# Cells

**1. Electric Cell**

a) It is a device which converts chemical energy into electrical energy.

b) There are two types of cells

i) Primary cell  ii) Secondary cell

**2. Electromotive force (e.m.f) of a Cell**

a) The work done is carrying a unit positive charge once in the whole circuit including the cell, is defined as the electromotive force.

b) Electromotive force is the potential difference between the terminals of a cell in open circuit.

c) Electromotive force depends on (1) nature of electrolyte (2) metal of the electrodes.

d) Electromotive force does not depend on (1) area of plates (2) distance between the electrodes (3) Quantity of electrolyte (4) size of the cell.

e) Electromotive force is the characteristic property of the cell. The direction of current inside the cell is always from negative to positive electrode.

f) The unit of electromotive force is volt.

**3. Internal resistance (r):** The internal resistance of a cell is the resistance offered by the column of the electrolyte between the positive plate and the negative plate.

i) The internal resistance of a perfect cell or ideal cell is zero.

ii) Internal resistance depends on

a) Strength of electrolyte ($r \propto$ strength)

b) Distance between plates ($r \propto d$)

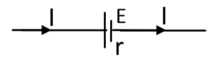
c) Area of the plates $\left[r \propto \frac{1}{A}\right]$

d) Temperature of electrolyte $\left[r \propto \frac{1}{t}\right]$

**4. Relation between EMF and PD**

1) In case of charging of a cell

a) The current flows from +ve to –ve terminal inside the cell.



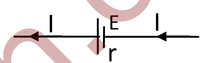

b) $V > E$

c) $V = E + ir$

2) In case of discharge of a cell

a) The current flows from –ve to +ve terminal inside the cells

b) $V < E$



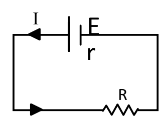

c) $V = E - ir$

3) The difference between E and V is called **lost volts**

$\therefore$ Lost volts $= E - V = ir$

4) A cell of emf 'E' and its resistance 'r' is connected to resistance 'R'.

a) $i = \frac{E}{R+r}$




b) P.D. across resistance R is given by

$V = iR = \frac{ER}{R+r}$

c) Fraction of energy useful $= \frac{V}{E} = \frac{R}{R+r}$

d) % of fractional useful energy$= \left(\frac{V}{E}\right)100 = \left(\frac{R}{R+r}\right)100$

e) Fraction of energy lost $= \frac{E-V}{E} = \frac{ir}{E} = \frac{r}{R+r}$

f) % of lost energy $= \left(\frac{r}{R+r}\right)100$

g) $r = \frac{(E-V)R}{V}$

h) For single cell, the condition for maximum current is $R = r$.

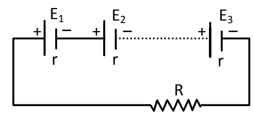
**5. Back emf**

a) The copper electrode gets covered with a layer of hydrogen and this hinders flow of current. In the neighbourhood of both electrodes, the concentrations of ions get altered. This results in an emf acting in a direction opposite to the emf of the cell. This is called back emf.

b) This formation of hydrogen around the anode is called polarization.

c) To reduce the back e.m.f manganese dioxide and potassium dichromate are added to electrolyte of cell. These are called **depolarizers**.

**6. Series combination of cells**




a) $E = E_1 + E_2 + E_3 + \ldots E_n$

b) $r = r_1 + r_2 + r_3 + \ldots\ldots. r_n$

c) When cells of e.m.f. are $E_1$, $E_2$, and E3…. and of internal resistances $r_1$, $r_2$, $r_3$….. are connected in series across an external resistance R, the current i is given by

$$i = \frac{E_1 + E_2 + E_3 \ldots\ldots..}{R + (r_1 + r_2 + r_3 + \ldots..)}$$

d) If the e.m.f s of all the n cells and their internal resistances are same, then

$$i = \frac{nE}{(R + nr)}$$

e) If n r >> R, then i = E/r, i.e. the current obtained from n cells is equal to that obtained from a single cell.

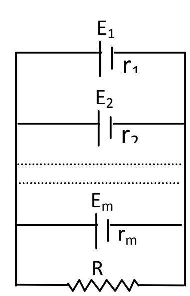
f) If n r << R then i = n E/R.

g) This type of combination is used when the internal resistance of battery is negligible in comparison to the external resistance and e.m.f required is high.

h) In this combination same current flows through all the cells.

