Chapter Overview

1. **Current:** net charge passing through an area per second; $i = \frac{dq}{dt}$ or $i = \frac{\Delta q}{\Delta t}$, where Δq = net charge passes over a time Δt.

2. **Ohm's law:** $V \propto I$ or $V = IR$.
R is a constant for the conductor at a given temperature, called **resistance** of the conductor. Unit: Ω.

3. *V-I* graph is a straight line passing through the origin and the slope of the line is equal to the resistance of the conductor.

4. **Colour Code for carbon resistors**:

Black	**0**
Brown	**1**
Red	**2**
Orange	**3**
Yellow	**4**
Green	**5**
Blue	**6**
Violet	**7**
Gray	**8**
White	**9**
Golden	**± 5%**
Silver	**± 10%**
No colour	**± 20%**

5. Resistivity (ρ) is resistance of unit length and unit cross section of a conductor.
Relation: $R = \rho \frac{l}{A}$. Unit: Ω-m.

6. If a wire has a fixed volume V then the relation is $R = \rho \frac{l^2}{V}$ or, $R = \rho \frac{V}{A^2}$

7. Conductance: $C = \frac{1}{R}$. Unit : $(\Omega)^{-1}$ or siemens.

8. Conductivity: $\sigma = \frac{1}{\rho}$. Unit : $(\Omega\text{-m})^{-1}$

9. Resistivity of different materials:

	Conductor	**Semi-conductor**	**Insulator**
Free Electron Density	$\approx 10^{28} m^3$	$\approx 10^{16} m^{-3}$ (*when doped* $\approx 10^{23} m^{-3}$)	*Practically no free electrons*
Resistivity	$\approx 10^{-8} \Omega m$	$\approx 10^{-3}$ to $10^{+3} \Omega m$	$\approx 10^{10}$ to $10^{16} \Omega m$
Temperature dependence of resistivity	*increases with temperature*	*decreases with temperature*	*Practically no dependence*

10. **Charge Carriers**:
Metals: electrons.
Ionic crystals and electrolytes: positive and negative ions.
Semiconductors: electrons and holes.

11. Current Density: Current per unit surface area perpendicular to the direction of flow is current density. $|\vec{j}| = \frac{i}{A}$, or $i = \vec{j}\cdot\vec{A}$.

Drift velocity: (i) $v_d = \frac{i}{Ane}$ or $\vec{v}_d = \frac{\vec{J}}{ne}$ and (ii) $\vec{v}_d = \frac{e\vec{E}}{m_e}\tau$ or $v_d = \frac{e\tau}{m_e}\frac{V}{l}$

12. Mobility: $\mu = \frac{v_d}{E} = \frac{e\tau}{m_e} = \frac{1}{en\rho}$.

13. Resistivity in microscopic parameters: $\rho = \frac{m_e}{ne^2\tau}$, or, $\rho = \frac{1}{ne\mu}$.

14. Conductivity in microscopic parameters: $\sigma = \frac{ne^2\tau}{m_e}$, or, $\sigma = ne\mu$.

15. Current is the flux of 'current density' over a cross section of the path of the current:

$$di = \vec{j}\cdot d\vec{s}\text{, or } i = \int \vec{j}\cdot d\vec{s}.$$

16. Equation of continuity: For a closed surface in the path of the current, $\oint \vec{j}\cdot d\vec{s} = 0$.

17. Total current density when positive and negative charge carriers constitute current: $\vec{j} = \rho_+\vec{v}_+ + \rho_-\vec{v}_-$. [$\rho$ = charge density.]

For metals, $\vec{v}_+ = 0$, therefore total current density $\vec{j} = \rho_-\vec{v}_-$.

18. Generalized Ohm's law: $\vec{j} = \sigma\vec{E}$, or $\vec{E} = \rho\,\vec{j}$.

19. Temperature dependence of resistivity: $\alpha = \frac{\rho - \rho_0}{\Delta T}$ or, $\rho = \rho_0(1 + \alpha\Delta T)$.

20. Temperature coefficient of resistance: $R = R_0(1 + \alpha\Delta T)$.

21. Combination of resistors:

(i) Series: $R = R_1 + R_2 + R_3$.......

(ii) Parallel: $\frac{1}{R} = \frac{1}{R_2} + \frac{1}{R_2} + \frac{1}{R_3}$.........

22. Kirchhoff's Rule:

(i) Point- rule (charge conservation principle): *In a circuit, algebraic sum of total currents meeting at a point is zero.*

Or, the *sum of incoming currents = sum of out going currents*. $\sum i = 0$.

(ii) Mesh or Loop rule (energy conservation principle): *In a closed circuit, sum of the potential drops* (*current* × *resistance*) *across the resistors is equal to the net emf inserted in the loop*. $\Rightarrow \sum iR = \sum E$

23. Current through two resistors in parallel if net current is *i*: $i_1 = \frac{R_2 i}{R_1 + R_2}$ and $i_2 = \frac{R_1 i}{R_1 + R_2}$.

24. Balancing condition of Whetstone's bridge: $\frac{P}{Q} = \frac{R}{S}$.

25. EMF (electromotive force) and **emf seat**: Energy supplied by the cell per unit flow of charge is called ***emf*** of the cell. Its unit is volt. A cell is called ***emf seat***.

26. Potential difference across a cell:

(i) While charging: $V = E + Ir$.

(ii) While discharging: $V = E - Ir$.

27. Combination of cells:

Series grouping of emf seats: $E = E_1 + E_2 + E_3$...... & $r = r_1 + r_2 + r_3$......

Parallel grouping of emf seats: $E = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3}......\right)r$ & $\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}$......

When n identical cells are connected in parallel:

Total emf : $\varepsilon_{net} = \varepsilon$ Total internal resistance: $r_{net} = \frac{r}{n}$

When n identical cells are connected in series:

Total emf : $\varepsilon_{net} = n\varepsilon$ Total internal resistance: $r_{net} = nr$

28. Electrical Power:

(a) Delivered by emf seat: $P_{cell} = VI$.

(b) Dissipated in resistor R: $P_R = I^2 R$.

(c) If many resistors are connected in series and to an emf seat then same current pass through all of them, and power dissipated in each of them is: $P = I^2 R$.

(d) If many resistors are connected in parallel with an emf seat then same voltage is across all of them, and power dissipated in each of them is: $P = \frac{V^2}{R}$.

29. Power dissipated in connecting wire: $P_C = \frac{P_s^2 R_C}{V^2}$.

(where P_S = power supplied, V = voltage at which power is supplied, R_C resistance of connecting wire)

30. Electrical energy and commercial unit of electrical energy: 1kWh = 1000×3600 J = 3.6 × 106J

31. Maximum power theorem for mixed combination of cells in a circuit with external resistance *R*: When external resistance is equal to the internal resistance, i.e., $r = R$, the power delivered to the external resistance is a maximum.

32. Voltage across external resistance *R* is $V = \frac{\varepsilon}{R + r} R$.

33. Meter bridge:

Value of unknown resistance Q in terms of known resistance P when null point in at x cm:

$$Q = \frac{100 - x}{x} P$$

34. Potentiometer:

(i) Comparison of emf: $\frac{E_1}{E_2} = \frac{l_1}{l_2}$ (where l_1 and l_2 are the null points for the *emf*s E_1 and E_2 respectively.)

(ii) Internal resistance: $r = \frac{x_1 - x_2}{x_2} R$ (where x_1 and x_2 are the null points for auxiliary circuit is off and on respectively.)

35. Charging of a capacitor (Optional):

(i) Charge at a time t: $q = q_0 \left(1 - e^{-\frac{t}{RC}}\right)$.

(ii) Potential difference across plates: $V = V_0 \left(1 - e^{-\frac{t}{RC}}\right)$.

(iii) Time constant: $\tau = RC$.

(iv) Current: $i = \frac{q_0}{RC} e^{-\frac{t}{RC}}$.

36. Discharging of a capacitor:

(i) Charge at a time t: $q = q_0 e^{-\frac{t}{RC}}$.

(ii) Potential difference across plates: $V = V_0 e^{-\frac{t}{RC}}$.

(iii) Time constant: $\tau = RC$.

(iv) Current: $i = \frac{q_0}{RC} e^{-\frac{t}{RC}}$.