

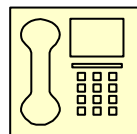
# **Internal Resistance of cell & Combinations of Cells**

**01.06.09**

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## Sources of emf:

The electro motive force is the maximum potential difference between the two electrodes of the cell when no current is drawn from the cell.

## Comparison of EMF and P.D:

	<b>EMF</b>	<b>Potential Difference</b>
<b>1</b>	<b>EMF is the maximum potential difference between the two electrodes of the cell when no current is drawn from the cell i.e. when the circuit is open.</b>	<b>P.D is the difference of potentials between any two points in a closed circuit.</b>
<b>2</b>	<b>It is independent of the resistance of the circuit.</b>	<b>It is proportional to the resistance between the given points.</b>
<b>3</b>	<b>The term 'emf' is used only for the source of emf.</b>	<b>It is measured between any two points of the circuit.</b>
<b>4</b>	<b>It is greater than the potential difference between any two points in a circuit.</b>	<b>However, p.d. is greater than emf when the cell is being charged.</b>

## Internal Resistance of a cell:

The opposition offered by the electrolyte of the cell to the flow of electric current through it is called the internal resistance of the cell.

## Factors affecting Internal Resistance of a cell:

- i) Larger the separation between the electrodes of the cell, more the length of the electrolyte through which current has to flow and consequently a higher value of internal resistance.
- ii) Greater the conductivity of the electrolyte, lesser is the internal resistance of the cell. i.e. internal resistance depends on the nature of the electrolyte.
- iii) The internal resistance of a cell is inversely proportional to the common area of the electrodes dipping in the electrolyte.
- iv) The internal resistance of a cell depends on the nature of the electrodes.

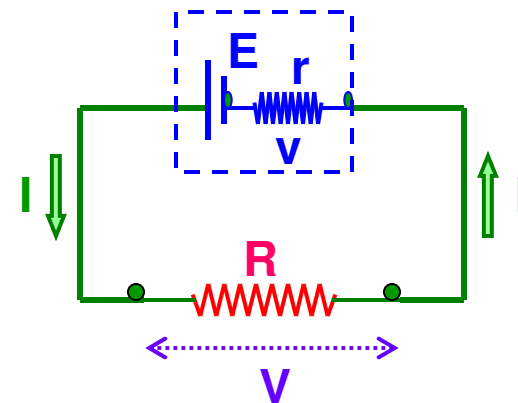
$$E = V + v$$

$$= IR + Ir$$

$$= I (R + r)$$

$$I = E / (R + r)$$

This relation is called **circuit equation**.



## Internal Resistance of a cell in terms of E,V and R:

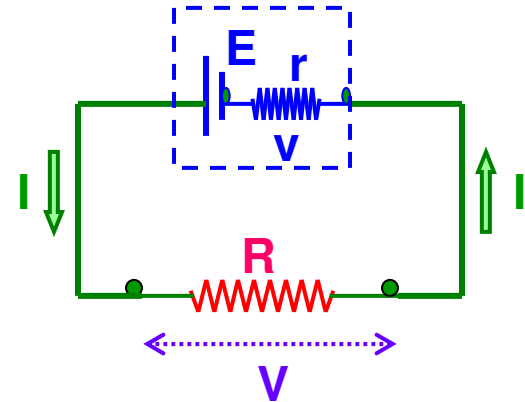
$$\begin{aligned} E &= V + v \\ &= V + Ir \\ Ir &= E - V \end{aligned}$$

Dividing by IR = V,

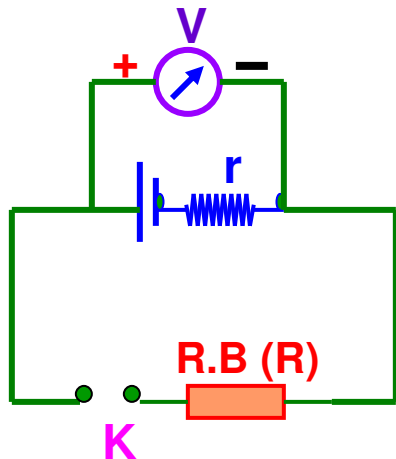
$$\frac{Ir}{IR} = \frac{E - V}{V}$$



$$r = \left( \frac{E}{V} - 1 \right) R$$

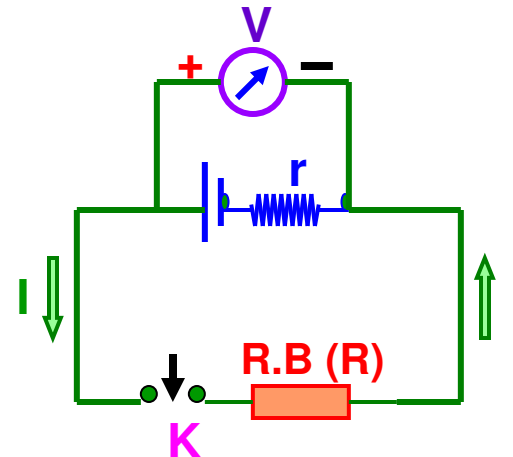


## Determination of Internal Resistance of a cell by voltmeter method:



Open circuit (No current is drawn)

