AIM

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

APPARATUS AND MATERIAL REQUIRED

A metre bridge, a sensitive galvanometer, two different resistances (carbon or wire-wound resistors), a resistance box, a jockey, a rheostat, a plug key, a cell or battery eliminator, thick connecting wires and a piece of sand paper.

PRINCIPLE

When two resistances R_1 and R_2 are connected in series, the resistance of the combination R_S is given by

(E 3.1)

$$R_S = R_1 + R_2$$

When connected in parallel, the resistance R_P of the combination is given by

(E 3.2)

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$$

PROCEDURE

1. Set up the circuit as shown in Fig. E 3.1.

2. Tighten all plugs in the resistance box (R_{BOX}) by rotating and pressing each plug to ensure that all plugs make good electrical contacts. Clean the ends of connecting wires using a sand paper before making the connections.

3. Remove some plug(s) from the resistance box to get suitable value of resistance R. Obtain the null point D on the metre bridge wire by sliding the jockey between ends A and C as was done in Experiment 2.
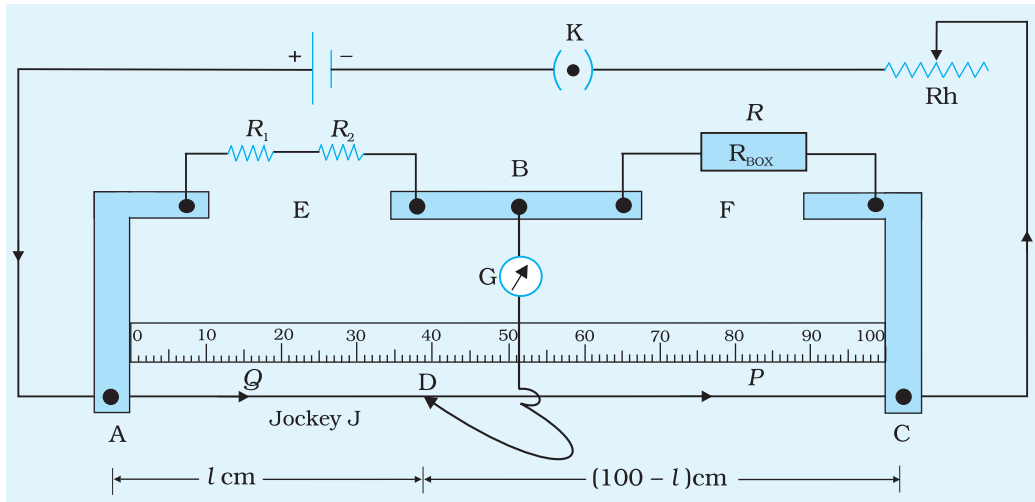
Fig. E 3.1 *Resistances R_1 and R_2 connected in series to one arm of a metre bridge*

4.   Note resistance *R* and lengths AD and DC in the observation table.

5.   Calculate the experimental value of the equivalent series resistance (*X*) of combination of resistances as shown in Table E 3.1.

6.   Repeat the experiment for four more values of resistances *R*. Obtain the mean value of unknown resistance.
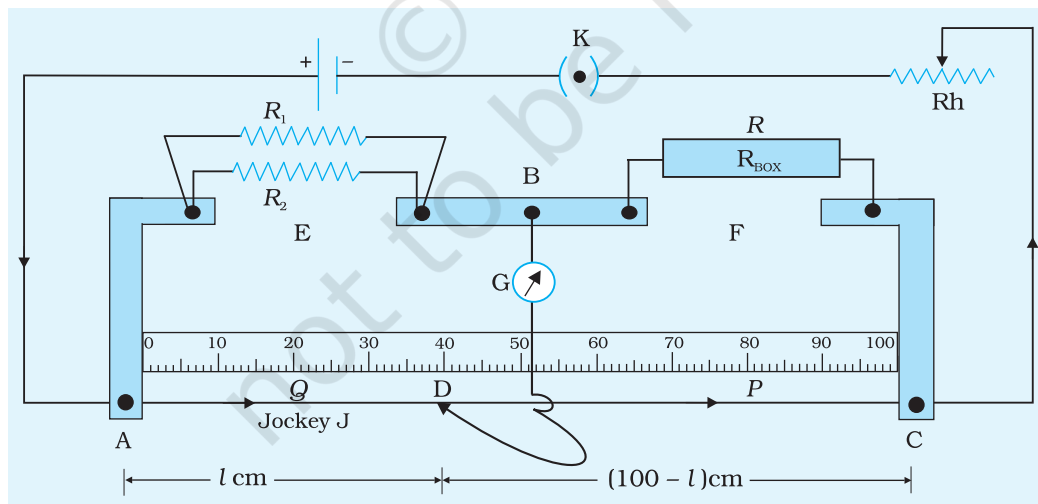

