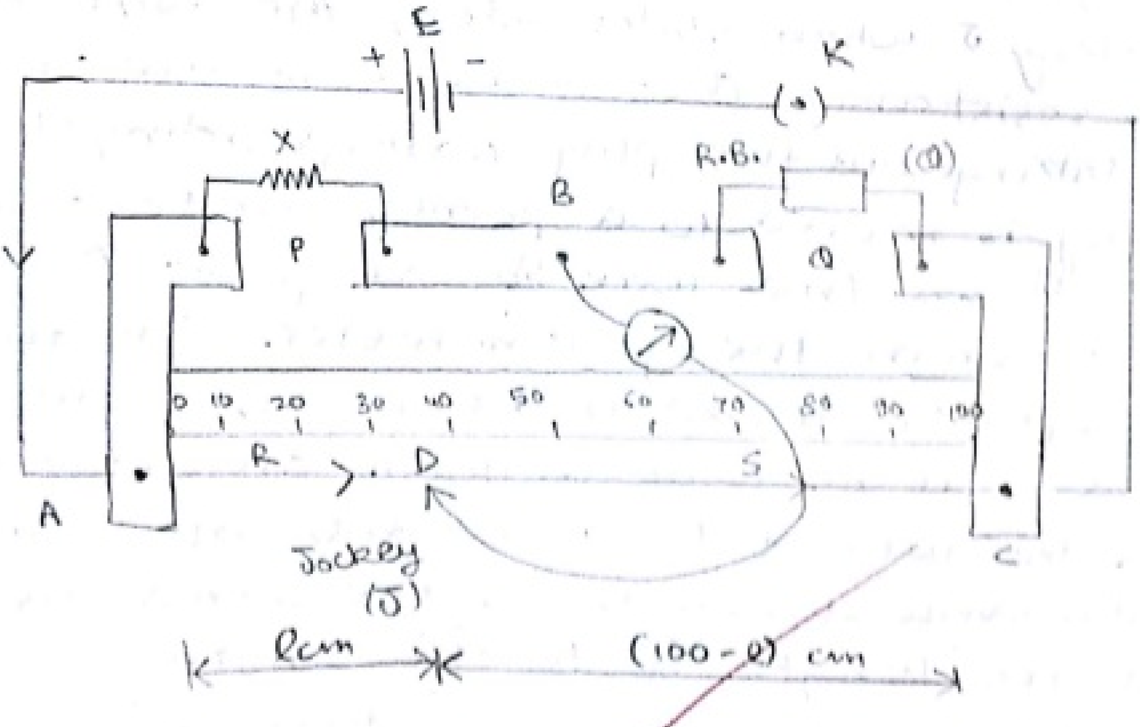


Another form of metre bridge



a) Measuring the unknown resistance of a wire by metre bridge.

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for a wire of uniform cross-section a, $R \propto l$ or $R = kl$. Here k is the resistance of wire per unit length.

If length AD = l cm, then length DC = (100 − l) cm

$$X = Q \times \frac{AD}{DC} = \frac{Q \times l}{100 - l}$$

Since l can be measured and Q is known, X can be determined

Another form of Metre Bridge

Another form of metre bridge used these days is shown in Fig. It differs from the conventional bridge in the manner that a metre long strip is fixed parallel to the one metre long constant wire at a distance of about 10 cm from it. Two terminals G and H are provided at the ends and another terminal B in the middle of the strip.

