AIM

To compare the emf of two given primary cells (Daniel and Leclanche cells) using a potentiometer.

APPARATUS AND MATERIAL REQUIRED

Potentiometer, a Leclanche cell, a Daniel cell, a two way key, a resistance box plug type (0 to 1000 Ω), a galvanometer (weston type), a voltmeter (0-3 V), a battery eliminator/lead accumulator, a low resistance rheostat (about 20 Ω), two one-way keys, connecting wires and sand paper.

DESCRIPTION OF APPARATUS

Potentiometer

A potentiometer consists of a uniform wire AB of low temperature coefficient of resistance stretched over a uniform wooden scale Fig. E 4.1(a). A B is often 100 cm, but for better accuracy it is also made of wire of length 400 cm or 1000 cm. Potentiometer wire is usually fixed on a wooden board with a 100 cm scale fixed alongside. To keep the arrangement compact, the wire is sometimes folded as shown in Fig. E 4.1(b) and Fig. E 4.1(c).
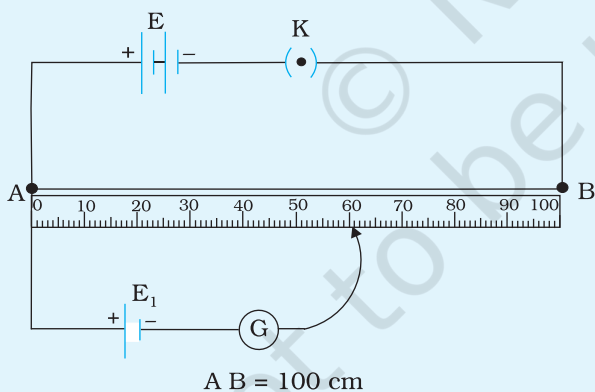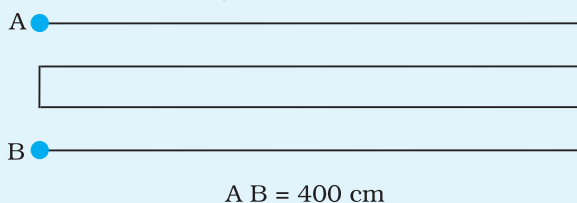
A B = 100 cm

Fig. E 4.1 (a)
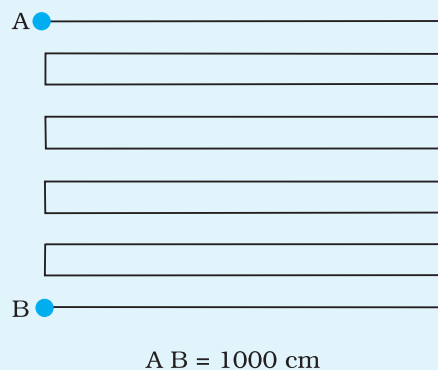
A B = 400 cm

Fig. E 4.1 (b)

A B = 1000 cm

Fig. E 4.1 (c)

PRINCIPLE

With the help of a voltmeter we can measure only the potential difference between the two terminals of a cell, but using a potentiometer we can determine the value of emf of a given cell. The two primary cells whose emfs are to be compared, are so connected in the circuit that their positive terminals are joined together to the end A of the potentiometer wire AB and their negative terminals 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. A resistance box, R_{BOX}, shunted with a key across its terminals, is also connected in the circuit between the two way key and the galvanometer G as shown in Fig. E 4.2.

The two primary cells with emfs E_1 and E_2 are connected in turn to the sliding contact J through the galvanometer G with the help of the two way key a, b, c.
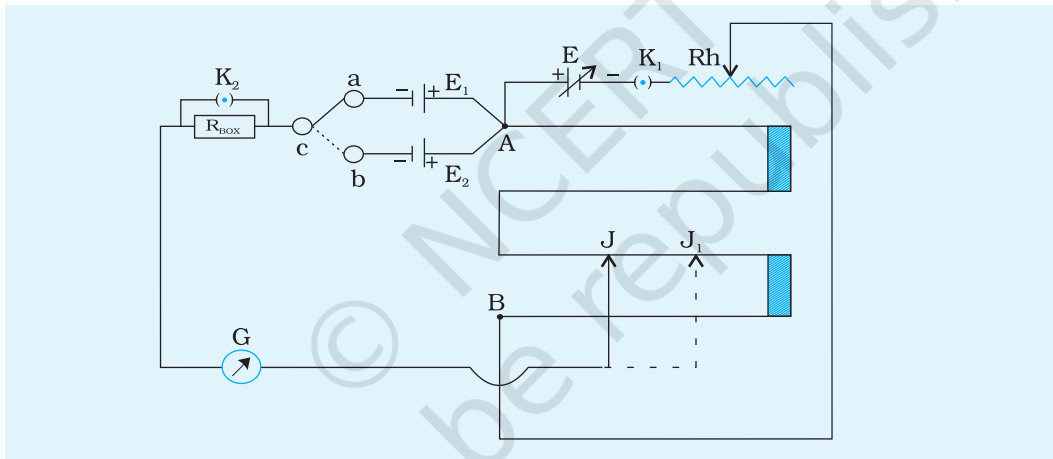

Fig. E 4.2 *Circuit to compare emf of two primary cells*

A steady potential difference could be maintained by using the battery E and rheostat Rh in series across the ends of the wire AB; the end A being at higher potential than the end B. Note that the emf $E >$ emf E_1 and also emf $E >$ emf E_2.

Close the gap 'a c' in the two way key to bring the cell E_1 in the circuit. Slide the jockey on the potentiometer wire to obtain null deflection in the galvanometer. Let it be at J. Note down the length AJ as $l_1$cm. Similarly, bring E_2 into circuit by closing the gap 'b c' and obtain the null point J_1 by sliding the jockey along the wire. Note the length AJ_1 as l_2 cm.

Now, according to the principle of potentiometer, when a steady current flows through a wire of uniform thickness and material, potential

difference between any two points on it is directly proportional to the length of the wire between the points. Thus,

$$V \propto l$$

$$V = \phi\, l$$

where ϕ is potential gradient.

The length of potentiometer wire is increased to decrease ϕ. A lower value of ϕ makes the potentiometer more sensitive and accurate. In case of two cells we have

$$E_1 = \phi\, l_1$$

$$E_2 = \phi\, l_2$$

where E_1 and E_2 are emfs of two cells, l_1 and l_2 are the balancing lengths when E_1 and E_2 are connected to the circuit respectively and ϕ is the potential gradient along the potentiometer wire.

$$E_1 / E_2 = \phi\, l_1 / \phi\, l_2 = l_1 / l_2$$

PROCEDURE

1. Make the circuit connections according to Fig. E 4.2. Connect positive terminals of the battery E and the two cells E_1 and E_2 to zero at end A of the potentiometer wire.

2. Connect negative terminal of E to the end B of the potentiometer wire through a one way key K_1 and a rheostat.

3. Connect negative terminals of the cell E_1 and E_2 to the terminals 'a' and 'b' of the two way key.

4. Shunt a resistance box R_{BOX} through a key K_2. Connect common terminal of the two way key to one end of R_{BOX}.

5. Connect other end of the resistance box to a galvanometer whose other end is joined to a jockey. Jockey can be slided on the potentiometer wire to obtain null deflection in the galvanometer.

6. Bring the cell E_1 in the circuit by inserting the plug between the gaps 'a' and 'c' of the two way key.

7. Leave the key K_2 open. Make rheostat resistance minimum. Take out high resistance (of the order of thousand ohm) from the resistance box. Make contact of the jockey at the zero end of the potentiometer wire. Note the direction of deflection in the galvanometer.

8. Next, move the jockey to bring it in contact with the other end of the wire. Note whether the direction of deflection of the galvanometer needle is opposite to that observed in step 7.

9. If the deflection of galvanometer needle is in opposite direction in the above two situations, connections are correct. If not, look out for the reason. Connections might be loose or emf of the battery E might be less than that of the cells E_1 and E_2. Make necessary changes as required.

10. Slide the jockey gently over the potentiometer wire till you get null deflection in the galvanometer. Plug in the key K_2 to get the accurate position of the null (or balance) point. The resistance in the resistance box limits the current flowing through the galvanometer. Near the balance point, the current flowing through the galvanometer is small, insertion of the key K_2 short circuits the resistances and hence increases the current. This improves the sensitivity of balance point detection.

    Note the length of the wire AJ, and record it as l_1. Repeat detection of balance point while moving the jockey in opposite direction and record the second value of l_1.

