

UNIT – 4: CURRENT ELECTRICITY

Applied Physics 2 | 2nd Semester | Diploma Engineering

1. Electric Current

1.1 Definition & Unit

- ELECTRIC CURRENT → Flow of electric charges through a conductor
- Symbol: I | Unit: AMPERE (A)

$$I = Q / t$$

- Q = charge (Coulombs) | t = time (seconds) | 1 A = 1 C/s

1.2 Types of Current

- DC (DIRECT CURRENT) → Flows in ONE fixed direction → Example: Battery, torch
 - AC (ALTERNATING CURRENT) → Reverses direction periodically → Example: 220V household supply (50 Hz)
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2. Resistance

2.1 Definition

- RESISTANCE → Opposition to the flow of electric current
- Symbol: R | Unit: OHM (Ω)

2.2 Specific Resistance (Resistivity)

- RESISTIVITY (ρ) → Resistance of a conductor of unit length and unit cross-section

$$R = \rho \times (L / A)$$

- ρ = resistivity ($\Omega \cdot m$) | L = length (m) | A = cross-section area (m^2)

★ Lower ρ → Better conductor | Higher ρ → Insulator

2.3 Conductance & Specific Conductance

- CONDUCTANCE (G) = $1 / R$ | Unit: SIEMENS (S)
 - SPECIFIC CONDUCTANCE (σ) = $1 / \rho$ | Unit: S/m
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3. Combination of Resistances

3.1 Series Combination

- Resistors connected END-TO-END → SAME current through each

$$R_{\text{total}} = R_1 + R_2 + R_3 + \dots$$

- Voltage adds up across each resistor

★ **More resistors in series** → **R_{total} INCREASES**

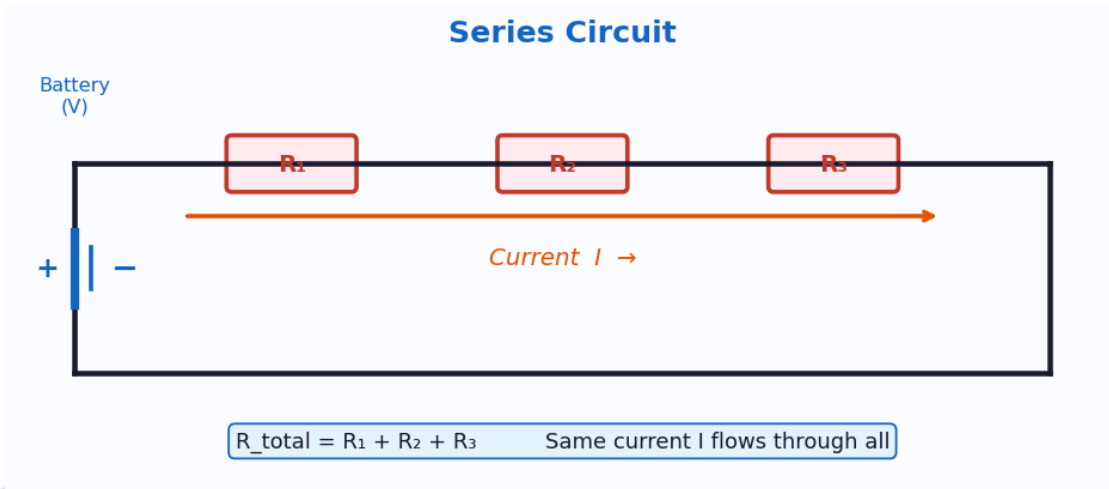


Fig: Series Circuit – Same current I through all resistors

3.2 Parallel Combination

- Resistors connected between SAME two nodes → SAME voltage across each

$$1/R_{\text{total}} = 1/R_1 + 1/R_2 + 1/R_3 + \dots$$

- For two resistors: $R_{\text{total}} = (R_1 \times R_2) / (R_1 + R_2)$
- Current divides through each branch