The connections are made as shown in Fig 3.8. The unknown resistance X is connected as P in between the terminals A and G and resistance box (R.B.) as Q between H and C one terminal of the galvanometer is connected to the terminal B on the strip and the other is connected to a jockey J which can be made to slide on the wire AC of the metre bridge. X and Q form one set of arms of the Wheatstone's Bridge and AJ and JC from the other set of arms as R and S, adjusted such that it balances the bridge, then

$$\frac{X}{Q} = \frac{\text{Resistance of length AJ}}{\text{Resistance of length JC}} = \frac{k.l}{k(100 - l)}$$

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Observation for resistance of wire

No. of Obs.	Resistance Q (ohm)	Balancing length AD = l (cm)	Length DC = 100 - l (cm)	$X = \frac{l}{100-l} \times Q = X_1$ (ohm)
1	0.5	62.2	37.8	0.82
2	0.7	54.0	46	0.82
3	1.0	45.2	54.8	0.81
4	1.5	35.5	64.5	0.82

mean value of resistance, $X = \frac{X_1 + X_2 + X_3 + X_4}{5} = 0.82$ ohm

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$$\frac{X}{Q} = \frac{l}{100-l}$$

where R the resistance per unit length cancels for a wire of uniform cross section and homogeneous composition.

$$X = \frac{l}{100-l} \times Q \quad \text{.... working formula}$$

Specific Resistance

The resistance of a resistor varies directly as its length L and inversely as its area of cross-section πr^2, where r is the radius of the wire.

$\therefore X \propto L$

and $X \propto (L/A)$ where $A = \pi r^2 = \frac{\pi d^2}{4}$.
r being the radius and d is the diameter of the wire.

Therefore $X = \rho \frac{4L}{\pi d^2}$, where ρ is specific resistance of the material of the coil.

$$\rho = \frac{\pi d^2}{4L} X \quad \text{.... working formula}$$

The values of d, L and X are substituted in the working formula to determine the value of specific resistance ρ.

Observations

1. Data available for the wire
   Material = manganin (usually manganin or constantan)
   Gauge (S.W.G) no. = 30 (if known)

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Observations for the diameter of a wire

No. of observations	main scale Reading S (cm)	Arular scale div. coinciding n	observed diameter $d_1 = S + na$	Corrected diameter $d = d_0 - e$
1.	0	53	0.53	0.23
2.	0	48	0.48	0.18
3.	0	49	0.49	0.19
4.	0	45	0.45	0.15

Mean corrected diameter (d) = 0.18 mm

mean radius (r) = d/2 = 0.9 mm

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Actual value of ρ_0 for the material from the tables of constants

$$\rho_0 = 5.45 \times 10^{-8} \text{ ohm-m}$$

Percentage Error in the value of ρ

$$\% \text{ error} = \frac{\rho - \rho_0}{\rho_0} \times 100 = 4.4 \%$$

Precautions

1. The ends of the connecting wires should be rubbed and cleaned with a sand paper. The connections should be neat, clean and tight
2. Plugs in the resistance box should be pressed and tightened by screwing them a little in the clockwise direction.

Sources of Error

1. The wire of the meter bridge may not be of uniform area of cross section throughout its entire length
2. The screw gauge may have backlash error due to loose fitting of its screw.
3. End corrections

Result

i) within the experimental error, the unknown value of resistance as determined by using a meter bridge is found to be 0.82 ohms

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ii) The value of specific resistance of the material of the wire is 5.60×10^{-8} ohm-m with a percentage error of 0.91 % per cent