EMF (E) is measured



Closed circuit (Current is drawn)

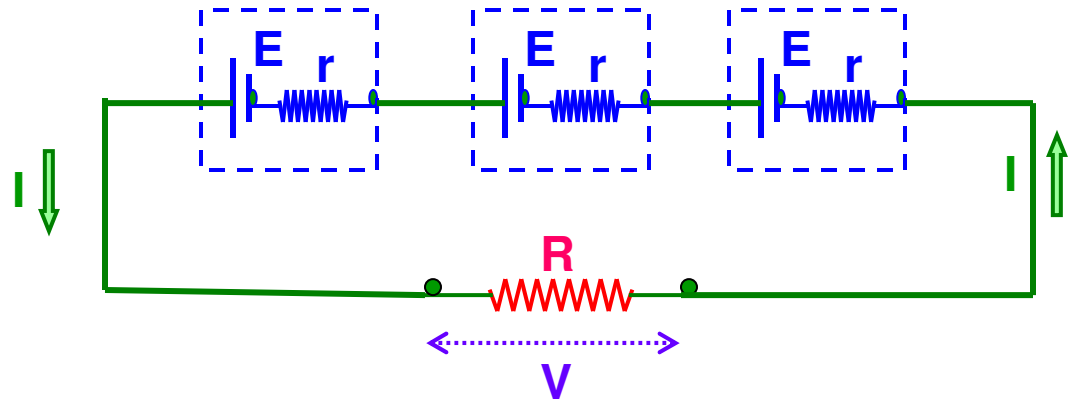
Potential Difference (V) is measured

## Cells in Series combination:

Cells are connected in series when they are joined end to end so that the same quantity of electricity must flow through each cell.

### NOTE:

1. The emf of the battery is the sum of the individual emfs
2. The current in each cell is the same and is identical with the current in the entire arrangement.
3. The total internal resistance of the battery is the sum of the individual internal resistances.



Total emf of the battery =  $nE$  (for  $n$  no. of identical cells)

Total Internal resistance of the battery =  $nr$

Total resistance of the circuit =  $nr + R$

$$\text{Current } I = \frac{nE}{nr + R}$$

(i) If  $R \ll nr$ , then  $I = E / r$  (ii) If  $nr \ll R$ , then  $I = n (E / R)$

Conclusion: When internal resistance is negligible in comparison to the external resistance, then the cells are connected in series to get maximum current.

## Cells in Parallel combination:

Cells are said to be connected in parallel when they are joined positive to positive and negative to negative such that current is divided between the cells.

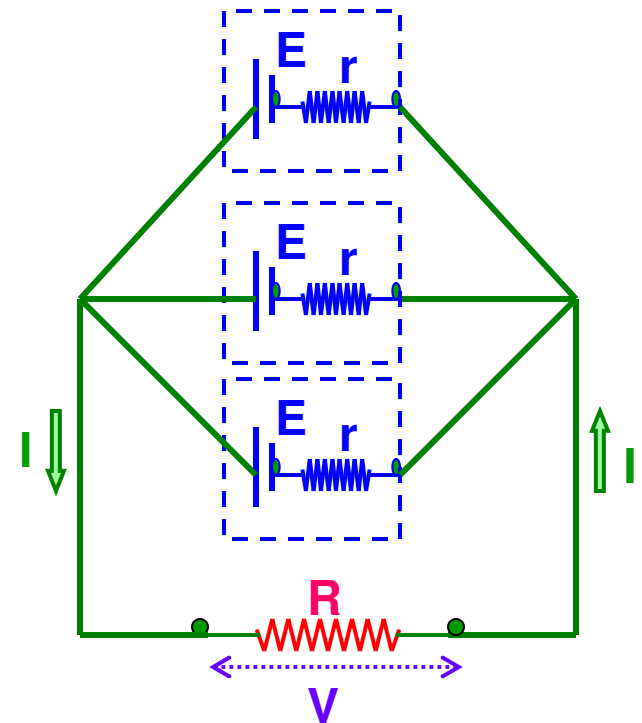
### NOTE:

1. The emf of the battery is the same as that of a single cell.
2. The current in the external circuit is divided equally among the cells.
3. The reciprocal of the total internal resistance is the sum of the reciprocals of the individual internal resistances.