★ **More resistors in parallel** → **R_{total} DECREASES**

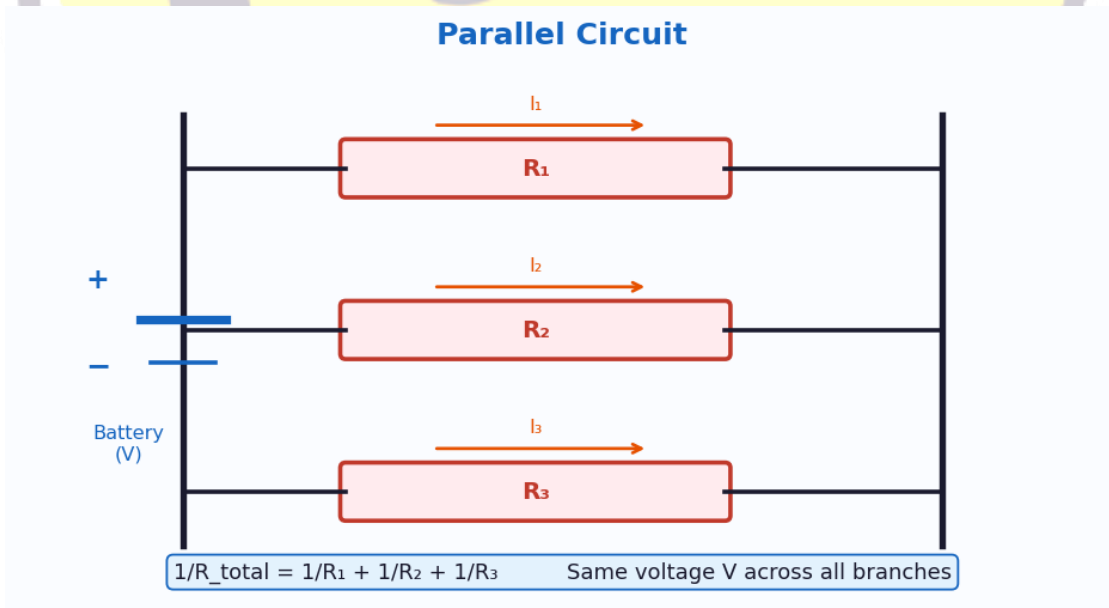


Fig: Parallel Circuit – Same voltage V , currents I_1 I_2 I_3 divide

4. Factors Affecting Resistance

- 1. LENGTH (L) → $R \propto L$ (longer = more resistance)
- 2. CROSS-SECTION AREA (A) → $R \propto 1/A$ (thicker = less resistance)
- 3. MATERIAL (ρ) → Depends on type of material
- 4. TEMPERATURE (T) → For metals, R increases with temperature

$$R_T = R_0 (1 + \alpha T)$$

- R_0 = resistance at 0°C | α = temperature coefficient of resistance

5. Carbon Resistance – Color Coding

Carbon resistors have COLOR BANDS printed on them to indicate resistance value.

- 4-band resistor: Band1 = 1st digit, Band2 = 2nd digit, Band3 = Multiplier, Band4 = Tolerance
- Memory trick: BB ROY of Great Britain has Very Good Wife
- Gold band = $\pm 5\%$ tolerance | Silver band = $\pm 10\%$ tolerance