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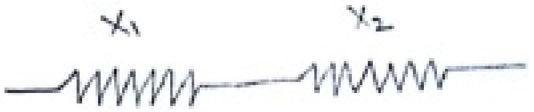
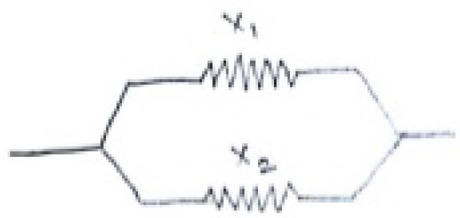
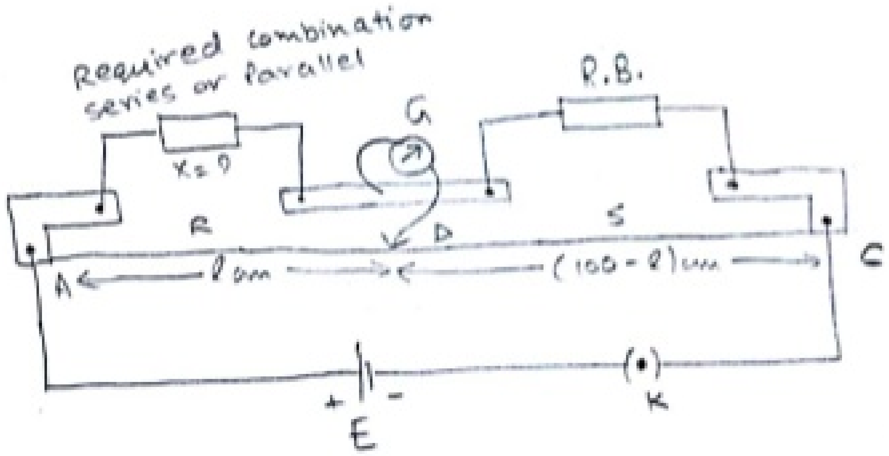
Aim :- To verify the laws of combination of resistances (in series and parallel) using a metre bridge.



Series combination



Parallel combination



Circuit diagram for study of the laws of resistances in series and parallel.

Aim :- To verify the laws of combination of resistances (in series and parallel) using a metre bridge

Apparatus - A meter bridge, three different resistances or resistance coils, a resistance box, a jockey, a one-way key, a galvanometer, battery eliminator or a daniell cell, thick connecting wires, sand paper etc

Theory -
laws of combination of resistances.

a) Series combination !
Two or more resistances $R_1, R_2, \ldots$ are said to be connected in series if they are connected end to end as shown in fig. a). The equivalent (or the total) resistance of this combination, R_s, between the ends A and D is given as :

$$R_s = R_1 + R_2 + R_3 \ldots$$

b) Parallel combination -
Two or more resistances R_1, R_2, R_3 are said to be connected in parallel when one end of each resistance is connected at one common point say A, and their other ends are connected to another common point say B, as shown in fig. The equivalent (or the total) resistance R_p of the combination is given by the relation

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$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots$$

The equivalent resistance R_p would thus be smaller than the smallest resistance used in the combination. In other words, R_p will be smaller than the smallest of R_1, R_2, R_3 ......

Metre Bridge

The value of an unknown resistance X of a resistor can be determined by using metre bridge as explained in the theory of experiment No. 2 11 is given by the formula

$$X = Q\left(\frac{l}{100-l}\right)$$ ..... working formula

The values of given individual resistances X_1, X_2 and X_3 are determined first and thereafter those of the series and parallel combinations.

The constrains on time may not permit the verification of laws by using three resistors so only two resistors may be used.

Observations and Calculations

Verification

Compute the values X_1 X_2 X_s and X_p by substituting the corresponding values of l and Q in the relation

$$X = Q\frac{l}{100-l}$$

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Observations and Calculations

Resistance used	No. of Obs.	Resistance Q (ohm)	Length AD = l	Length DC = 100 − l	Resistance $X = \frac{Q \cdot l}{100-l}$	Mean value of the resistance X (ohm)
X_1	1	2	40.5	59.5	2.93	2.76
	2	4	60.5	39.5	2.61	
	3	5	64.5	35.5	2.25	
X_2	1	2	55	45	1.63	1.73
	2	4	69.6	30.4	1.76	
	3	5	72.0	28	1.94	
X_1 and X_2 in series	1	2	30.2	69.8	4.62	4.79
	2	4	46.0	54.0	4.69	
	3	5	50.5	49.5	4.90	
X_1 and X_2 in parallel	1	2	63.0	37.0	1.17	1.17
	2	4	77.0	23.0	1.19	
	3	5	81	19.0	1.17	

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Verifying the law of series combination

compute the value :

a) series resistance by theoretical formula

$X'_s = X_1 + X_2 = 4.53$ ohm

b) Experimental value of the series combination,

$X_s = 4.70$ ohm.

within the experimental error, experimental and theoretical values of the series combination of X_1 and X_2 ie X_s and X'_s respectively are almost equal ie $X_s \approx X'_s$.

Hence the law of combination of resistance in series stands verified.

Verifying the law of parallel combination

compute the value of :

a) Parallel combination by theoretical formula

$$\frac{1}{X'_p} = \frac{1}{X_1} + \frac{1}{X_2}$$

or

$$X'_p = \frac{X_1 X_2}{X_1 + X_2}$$

b) Experimental value of the parallel combination.

$X_p = 1.17$ ohm

Since, within experimental errors, the experimental value of parallel combination of X_1 and X_2, ie X_p and theoretical value X'_p are equal,

ie $X_p \simeq X'_p$.

so the law of combination of resistances in parallel also stands verified.

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Precautions

1. The connecting wires used should be thick copper wires and the insulation of their ends should be removed by rubbing them with a sand paper.
2. Connection should be tight.

Result

1. The values of the individual resistances measured by the metre bridge are:
   $X_1 = \underline{2.76}\ \Omega$ $X_2 = \underline{1.73}\ \Omega$
2. The equivalent resistance of series combination of X_1 and X_2 is $X_s = \underline{4.53}\ \Omega$
3. The equivalent resistance of parallel combination of X_1 and X_2 is $X_p = \underline{1.17}\ \Omega$
4. The value of series combination of X_1 and X_2, $X_1 + X_2 = \underline{4.53}\ \Omega$ whereas $X_s = \underline{4.79}\ \Omega$ Since X_s is nearly equal equal to $X_1 + X_2$, the law of series combination of resistance stands verified.
5. The sum of the reciprocals of X_1 and X_2
   $\frac{1}{X_1} + \frac{1}{X_2} = \underline{0.94}$ (ohm)$^{-1}$ whereas $\frac{1}{X_p} = \underline{0.94}$ ohm^{-1}
   or $X_p = \underline{1.06}$ ohm

Since the sum of the reciprocal of X_1 and X_2 ie $\left(\frac{1}{X_1} + \frac{1}{X_2}\right)$ ie X_p' is nearly equal to X_p. their difference $X'_p - X_p = \underline{0.106}$ (ohm) being negligibly small, so, the law of combination of resistances

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in parallel stands verified.