**7. Wrongly connected cells**

Suppose by mistake m cells are wrongly connected in above circuit then




a) Total emf = emf due to properly connected cells – emf due to wrongly connected cells

$= (n - m) E - mE = (n - 2m) E$

b) Total internal resistance of cells = nr

c) Total resistance in the circuit = R + nr

d) The current in circuit $= \frac{(n-2m)E}{R + nr}$

**8. Cell in parallel**

i) $i = i_1 + i_2 + i_3 + \ldots\ldots\ldots\ldots i_n$

ii) The e.m.f of the combination is equal to the e.m.f of a single cell i.e. $E = E_1 = E_2 = E_3 = \ldots\ldots i = \frac{E}{\left(R + \frac{r}{m}\right)}$

iii) If $r >> R$ then $I = mE/r$

$i = n \times$ (current obtained from a single cell)

iv) If $r << R$ then $i = E/R$

This type of combination is used when $r >> R$ and more current is required in the circuit.

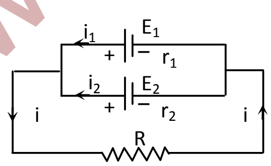
v) If the e.m.f of m cells and their internal resistance are different then

1) $i = i_1 + i_2 + i_3 \ldots\ldots i_n$

2) $$I = \frac{\left[\frac{E_1}{r_1} + \frac{E_2}{r_2} + \ldots\ldots \frac{E_m}{r_n}\right]}{\left[1 + R\left(\frac{1}{r_1} + \frac{1}{r_2} + \ldots\ldots\ldots\ldots \frac{1}{r_n}\right)\right]} = \frac{\left(\frac{\sum \frac{E}{r}}{\sum \frac{1}{r}}\right)}{\left(R + \frac{1}{\sum \frac{1}{r}}\right)}$$

3) $E_{total} = \frac{\sum \frac{E}{r}}{\sum \frac{1}{r}}$ 4) $r_{total} = \frac{1}{\sum \frac{1}{r}}$

**9.** If two cells of emf $E_1$ and $E_2$ having internal resistances $r_1$ and $r_2$ are connected in parallel to an external resistance R, then

i) 


a) The effective emf, $E = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$

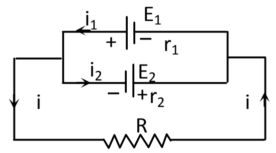
b) The effective internal resistance, $r = \frac{r_1 r_2}{r_1 + r_2}$

c) Current through the circuit, $i = \frac{E}{r + R}$

d) $i = i_1 + i_2$

e) $i_1 = \frac{E_1 - iR}{r_1}$ and $i_2 = \frac{E_2 - iR}{r_2}$

ii)




a) The effective emf, $E = \frac{E_1 r_2 - E_2 r_1}{r_1 + r_2}$

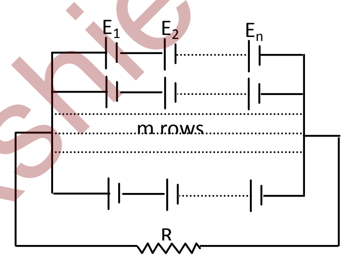
b) The effective internal resistance, $r = \frac{r_1 r_2}{r_1 + r_2}$

c) Current through the circuit, $i = \frac{E}{r + R}$

d) $i = i_1 - i_2$

e) $i_1 = \frac{E_1 - iR}{r_1}$ and $i_2 = \frac{E_2 + iR}{r_2}$

**10. Mixed grouping of cells**




i) The e.m.f of cells in a row = nE.

ii) Total e.m.f of the combination = nE

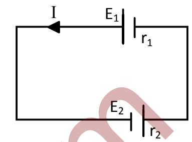
iii) The total internal resistance = $\frac{nr}{m}$

iv) The total resistance of the circuit = $R + \frac{nr}{m}$

v) The current flowing through the external resistance (i) $= \frac{nE}{R + \frac{nr}{m}} = \frac{mnE}{mR + nr}$

vi) For maximum current to flow through the external circuit, the external resistance should be equal to the total internal resistance. or $R = \frac{nr}{m}$ or, $mR = nr$

**11.** Two cells if e.m.f.s $E_1$ and $E_2$ be connected in a circuit. Let $r_1$ and $r_2$ be the internal resistance of the cells.

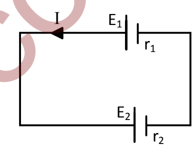



a) The current through the circuit $I = \frac{E_1 + E_2}{r_1 + r_2}$

b) The terminal voltage across the cells

$V_1 = E_1 - Ir_1$

$V_2 = E_2 - Ir_2$




**12.** Let two cells of e.m.f.s $E_1$ and $E_2$ be connected in parallel in a circuit. Let $r_1$ and $r_2$ be the internal resistance of the cells.

a) The direction of the resultant current is determined by the direction of the higher e.m.f.

b) If $E_1 < E_2$, the current through the circuit is $I = \frac{E_1 - E_2}{r_1 + r_2}$.

c) While the cell $E_1$ is discharging, the cell $E_2$ is in the charging. The terminal voltage across the cells $V_1 = E_1 - Ir_1$ and $V_2 = E_2 + Ir_2$.