Fig. E 3.2 *Resistances R_1 and R_2 connected in parallel to one arm of a metre bridge*

7.   Repeat steps 2 - 6 by connecting resistances R_1 and R_2 in parallel as shown in Fig. E 3.2 and calculate the experimental value of the equivalent parallel resistance (*X*) of combination of resistance.

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OBSERVATIONS

Table E 3.1: Series and parallel combination of resistances

	Sl No.	Resistance R (ohm)	Length AD = l (cm)	Length DC, l' = 100 - l (cm)	Unknown resistance $X(R_S \, or \, R_P) = \dfrac{R \times l}{l'}$ (ohm)	ΔR_S or ΔR_P (ohm)
R_1 and R_2 in series, R_S	1 2 -- 5					
					Mean R_S =	
R_1 and R_2 in parallel, R_P	1 2 -- 5					
					Mean R_P =	

CALCULATIONS

1. The theoretically expected value of the series combination of resistances is $R_S = R_1 + R_2$

   Note that R_1 and R_2 are to be obtained from colour code on carbon resistors or are the given values in case of resistances made of wires of materials like nichrome, constantan etc.

2. Theoretically expected value of the parallel combination of resistances is $R_P = \dfrac{R_1 \, R_2}{R_1 + R_2}$

Error

In estimating errors, we have presumed that error in R is zero i.e., R is expected to be the same as indicated on resistance box.

(E 3.3)

In such a case, $$\frac{\Delta R_S}{R_S} = \frac{\Delta l}{l} + \frac{\Delta l'}{l'}$$

where R_s, l and l' values are to be taken from the Observation Table E 3.1, Δl, $\Delta l'$ indicate the least count of the measuring scale on the metre bridge.

i.e.
$$\Delta R_S = R_S \left[\frac{\Delta l}{l} + \frac{\Delta l'}{l'} \right]$$
(E 3.4)

Similarly,
$$\Delta R_P = R_P \left[\frac{\Delta l}{l} + \frac{\Delta l'}{l'} \right]$$
(E 3.5)

Maximum of the five values of ΔR_S and ΔR_P should be reported as the estimation in errors. It can be seen from equation (E 3.4) and (E 3.5) that the error will be minimum if balancing lengths $l \approx l'$.

Therefore the null points should be obtained in the central region of the wire AC. For this reason, it is essential to plug out resistances from resistance box such that resistances in the left and right gaps are comparable.

RESULT

Table E 3.2: Theoretical and experimental values of resistance

	Theoretically expected resistance(Ω)	Experimentally obtained resistance (Ω)
Series Combination	$R_1 + R_2$	$R_S \pm \Delta R_S$
Parallel Combination	$\dfrac{R_1 R_2}{R_1 + R_2}$	$R_P \pm \Delta R_P$

R_S and R_P are the mean values of equivalent resistance for the combination of R_1 and R_2 in series and in parallel respectively.

PRECAUTIONS

1. All the connections and plugs should be tight.
2. Jockey should be moved gently over the metre bridge wire.
3. Plug keys of the resistance box should be made tight by rotating it in clockwise direction.
4. Null points should be in the central region of the wire (30 cm to 70 cm).

SOURCES OF ERROR

1. The jockey should not be pressed too hard on the metre bridge wire. Otherwise, the wire may become non-uniform during the course of time.

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2. The length measurement l and l' may have error if the metre bridge wire is not taut and along the scale in the metre bridge.

3. If large current is passed for a sufficiently long time, the wire AC may get heated and its resistance may change considerably during the time of experiment.

4. Galvanometer pointer is expected to be at zero when no current flows through it. However, many a time it is observed that it is not so. In such cases, pointer has to be adjusted to zero by gently moving the screw below the scale with the help of a screw driver. Otherwise, null point must be obtained by sliding the jockey on wire AC and observing the point, where tapping the galvanometer does not produce any deflection in it.

5. Many a time, it is found that the resistance offered by resistance box is not the same as is indicated on it. Therefore, the error in R will cause an additional error in the result.

DISCUSSION

1. It may be noted that if carbon resistors are used, ΔR_1 and ΔR_2 are to be obtained from tolerance limits shown by band of the colour codes* marked on them and error ΔR_S and ΔR_P can also be calculated using these values as shown in *Example 2.10 (p.27) in PHYSICS Textbook for Class XI Part-I (NCERT, 2006).* Maximum of values of ΔR_S and ΔR_P so obtained together with that from equations (E 3.4) and (E 3.5) should be reported as estimation in errors.

2. The accuracy with which the null point can be detected also depends upon the sensitivity of the galvanometer. To investigate sensitivity, find the distance through which the jockey has to be moved to cause a just perceptible deflection of the galvanometer. Make a note of the range of distance over which null point is obtained at all points. Ideally, this range should not be more than the least count of the measuring scale.

3. In some cases, it is possible that the bridge wire is not exactly 100 cm long. In such cases its exact length should be used for the calculation.

4. If resistances R_1 and R_2 are made of wires of materials like constantan, nichrome etc., their values along with the corrected errors in their measurement should be considered for calculating equivalent resistance.

SELF ASSESSMENT

1. Comment on the difference between theoretically expected and experimentally obtained values of the effective resistances.

* For details of colour codes, see appendix 3.

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2. Given n resistors of resistance R each, how will you combine them to get the maximum and the minimum effective resistance? Extend this experiment using filament of bulbs as resistors.

3. Identify some method(s) to reduce the effect of 'end-resistance' at connections between the wire and copper strip or because of the improper soldering of wire.

4. How will the sensitivity of metre bridge change under following condition?

   Rheostat head is moved from minimum resistance to maximum resistance positions.

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Replace the galvanometer with a torch bulb and repeat the experiment. Explain the variation in the glow of the bulb with position of jockey on wire AC (Fig. E.3.1).

2. Making use of your observations, plot a graph between $\left(\dfrac{l'}{l}\right)$ and R taking $\left(\dfrac{l'}{l}\right)$ on y-axis and R on x-axis. Find the unknown resistance from the slope of the graph.

3. Use a wire of arbitrary length L. Measure its resistance across ends A and B, say R_1, using the metre bridge. Next, fold the wire so as to reduce its length to $(L/2)$ and measure the new resistance, say R_2, across the ends A′ and B′. Finally, fold it again and repeat the observation for resistance across ends A″ and B″. Plot a graph of n (number of folds) and the effective resistance, by folding the wire a number of times and obtaining resistances as described above. Take care that folded wires do not make electrical contact with each other at any point except at their ends (A, B, A′, B′ and A″, B″).
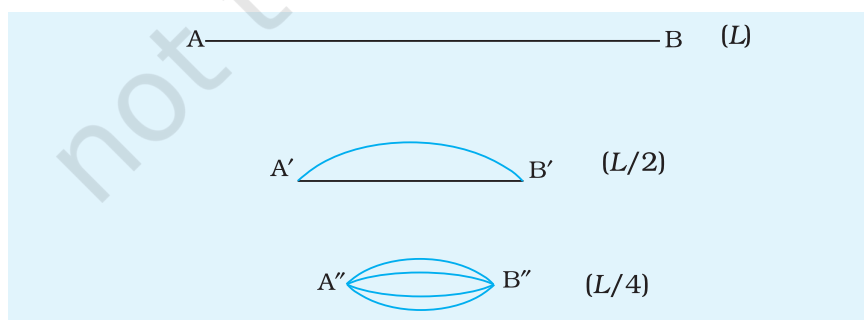
A——————————————————————— B   (L)

A′ ⌒ B′   ($L/2$)

A″ ⌒⌒ B″   ($L/4$)

Fig. E 3.3