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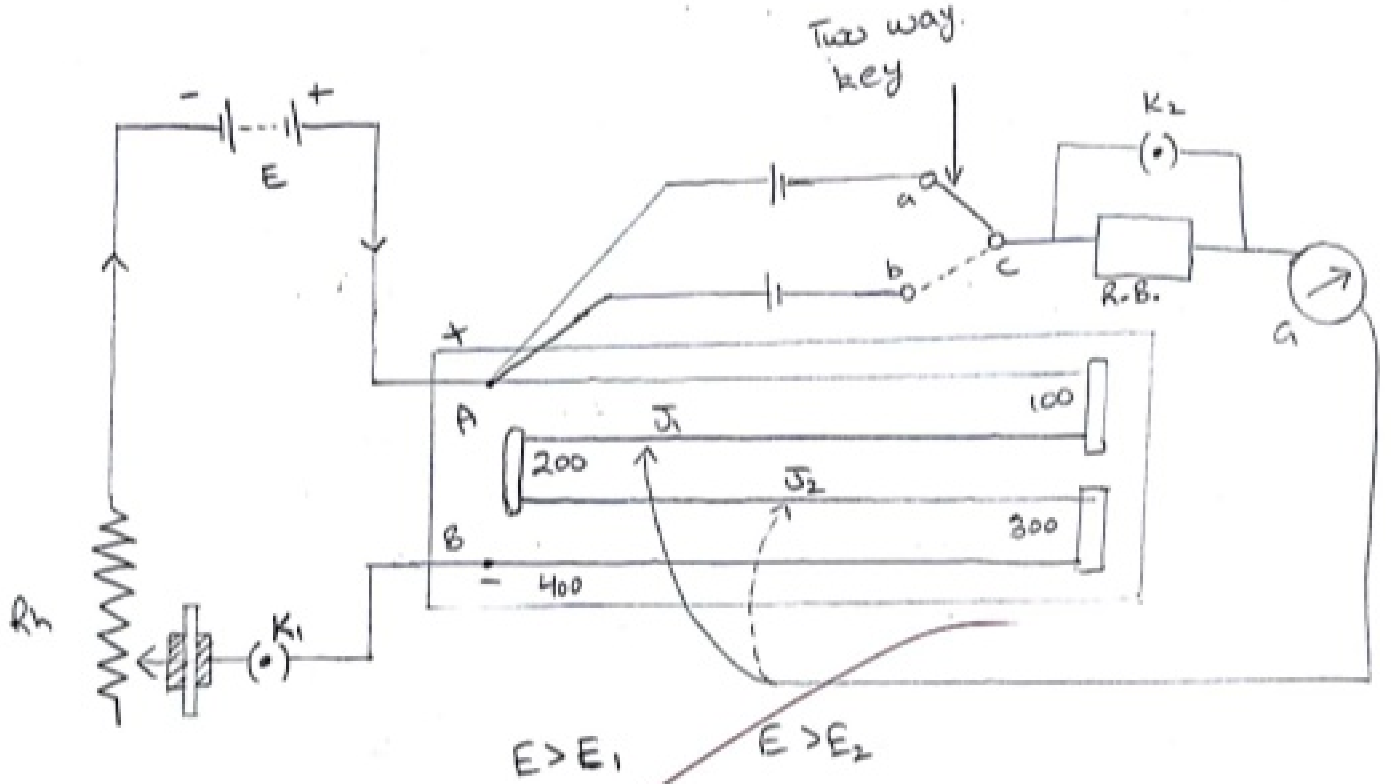
Aim - To compare the e.m.f.s of two given primary cells (Daniel and Lechlanche) using a potentiometer



Circuit diagram for comparison of emfs of two primary cells.

Aim :- To compare the emfs of two given primary cells (Daniell and Lechlanche) using a potentiometer.

Apparatus -
A potentiometer (with 10 wires stretched on the board), with a sliding jockey, two primary cells (Daniel and lechlanche), a one-way key, a plug-type resistance box (0 to 100Ω), two-way key, a weston type galvanometer, a battery or battery eliminator, a low resistance rheostat about 20Ω, one-way keys needed will be two, as is clear from K_1 and K_2 in the figure 4.2 ~~conducting~~ connecting wires and sand paper.

Theory
Let the two primary cells whose e.m.f.s are to be compared be so connected in the circuit that their positive poles are joined together to the end A of the potentiometer wire AB and their negative poles are joined to a galvanometer through a two-way key a,b,c. The other terminal of the galvanometer is connected to a jockey J as shown in fig 4.2. The two primary cells with emf's E_1 and E_2 can be connected in turn to the sliding contact J through the galvanometer G with the help of the two-way key a b c. Let a steady potential difference be maintained (using the battery E and rheostat Rh) across the ends of the wire AB, the end A being at higher potential than the end B.

By closing the gap ac in the two-way key when the cell E_1 is connected in the circuit and by sliding the jockey J, a position of the null deflection in the galvanometer is found at J_1. Let l_1 be the length AJ_1 of the wire.

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Observation Table

No. of Obs.	Balance length when E_1 Lechlanche cell is in the circuit l_1 (cm)	Balance length when E_2, Daniel cell is in the circuit l_2 (cm)	Ratio $\frac{E_1}{E_2} = \frac{l_1}{l_2}$
1.	576	422	1.36
2	569	440	1.293
3.	453	335	1.352
4.	448	333	1.346
5	451	334	1.350
6.	460	340	1.353

Mean value of $\frac{E_1}{E_2}$ = 1.337

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Similarly, on joining the terminals b and c ie. using the cell E_2, the length l_2 is determined for null deflection. Now according to the principle of potentiometer as discussed, we have

$$E_1 = kl_1$$

$$E_2 = kl_2$$

where k is the potential gradient ie drop of potential per unit length

$$\frac{E_1}{E_2} = \frac{kl_1}{kl_2} = \frac{l_1}{l_2}$$

$$\boxed{\frac{E_1}{E_2} = \frac{l_1}{l_2}}$$ working Formula

where E_1 and E_2 are e.m.f.s of the two cells of low internal resistance; l_1 and l_2 are respectively the balancing lengths, when E_1 and E_2 are connected to the circuit.

Observations

1. No. of wires on the potentiometer board = 4 (usually 10 in a good instrument)
2. Range of Voltmeter ~~for observing~~ emfs. of battery and cells = 1 V
3. Least count of the Voltmeter scale = 0.5 V
4. Source of supply of current to auxiliary circuit = ______ (Lead batteries or eliminator)
5. Drop of potential across the battery E = 4 V.
6. Drop of potential across the cell E_1 (Lechlanche) = 2 V
7. Drop of potential across the cell E_2 (Daniell) = 3 V

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Precautions

1. Ensure that emf of battery E is greater than E_1 and E_2 of the cells
2. The wires of the potentiometer should be thoroughly cleaned
3. All the positive terminals should be connected at one point.

Sources of Error

1. Potentiometer wire may not be having uniform cross-section throughout its length
2. Heating of the potentiometer wire may introduce some error.
3. Resistances at the ends of wire of potentiometer may not be negligible

Result

The ratio of e.m.f.s. (expected value (1.35 to 1.55)) of E_1/E_2 for Lechlanche cell to Daniell cell = 1.337

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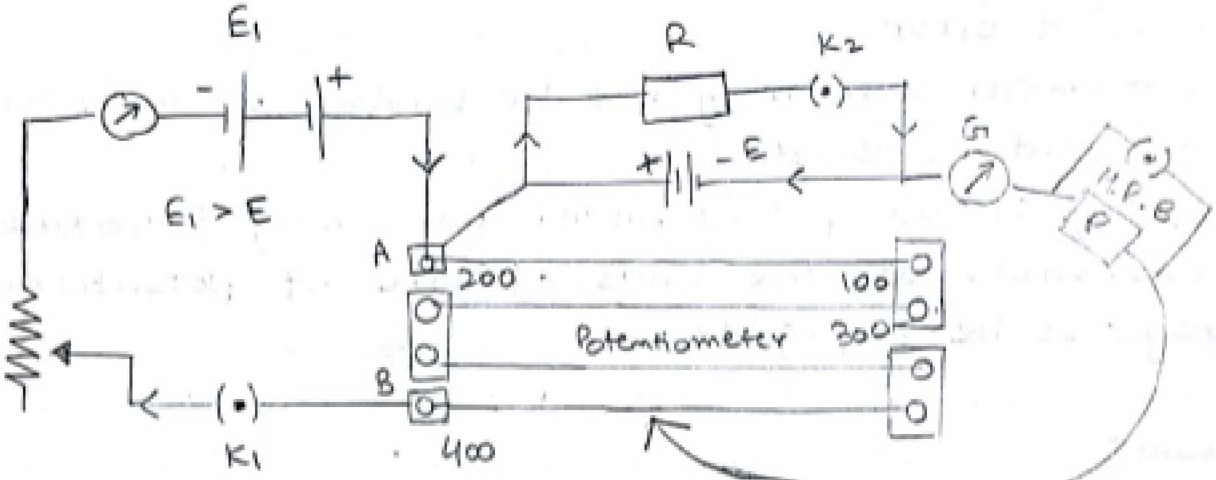
Aim:- To determine the internal resistance of a given primary cell by using a potentiometer.