Total emf of the battery =  $E$

Total Internal resistance of the battery =  $r / n$

Total resistance of the circuit =  $(r / n) + R$



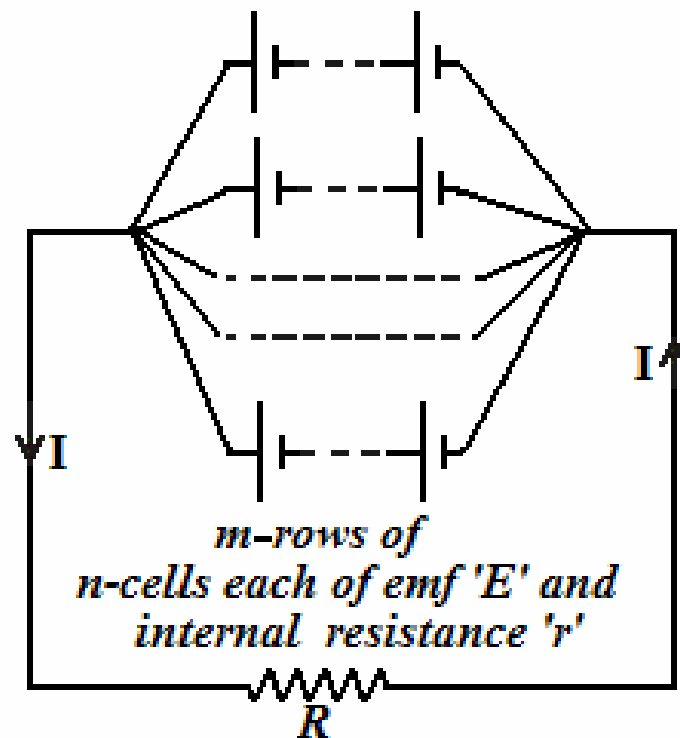
$$\text{Current } I = \frac{nE}{nR + r}$$

(i) If  $R \ll r/n$ , then  $I = n(E / r)$  (ii) If  $r/n \ll R$ , then  $I = E / R$

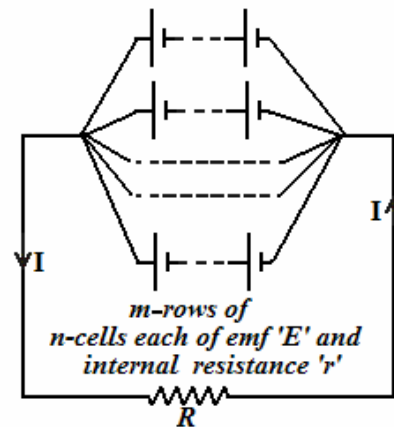
**Conclusion:** When external resistance is negligible in comparison to the internal resistance, then the cells are connected in parallel to get maximum current.

# Mixed Grouping

Cells are said to be in mixed grouping if are connected in the manner as shown.



# Mixed Grouping



Let  $n$  be the no. of cells in series in each row and  $m$  be the no. of such rows. Let  $E$  be the e.m.f. of each cell and ' $r$ ' be the internal resistance of each cell.

In each row, there are  $n$  cells in series, therefore their total resistance is ' $nr$ ' and total e.m.f. is  $nE$ .

Thus are ' $m$ ' rows of cells in parallel, therefore total internal resistance of all the cells is given by

$$\frac{1}{r_p} = \frac{1}{nr} + \frac{1}{nr} + \dots + \frac{1}{nr} \quad (m \text{ terms}) = \frac{m}{nr}$$

# Mixed Grouping

Hence total resistance in the circuit is =  $\frac{nr}{m}$

and effective e.m.f. is =  $nE$

Hence total current  $I = \frac{nE}{R + \frac{nr}{m}} = \frac{mnE}{mR + nr}$  ----- (1)

For current  $I$  to be maximum  $mR + nr$  should be minimum which can be proved to be minimum when  $mR = nr$  as follows

# Mixed Grouping

$$\begin{aligned}mR + nr &= \left(\sqrt{mR}\right)^2 + \left(\sqrt{nr}\right)^2 \\&= \left(\sqrt{mR}\right)^2 + \left(\sqrt{nr}\right)^2 - 2\sqrt{mR}\sqrt{nr} + 2\sqrt{mR}\sqrt{nr} \\&= \left(\sqrt{mR} - \sqrt{nr}\right)^2 + 2\sqrt{mR}\sqrt{nr}\end{aligned}$$

Which is minimum when

$$\sqrt{mR} - \sqrt{nr} = 0 \text{ or } \boxed{mR = nr}$$

And maximum current is given by

$$\boxed{I_{\max} = \frac{mE}{2r} = \frac{nE}{2R}}$$