11. Next bring E_2 in the circuit by inserting plug between the gaps 'b' and 'c' of the two way key. Obtain the balance point J_1 in the same way as you did in finding l_1 and note the length AJ_1 as l_2.

12. Repeat steps 6 to 11 three times by shifting the contact point of the rheostat and calculate l_1/l_2 for each set of readings, for E_1 and E_2.

13. Record your observations in tabular form.

OBSERVATIONS

1. No. of wires on the potentiometer board = …

2. Range of the voltmeter = 0…V to … V

3. Least count of the voltmeter = …V

4. Potential drop across E = …V

5. Potential drop across E_1 = …V

6. Potential drop across E_2 = …V

Table E 4.1: Balance length

Sl. No.	l_1 cm Leclanche cell (E_1) in the circuit			l_2 cm Daniel cell (E_2) in the circuit			Ratio $\dfrac{E_1}{E_2} = \dfrac{l_1}{l_2}$	$\Delta\left(\dfrac{E_1}{E_2}\right)$
	Jockey being moved in one direction (i)	Jockey being moved in another direction (ii)	Mean	Jockey being moved in one direction (i)	Jockey being moved in another direction (ii)	Mean		
1								
2								
3								
4								

Mean

CALCULATIONS

Calculate l_1 / l_2 for each set of readings.

Error

(E 4.3)
$$\frac{\Delta\left(\dfrac{E_1}{E_2}\right)}{\left(\dfrac{E_1}{E_2}\right)} = \frac{\Delta l_1}{l_1} + \frac{\Delta l_2}{l_2}$$

(E 4.4)
$$\therefore \ \Delta\left(\frac{E_1}{E_2}\right) = \left(\frac{\Delta l_1}{l_1} + \frac{\Delta l_2}{l_2}\right)\left(\frac{E_1}{E_2}\right)$$

Δl_1 and Δl_2 represent the error in the measurement of l_1 and l_2 respectively.

Calculate $\Delta\left(\dfrac{E_1}{E_2}\right)$ for the four sets of observations and write the maximum of the four values in the result as estimated error.

RESULT

The ratio of emfs E_1/E_2 for Leclanche cell to Daniell cell

$$= \frac{E_1}{E_2} \pm \Delta \left(\frac{E_1}{E_2} \right)_{max.} = ... \pm ...$$

$\frac{E_1}{E_2}$ is mean value of the ratio of emfs of the two cells.

PRECAUTIONS

1. Keys plugged into the resistance box must ensure good electrical contact.

2. Jockey should be pressed gently on the potentiometer wire to prevent formation of any kinks in it.

3. Position of rheostat contact should not be disturbed before finishing the task of finding the balance length with both the cells.

SOURCES OF ERROR

1. The area of cross section of the potentiometer wire may not be uniform throughout its length.

2. Avoid continuous discharge of the two cells whose emf are to be compared by keeping the keys open when E_1 and E_2 are not in use.

3. The length measurement may have error if the potentiometer wire is not taut and along the scale on the board.

4. Multiple key jockey may not have correct alignment with the scale.

DISCUSSION

1. Current should not be passed for a long time in order to avoid heating due to current.

2. Battery E should have greater emf than that of E_1 and E_2, the two primary cells, so that a balance point is obtained on the wire.

3. High resistance box is used in order to make currents low so that the galvanometer coil is not damaged.

4. When looking for a balance point, there may be a small range of positions (rather than one position) of the jockey for

which there is no visible deflection of galvanometer. A good estimate of the balance point in such a case is the middle point of that range.

SELF ASSESSMENT

1. A voltmeter connected across the terminals of a battery measures the potential difference. How is it different from emf ?

2. What would you conclude if galvanometer needle keeps shaking in your experimental set up?

3. Use a voltmeter to obtain the ratio of potential difference of the two cells. Does it differ considerably from the ratio of their emfs? If not, what can you conclude?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Can the resistances of two resistors be compared using a potentiometer? If yes, draw a circuit diagram and perform the experiment.

2. Plot a graph of l_1 and l_2 with l_1 on y-axis and l_2 on x-axis. Calculate $\dfrac{E_1}{E_2}$ from the slope of graph.

3. Compare emf of cells available in the market and draw bar graphs for dry cells of different makes.