Internal Resistance of a cell, circuit diagram.

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Aim - To determine the internal resistance of a given primary cell by using a potentiometer

Apparatus

A potentiometer, a rheostat, battery eliminator or cells in series (e.m.f. of battery $E > E_1$ of the cell), two one-way keys, a Lechlanche cells, a resistance box (0 to 20 ohms), a R.B. (0 to 2000Ω), a jockey, a galvanometer, connecting wires etc.

Theory -

If a cell of emf E and ~~potential~~ internal resistance r, connected to an external resistance R, then the circuit has the total resistance (R+r). The current I in the circuit is given by $I = \frac{E}{R+r}$ $E = I(R+r)$

Hence, $V = IR = E - Ir$

This means, V is less than E by an amount equal to the fall of potential inside the cell due to its internal resistance. from the above equation,

$$\frac{r}{R} = \frac{E-V}{V} \qquad r = R\,\frac{E-V}{V}$$

Using potentiometer, we can adjust the rheostat to obtain the balancing lengths l_1 and l_2 of the potentiometer for open and closed circuits respectively.

Then, $E = kl_1$ and $V = kl_2$, where k is the potential gradient along the wire

Now we can modify the equation for getting the internal resistance of the given cell, by using the above relations as

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Observations

Potential drop across the battery E_1 = 4 volt
Potential drop across the cell E = 2 volt

No. of Obs	R (ohm)	Balancing length for Lechlanche cell (in cm) Open circuit when key K_2 open length l_1 (cm)	Closed circuit when key K_2 closed length l_2 (cm)	Internal Resistance $r = R \times \frac{(l_1 - l_2)}{l_1}$ (ohm)
1	10	146.0	112	3.03
2	10	143.5	118	2.16
3	10	251	193	3.0
4	10	172.5	132.3	3.0

Result -
The internal resistance of the given Lechlanche cell varies with the current drawn from it and its determined value lies between 2.16 and 3.03 ohms

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$$r = \frac{R(l_1 - l_2)}{l_2}$$ ... working formula

Precautions

1. The cell whose internal resistance is to be determined, should not be disturbed during the experiment. The disturbance may alter the internal resistance of the cell.
2. As soon as the observations are taken, the plugs K_1 and K_2 should be taken out to avoid too much heating of the potentiometer wire as well as that of the resistance box coils from box P.
3. Ensure that e.m.f. of battery E is greater than E_1 and E_2 of the cells.
4. The wires of the potentiometer should be thoroughly cleaned

Sources of Error

1. Potentiometer wire may not be of uniform area of cross-section throughout its entire length.
2. If the end resistances of potentiometer wire are not taken into account, some error may creep in.

Result

The internal resistance of the given lechlanche cell varies with the current drawn from it and its determined value lies between 2.16 and 3.03 ohms

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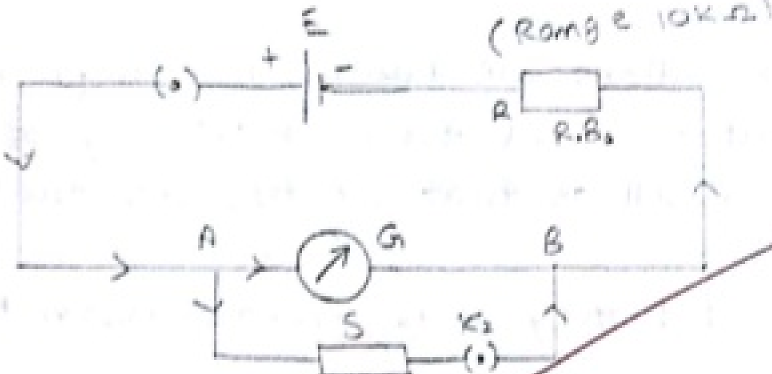
Aim - To determine the resistance of a galvanometer by half deflection method



Circuit for determination of resistance of galvanometer by half deflection method

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