Example: Red-Violet-Orange-Gold = $27 \times 1000 \pm 5\% = 27 \text{ k}\Omega$

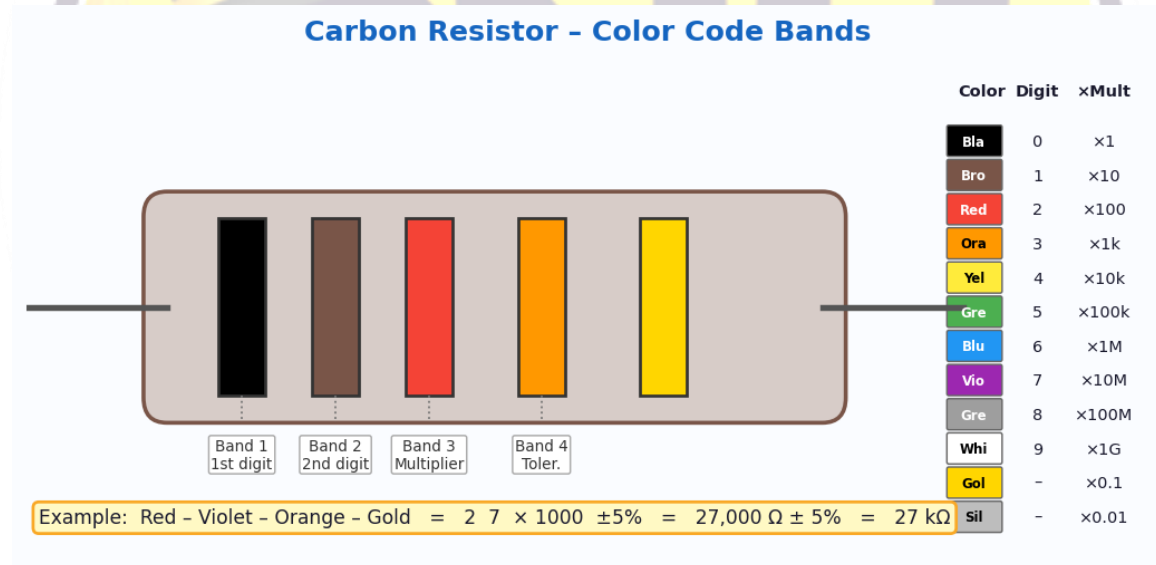


Fig: Carbon Resistor – 4 Color Bands with complete color code table

6. Ohm's Law

- STATEMENT: Current through a conductor is DIRECTLY PROPORTIONAL to voltage,
 - provided temperature and physical conditions remain constant.

$$V = I \times R \quad I = V/R \quad R = V/I$$

- V = Voltage (V) | I = Current (A) | R = Resistance (Ω)
- V-I graph → Straight line through origin for Ohmic conductors

★ Ohm's Law is valid only for metallic conductors at constant temperature

7. Kirchhoff's Laws

7.1 KCL – Kirchhoff's Current Law

- STATEMENT: Sum of currents ENTERING a junction = Sum of currents LEAVING it
$$\Sigma I_{in} = \Sigma I_{out} \quad (\text{or}) \quad \Sigma I = 0 \quad \text{at a node}$$
- Based on: CONSERVATION OF CHARGE

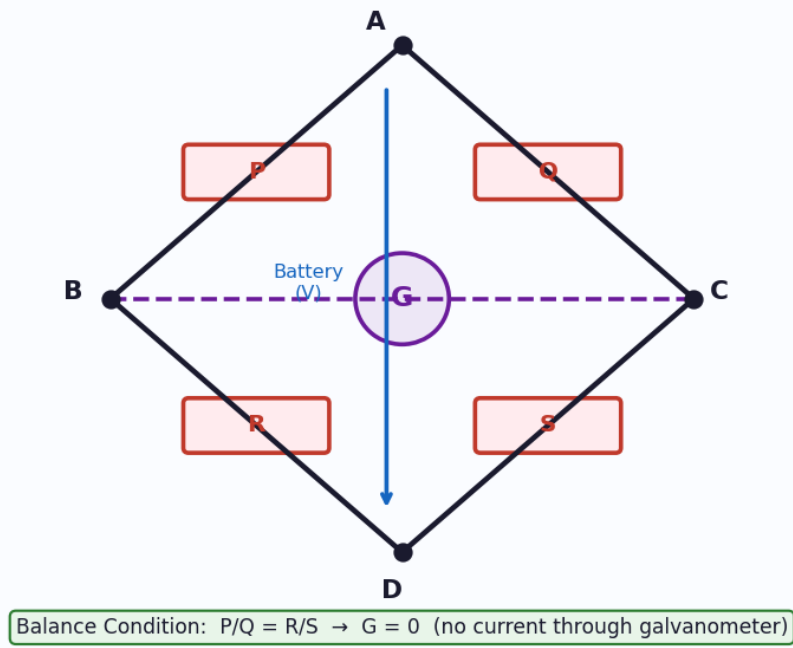
7.2 KVL – Kirchhoff's Voltage Law

- STATEMENT: Sum of all voltages around any closed loop = ZERO
$$\Sigma V = 0 \quad (\text{around a closed loop})$$
 - Based on: CONSERVATION OF ENERGY
- ★ KCL → Junction Rule | KVL → Loop Rule
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8. Wheatstone Bridge

- PRINCIPLE: Used to measure unknown resistance with high precision
 - Four resistors P, Q, R, S arranged in a diamond (bridge) circuit
 - Galvanometer (G) connected between the middle nodes
 - BALANCE CONDITION (null condition):
$$P / Q = R / S$$
 - At balance → Galvanometer reads ZERO → no current through it
 - Unknown resistance: $S = (R \times Q) / P$
 - APPLICATION → Precision measurement of unknown resistance in labs
- ★ Bridge is BALANCED when $P/Q = R/S \rightarrow G = 0$

