DC CIRCUIT : ELECTRICITY

KIRCHHOFF'S LAWS

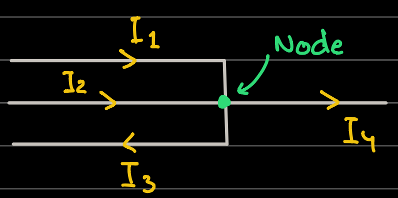
Purpose : To help us determine the value of current in electrical circuits involving multiple batteries

2 laws :

1. KCL (Kirchhoff's Current Law)

This law states that current arriving at a node or junction must be equal to the current leaving the node or junction

Note / junction refers to any point in a circuit where multiple wires meet or intersect



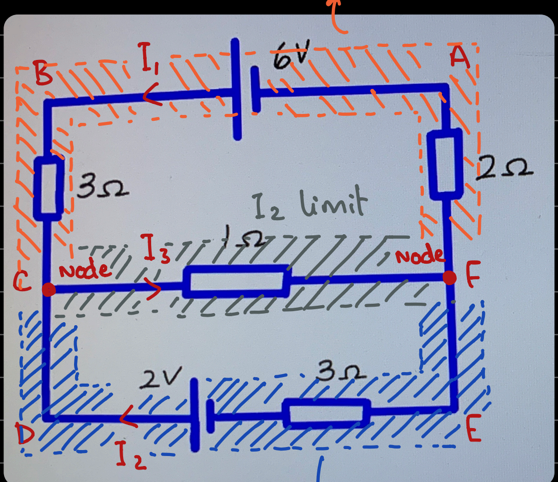
Forming an equation according to KCL

$$\text{Current arriving} = \text{Current leaving}$$

$$I_1 + I_2 = I_3 + I_4$$

Note : This law is based on law of conservation of charge, which states that charges can neither be created nor destroyed

Limitation of I_1



Limit of I_2

KCL

1. Label Circuit (A, B, C ...)
2. Identify nodes
3. Randomly mark direction of current in all branches and based on that, form an equation for current.

$$I_1 + I_2 = I_3$$

Note : Every current is limited in it's respective branch extending from one node to the other node

2. KVL (Kirchhoff's Voltage Law)

- Consider any closed loop and imagine that you are moving in that loop

1. If you see a battery such that you observe the negative terminal first and then the positive terminal, assume that the voltage is getting raised and write down this voltage as a positive value $+6$

2. If instead, you observe the positive terminal of the battery first and then the negative terminal, assume that the voltage is getting dropped and write down this voltage as a negative value

- If, while moving in the circuit, you come across a resistor, use rule 3 and 4:

3. If your direction of movement is the same as the direction of current in that branch, then write down the voltage of the resistor with a negative sign. (ie. $-IR$)

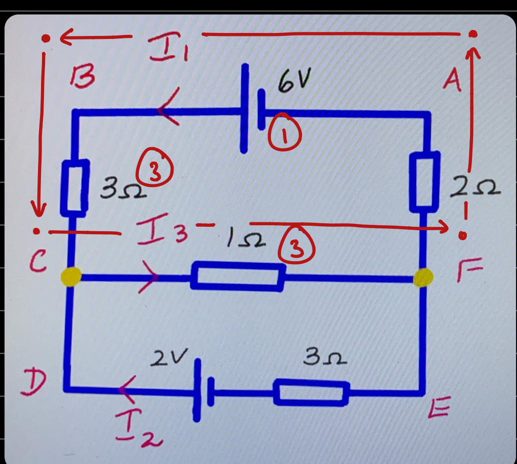
4. If your direction of movement is opposite to the direction of current in that branch, then write down the voltage of the resistor with a positive sign ($+IR$)

- When you return back to your starting point equate your equation to 0.

- This law is based on the law of conservation of energy which states that the voltage provided by the battery is consumed by the resistor.

  $\therefore$, sum of voltage in a closed loop is equal to 0.

Closed loop : ABCFA



$A \longrightarrow B$

$+6$

$B \longrightarrow C$

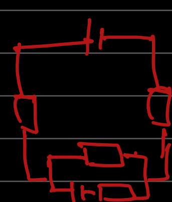
$+6 - I_1(3)$

$C \longrightarrow F$

$+6 - I_1(3) - I_3(1)$

$F \longrightarrow A$

$+6 - I_1(3) - I_3(1) - I_1(2) = 0$



① $6 - 5I_1 - I_3 = 0$

2nd Closed loop : ABCDEFA

$$+6 - I_1(3) - 2 + I_2(3) - I_1(2) = 0$$

$$(2) \quad 4 - 5I_1 + 3I_2 = 0$$

Note: Positive ans. for current would mean that the direction for current marked on the diagram is the correct direction whereas a negative answer, if obtained, implies that actual current is opposite to the direction marked

