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Experiment no: 07

Name of the Experiment: Determination of the internal resistance of a cell by using potentiometer

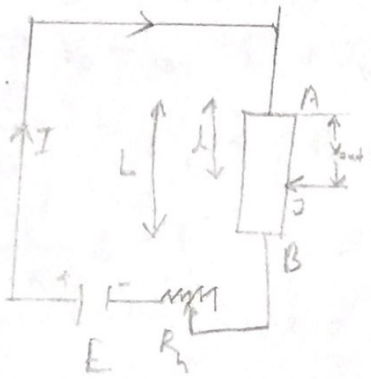
Questions on theory (all diagrams should be drawn by using a pencil and a scale)

*1) What is internal resistance of a cell? [0.25]

Ans: The resistance faced by the current inside a cell is the internal resistance of a cell.

*2) See Figure 2. Draw it and work out an expression of V_{out} in terms of E, l, L, R, R_h and σ. σ is the resistance per unit length of the conductor AB. R is the total resistance of the conductor. [1]

Ans:



Let the resistances of the conductor's segments AJ and JB are R_{AJ} and R_{JB} respectively.
Total resistance, $R = R_{AJ} + R_{JB}$.
Length of the conductor = L
Length of the AJ segment = l
resistance per unit length = σ
$\therefore R_{AJ} = l\sigma$ and $R = L\sigma$

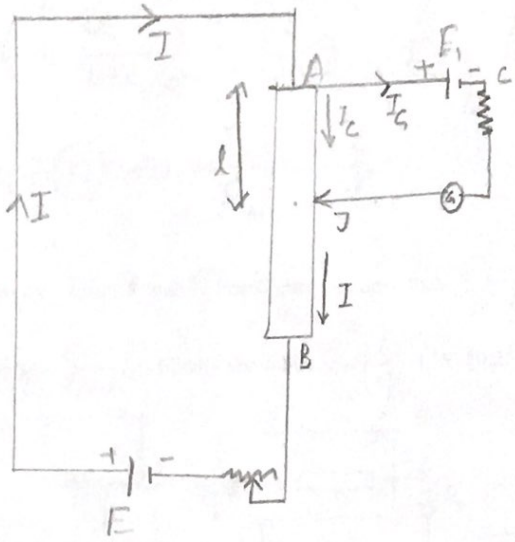
According to the potential division rule:

$$V_{out} = \frac{R_{AJ}}{R_{AJ} + (R_{JB} + R_h)} E = \frac{R_{AJ}}{R + R_h} E = \frac{I\sigma}{L\sigma + R_h} E = \frac{E}{L + R_h/\sigma} l$$

$$\therefore V_{out} = \frac{E}{L + R_h/\sigma} l$$

*3) See Figure 3. Draw it and work out an expression of the current passing through the galvanometer, I_G as shown in equation (6). [2]

Ans:



After reaching the junction A, the current I gets divided into two flows: I_G and I_C. I_G passes through the E_1, R_0 and G. On the contrary, I_C passes through the AJ segment of the conductor. According to Kirchhoff's current rule = $I = I_G + I_C$. Voltages at nodes A, C and J are V_A, V_C and V_J respectively.

According to Ohm's law, $V_C - V_J = I_G R_0 \quad \cdots (i)$

$V_A - V_C = E_1 \quad \cdots (ii)$

$(i) + (ii) \Rightarrow V_A - V_J = E_1 + I_G R_0$

$$\frac{E\,l}{L + R_h/\sigma} = E_1 + I_G R_0$$

$$\Rightarrow \frac{E}{L + R_h/\sigma} l - E_1 = I_G R_0 \quad \Big| \quad \therefore I_G = \frac{1}{R_0}\left[\frac{E}{L + R_h/\sigma} l - E_1\right]$$

*4) When I_G is zero, then show that, $E_1 = \dfrac{E}{L + R_h/\sigma} l$ [0.25]

Ans: When, $I_G = 0$

$$\frac{1}{R_0}\left[\frac{El}{L + R_h/\sigma} - E_1\right] = 0$$

$$\Rightarrow \frac{El}{L + R_h/\sigma} - E_1 = 0$$

$$\Rightarrow E_1 = \frac{El}{L + R_h/\sigma}$$

*5) If l_1 and l_2 are the length of the segment of the potentiometer's wire between end A and the null point, correspond to E_1 and E_1, then show that $\frac{E_1}{E_2}=\frac{l_1}{l_2}$ [0.25]

Ans: $E_1 = \frac{El_1}{L+R_h/\sigma}$ ..... (I) $E_2 = \frac{El_2}{L+R_h/\sigma}$ ..... (II)

(I) ÷ (II) $\Rightarrow \frac{E_1}{E_2} = \frac{l_1}{l_2}$

*6) Draw the Figure 5 and 7. For Figure 5, show that $E_1 = \frac{E}{L+R_h/\sigma} l_1$ and for Figure 7 show that $E_1 - Ir = \frac{E}{L+R_h/\sigma} l_2$. Finally show that, $r = \left(\frac{l_1}{l_2} - 1\right)R$. [0.25]

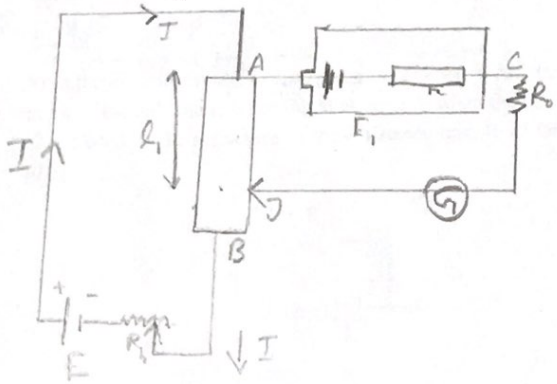


Figure 5

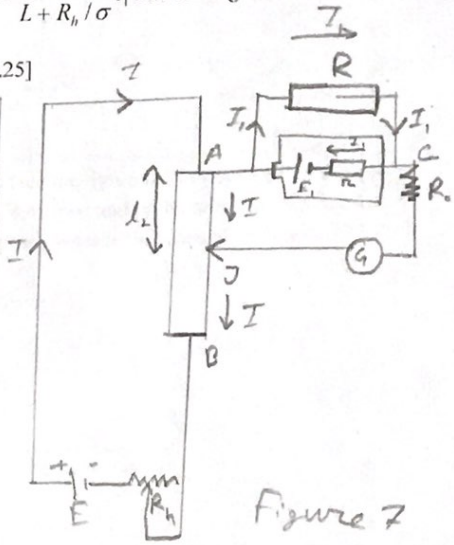


Figure 7

For Figure 5,

$I_G = \frac{1}{R_0}\left[\frac{E}{L+R_h/\sigma} l_1 - E_1\right]$

If $I_G = 0$

$\frac{1}{R_0}\left[\frac{El_1}{L+R_h/\sigma} - E_1\right] = 0$

$\Rightarrow \frac{El_1}{L+R_h/\sigma} - E_1 = 0$

$\Rightarrow E_1 = \frac{E}{L+R_h/\sigma} l_1$ ..... (I)

For Figure 7,

$IR = \frac{E}{L+R_h/\sigma} l_2$

$\Rightarrow E_1 - I_r = \frac{E}{L+R_h/\sigma} l_2$ ... (II)

$[\because E_1 = IR + I_r]$

(II) ÷ (I) $\Rightarrow$

$\frac{E_1 - I_r}{E_1} = \frac{l_2}{l_1}$

$\Rightarrow 1 - \frac{r}{E_1} \cdot \frac{E_1}{R+r} = \frac{l_2}{l_1}$

$\Rightarrow 1 - \frac{r}{R+r} = \frac{l_2}{l_1}$

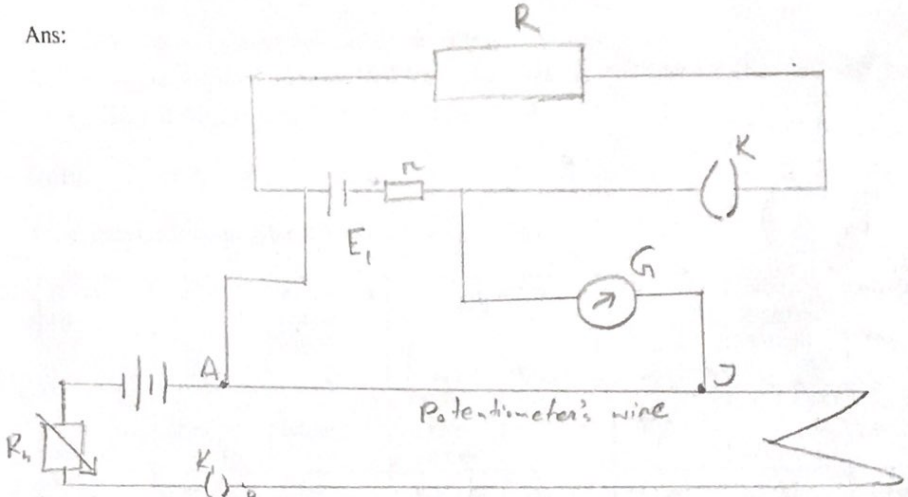
$\Rightarrow \frac{R+r}{R} = \frac{l_1}{l_2}$

$\Rightarrow 1 + \frac{r}{R} = \frac{l_1}{l_2}$

$\Rightarrow r = \left(\frac{l_1}{l_2} - 1\right)R$

*7) Draw the schematic diagram of the circuit construction to determine the internal resistance of a given cell by using a potentiometer. [0.5]

Ans:



8) In the experiment of the determination of internal resistance (see the figure below) of a cell E_1 the null point of the galvanometer is found at point J_1 when the key K is opened and at the point J_2 when the key K is closed. If the resistance of the resistance box, R= 5 Ohm then what is the internal resistance of E_1? [0.5]

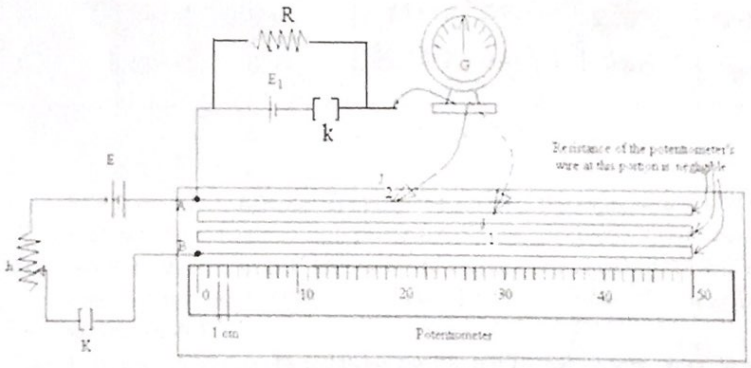


Figure 10: Figure for question (8)

Ans: Here, $l_1 = 70$ cm, $l_2 = 20$ cm, $R = 5\Omega$

$$r = \left(\frac{l_1}{l_2} - 1\right) R$$

$$= \left(\frac{70}{20} - 1\right) \times 5$$

$$= 12.5\Omega$$

- **Draw the data table(s) and write down the variables to be measured shown below (in the 'Data' section), using pencil and ruler BEFORE you go to the lab class.**

- **Write down your NAME and ID on the top of the page.**
- **This part should be separated from your Answers of "Questions on Theory" part.**
- **Keep it with yourself after coming to the lab.**

Data

Table: Data for calculating the electromotive force of a cell.

No of Obs.	Circuit	Resistance R (in ohms)	Value of l_1 (cm)	Mean l_1 (cm)	l_2 (cm)	Internal Resistance r of cell	Mean r In ohms
	open	infinity	856 852 854	859	840		
1.	Closed	10	831	831	821	0·12	
2	Closed	20	838·33	838·33	830	0·20	
3.	Closed	30	842·5	842·5	833·17	0·33	0·316
4.	Closed	40	845·17	845·17	835	0·48	
5.	Closed	50	848·17	848·17	840·5	0·45	

- **READ the PROCEDURE carefully and perform the experiment by YOURSELVES. If you need help to understand any specific point draw attention of the instructors.**
- **DO NOT PLAGIARIZE data from other group and/or DO NOT hand in your data to other group. It will bring ZERO in this experiment. Repetition of such activities will bring zero for the whole lab.**
- **Perform calculations by following the PROCEDURE . Show every step in the Calculations section.**
- **Write down the final result(s)**

Calculations

Internal Resistance,

$$r = \left(\frac{l_1}{l_2} - 1\right) \times R$$

$$= \left(\frac{831}{821} - 1\right) \times 10$$

$$= 0.12\,\Omega$$

$$\therefore \text{Mean, } r = \frac{0.12 + 0.20 + 0.33 + 0.48 + 0.45}{5}$$

$$= 0.316\,\Omega$$

Results

Questions for Discussions

1) Explain a way to determine the internal resistance of a cell by using a voltmeter and a resistance box. Show the derivation of the working formula by assuming the current passing through the voltmeter is negligible. [0.5]

Ans: If we measure the voltage difference of cell without any connection, we will get V_1. After that if we connect a resistance of R Ω with the cell and get the voltage difference using voltmeter. We will get V_2.

Now, $V_1 = \frac{r}{r+0} \times E$

$= \frac{r}{r} \times E$

$\therefore V_1 = E \ldots\ldots (i)$

Again, $V_2 = \frac{R}{r+R} \times E \ldots (ii)$

(i) ÷ (ii) $\Rightarrow \frac{V_1}{V_2} = \frac{E}{\frac{RE}{r+R}}$

$\Rightarrow \frac{V_1}{V_2} = \frac{r+R}{R}$

$\Rightarrow \frac{V_1}{V_2} = \frac{r}{R} + 1$

$\Rightarrow \frac{r}{R} = \frac{V_1}{V_2} - 1$

$\therefore r = \left(\frac{V_1}{V_2} - 1\right) R$

2) We can use a voltmeter/multi-meter and a resistance box to measure the internal resistance of a cell. What might be a drawback of using a voltmeter or a multi-meter for this purpose? How can a potentiometer be useful to avoid this drawback? [1]

Ans: To determine the internal resistance of a cell by using a voltmeter or a multimeter, we will face one drawback. Electricity flows through voltmeter or multimeter and because of ~~this~~ this internal flow there is a voltage drop occurs which results in not showing exact internal resistance of the cell. On the other hand, when we use potentiometer no electricity flows through the potentiometer for that we get exact value.

3) Mention the properties of a good potentiometer for performing this experiment. [0.5]

Ans: (i) A potentiometer has 10 segments

(ii) It should have uniform cross section.

(iii) It has significant resistance

(iv) Segments are connected in a combination.