Wheatstone Bridge



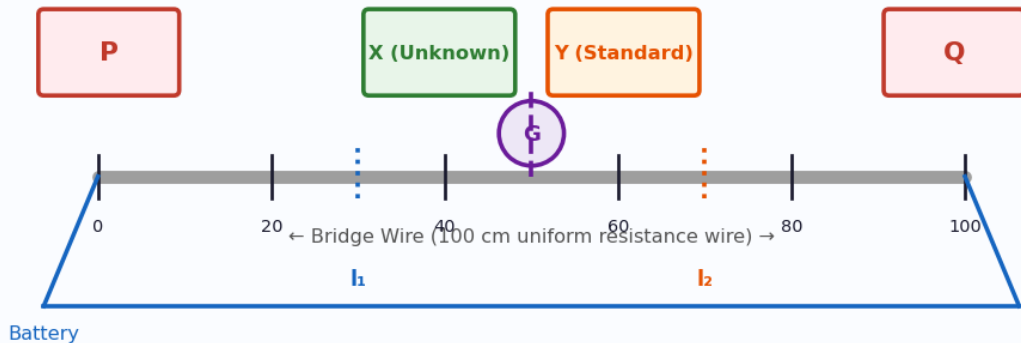
Balance Condition: $P/Q = R/S \rightarrow G = 0$ (no current through galvanometer)

Fig: Wheatstone Bridge – Balance condition $P/Q = R/S$

9. Carey Foster Bridge

- Modified Wheatstone bridge using a UNIFORM WIRE instead of one arm
 - Used to compare two NEARLY EQUAL resistances accurately
 - Balance point shifts on wire when X and Y are swapped
- $$(X - Y) = \rho \times (l_1 - l_2)$$
- ρ = resistance per cm of wire | l_1, l_2 = balance positions (cm)
 - APPLICATION \rightarrow Comparing small or nearly equal resistances in laboratory

Carey Foster Bridge



$$\text{Formula: } X - Y = \rho \times (l_1 - l_2) \quad | \quad \rho = \text{resistance per cm of wire}$$

Fig: Carey Foster Bridge – Balance points l_1 and l_2 on uniform wire

10. EMF & Terminal Voltage

10.1 EMF

- EMF (ϵ) → Total energy supplied by cell per unit charge | Unit: Volt
- Measured when NO current flows → open circuit value

10.2 Terminal Voltage

- TERMINAL VOLTAGE (V) → Voltage available at cell terminals when current flows

$$V = E - I \times r$$

- r = internal resistance | $V < E$ (always, during current flow)

★ EMF → open circuit | Terminal Voltage → closed circuit | $V = E - Ir$

11. Heating Effect of Current – Joule's Law

- When current flows through a resistor → HEAT is produced
- Heat produced is proportional to: I^2 (current squared) $\times R \times t$

$$H = I^2 \times R \times t \quad (\text{Joules})$$

- APPLICATION: Electric heater, electric iron, electric fuse, electric bulb

★ Joule's Law → $H \propto I^2 R t$

12. Electric Power & Energy

12.1 Electric Power

- POWER (P) → Rate of electrical energy consumption | Unit: WATT (W)

$$P = V \times I = I^2 R = V^2 / R$$

- 1 kW = 1000 W

12.2 Electric Energy

- ENERGY = Power × Time | Unit: Joules (J) or kWh

$$E = P \times t \quad (\text{Joules or kWh})$$

- 1 kWh = 1 unit of electricity = 3.6×10^6 Joules

12.3 Numericals

Numerical 1:

A 60 W bulb is connected to 220 V supply. Find current and resistance.

- Given: P = 60 W, V = 220 V
- $I = P / V = 60 / 220 = 0.273$ A
- $R = V^2 / P = (220)^2 / 60 = 807$ Ω
- ★ Answer: $I \approx 0.27$ A, $R \approx 807$ Ω

Numerical 2:

Find heat produced in 5 minutes by a 10 Ω resistor carrying 2 A.

- Given: R = 10 Ω, I = 2 A, t = 5 × 60 = 300 s
- $H = I^2 \times R \times t = (2)^2 \times 10 \times 300 = 12,000$ J
- ★ Answer: $H = 12,000$ J = 12 kJ

Numerical 3:

A fan of 80 W runs 10 hrs/day. Find electricity units consumed in 30 days.

- Energy per day = 80 × 10 = 800 Wh = 0.8 kWh
- Monthly = 0.8 × 30 = 24 kWh
- ★ Answer: 24 units consumed per month

Numerical 4:

Resistors 4 Ω, 6 Ω, 12 Ω in parallel. Find equivalent resistance.

- $1/R = 1/4 + 1/6 + 1/12 = 3/12 + 2/12 + 1/12 = 6/12 = 1/2$
 - R = 2 Ω
 - ★ Answer: Equivalent Resistance = 2 Ω
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13. Thermoelectric Effect

13.1 Seebeck Effect

- Two DIFFERENT metals joined at two junctions → different temperatures → EMF is generated → current flows
- More temperature difference → MORE EMF
- APPLICATION: Thermocouple (temperature measurement)

13.2 Peltier Effect

- REVERSE of Seebeck effect
 - When CURRENT is passed through a thermocouple → one junction HEATS UP, other COOLS DOWN
 - APPLICATION: Thermoelectric coolers, Peltier cooling modules in electronics
- ★ Seebeck → Heat difference to Electricity | Peltier → Electricity to Heat/Cold

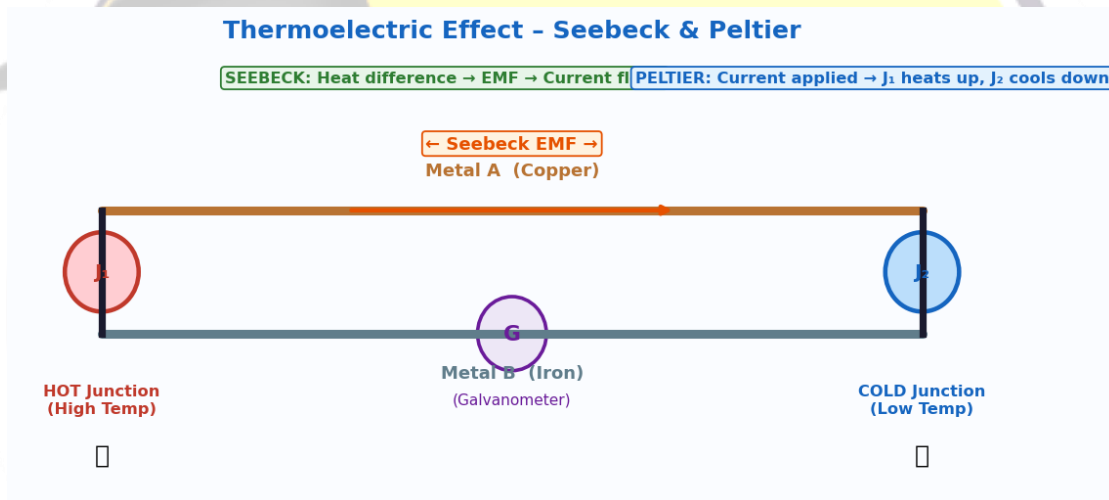


Fig: Seebeck Effect – Hot & Cold junctions produce EMF, Peltier is its reverse

★ IMPORTANT FOR EXAM

1. State and explain Ohm's Law with formula
2. Derive equivalent resistance in series and parallel (with diagram)
3. State and explain Kirchhoff's Laws (KCL and KVL)
4. Explain Wheatstone Bridge with diagram and balance condition
5. Explain Seebeck Effect and Peltier Effect with applications
6. Define EMF and Terminal Voltage — state the difference
7. State Joule's Law of heating with formula and application
8. Explain Carbon Resistor color coding with example
9. Solve numericals on Power, Energy, Joule's heating, equivalent resistance

◆ COMMON VIVA QUESTIONS

- Q1. What is the unit of resistivity? → Ohm-metre ($\Omega \cdot m$)
- Q2. What is 1 unit of electricity? → $1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$
- Q3. Balanced Wheatstone bridge condition? → $P/Q = R/S$, $G = 0$
- Q4. Does Ohm's Law apply to semiconductors? → No, only Ohmic conductors
- Q5. Difference between EMF and Terminal Voltage?
 - → EMF = open circuit | Terminal $V = E - Ir$ (closed circuit)
- Q6. What happens to resistance when temperature increases (metals)? → R increases
- Q7. Application of thermoelectric effect? → Thermocouple temperature sensor
- Q8. In parallel, does total R increase or decrease? → DECREASES
- Q9. What does gold band on carbon resistor mean? → $\pm 5\%$ tolerance
- Q10. Carey Foster Bridge is used for? → Comparing nearly equal resistances

End of Unit 4: Current Electricity | Applied Physics – 2nd Semester