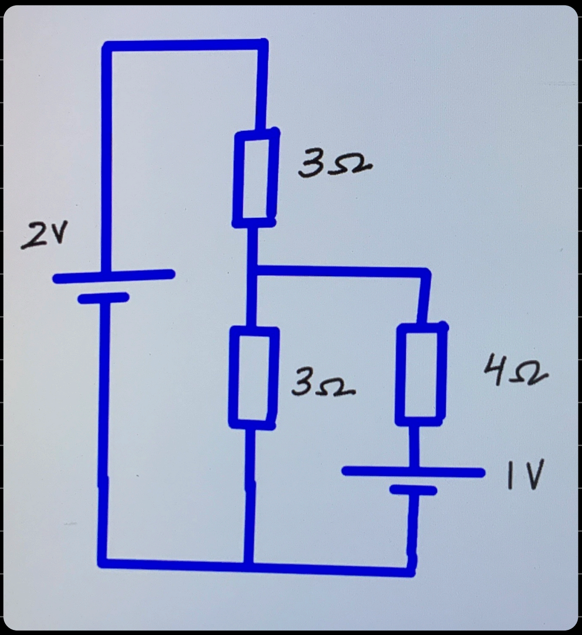
And remember... $I_1 + I_2 = I_3$

And then solve simultaneously

$$4 - 5I_1 + 3I_2 = 6 - 5I_1 - (I_1 + I_2)$$

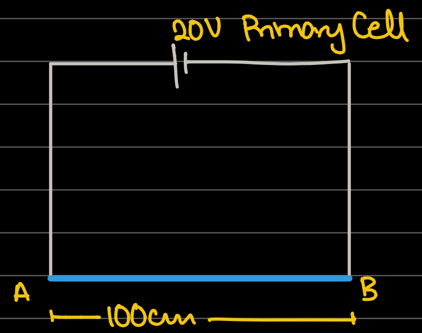
$$4 - 5I_1 + 3I_2 = 6 - 5I_1 - I_1 - I_2$$

$$4I_2 = 2 - I_1$$



WORKING OF A POTENTIOMETER

Purpose: It is a circuit which makes use of a primary cell in order to help us calculate the unknown voltage of the secondary cell



- the wire AB is a resistance wire of length 100cm
- the connecting wires have zero resistance
- Voltage of the primary cell (PC) = 20V

Q. How much voltage will be available across the wire AB

A. 20V

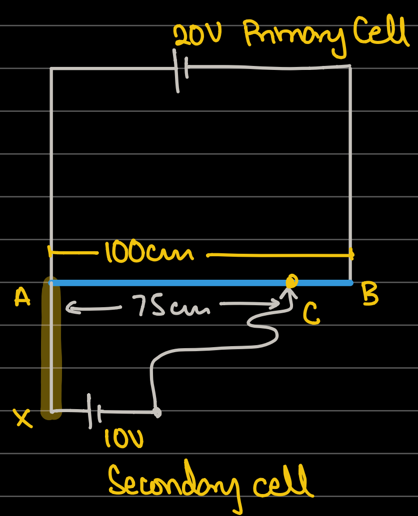
because this wire is the only component that offers resistance

Q. How much voltage will be available for wire AC?

A. AC = 25cm so V_{AC} = 5V

Q. Suggest why direction of current in the highlighted branch will be from X to A ?

A. Current flows from a higher potential (10V) to a lower potential (5V)

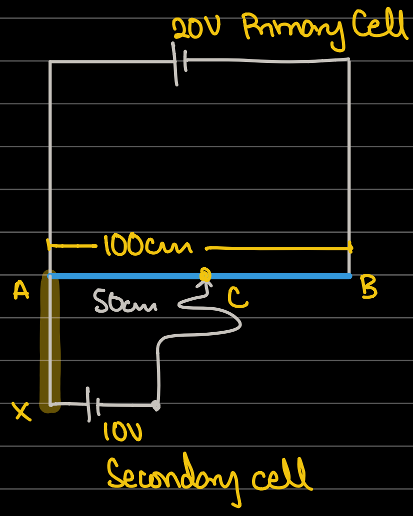


Q. Calculate voltage across wire AC

A. AC = 75cm so V_{AC} = 15V

Q. Predict the direction of current in the highlighted branch.

A. A to X.

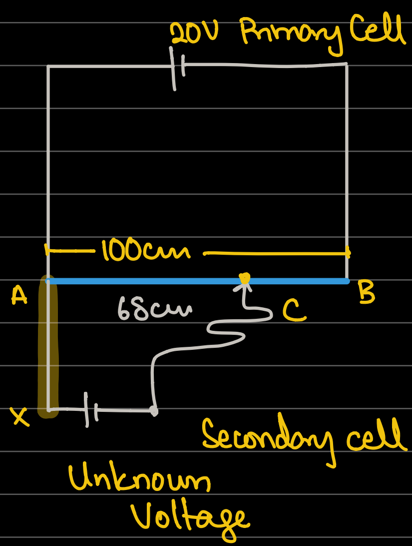


Q. Suggest the direction of current in the highlighted branch. Justify your answer

Since AC = 50cm, V_{AC} = 10V. Since this is equal to the secondary cell, there will be no difference in potential hence there will be no flow of current

aka. null deflection / balance point

Example Q:



Q. Given that a null deflection / balance point is achieved when the length of resistance wire AC = 68cm. Use this information to calculate the unknown voltage of the secondary cell.

$AC = \frac{68}{100}$ so $V_{AC} = \frac{68}{100} \times 20$

$= \underline{13.6V}$

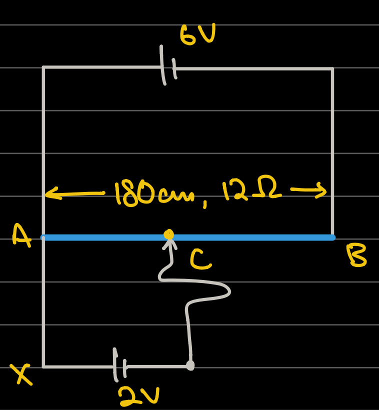
↳ Ans, the voltage of the secondary cell

General Formulae:

$$\boxed{V_{SC} = \frac{l_{AC}}{l_{AB}} \times V_{PC}} \qquad \boxed{V_{SC} = \frac{R_{AC}}{R_{AB}} \times V_{PC}}$$

where V_{SC} = voltage of the secondary cell
V_{PC} = voltage of the primary cell

Example Q:



Q. Calculate the length AC given that a null deflection is observed.

A.

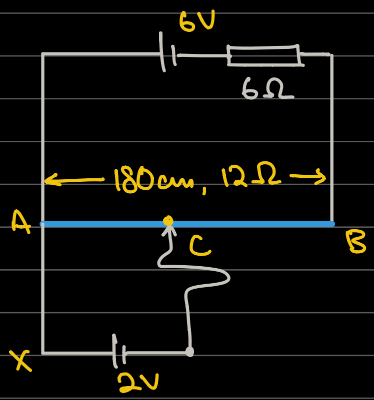
$V_{SC} = \frac{l_{AC}}{l_{AB}} \times V_{PC}$

$2 = \frac{x}{180} \times 6$

$180 \times \frac{2}{6} = x$

$\underline{60cm} = x$

↳ Ans, length of AC



Q. A 6Ω resistor is now placed in the primary circuit. Calculate the new length of AC for balance point to be achieved

A. How much voltage does AB now get?

AB				Total
12	:	6	:	18
4	:	2	:	6

$$V_{SC} = \frac{l_{AC}}{l_{AB}} \times V_{PC}$$

$$2 = \frac{l_{AC}}{180} \times 4$$

$$180\left(\frac{1}{2}\right) = l_{AC}$$

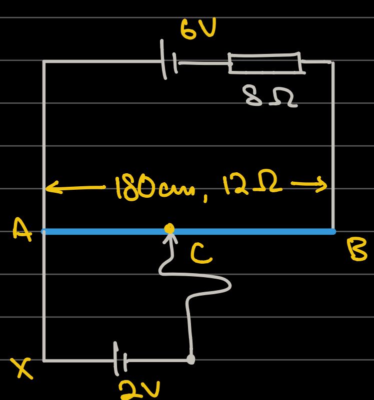
$$90\text{ cm} = l_{AC}$$

Note: placing any extra component in the primary circuit causes the length of the balance point to increase

Q. Explain what happens to the length of the balance point if a resistor is placed in the primary circuit.

Ans. Placement of extra resistor causes voltage to be shared. Hence, voltage now available for wire AB is reduced.

Therefore, for the same voltage applied by the secondary cell, we need to accommodate a longer length to achieve a balance point



Q. Calculate the new length of AC now required to achieve a balance point.

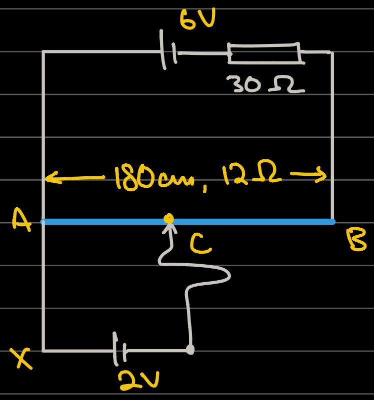
				Total
12	:	8	:	20
3	:	2	:	5
3.6	:	2.6	:	6

↳ 3.6V

$$V_{SC} = \frac{l_{AC}}{l_{AB}} \times V_{PC}$$

$$2 = \frac{l_{AC}}{180} \times 3.6$$

$$180\left(\frac{2}{3.6}\right) = 100\text{ cm}$$



Q. Suggest why this circuit is not effective in helping us calculate the balance point.

A. $V_{AB} = 1.7\,V$

The entire length AB only gets 1.7V, which is less voltage than the secondary cell.
To achieve a balance point, length AC would have to exceed AB, which is impossible

Points to be considered while setting up a potentiometer circuit:

- the +ve terminal of the primary cell must be connected with the +ve terminal of the secondary cell.
- the voltage across the wire (resistance wire) $\geq$ voltage of secondary cell

Example Q: