Subject Name & Code:

BASIC ELECTRICAL ENGINEERING- BE01R00051

Assignment – 1

Q-1: Define electrical circuit elements Resistor (R), Inductor (L), and Capacitor (C).

Answer:

Resistor (R):
A resistor is a passive two-terminal element that opposes the flow of electric current. It obeys **Ohm's Law**:

$$V = IR$$

where V is voltage across the resistor, I is current through it, and R is resistance in ohms (Ω). It dissipates electrical energy as heat.

Inductor (L):
An inductor is a passive two-terminal element that stores energy in a magnetic field when current flows through it. Its voltage–current relationship is:

$$V = L\frac{dI}{dt}$$

where L is inductance in henrys (H). Under steady DC, an inductor acts as a short circuit.

Capacitor (C):
A capacitor is a passive two-terminal element that stores energy in an electric field between two conductive plates. Its voltage–current relationship is:

$$I = C\frac{dV}{dt}$$

where C is capacitance in farads (F). Under steady DC, a capacitor acts as an open circuit.

Q-2: Write the V–I relationship for R, L, and C.

Answer:

- **Resistor (R):**
  For a purely resistive element, the voltage V and current I are related by **Ohm's law**:

$$V = IR$$

where R is the resistance in ohms (Ω). The voltage and current are in phase in an AC circuit.

- **Inductor (L):**
  For an ideal inductor, the voltage is proportional to the rate of change of current:

$$V = L\frac{dI}{dt}$$

In AC circuits with sinusoidal excitation $I = I_m \sin(\omega t)$,

$$V = \omega L I_m \cos(\omega t) = X_L I_m \cos(\omega t)$$

where $X_L = \omega L$ is the inductive reactance. Voltage leads current by 90°.

- **Capacitor (C):**
  For an ideal capacitor, the current is proportional to the rate of change of voltage:

$$I = C\frac{dV}{dt} \text{ or } V = \frac{1}{C}\int I\, dt$$

For sinusoidal AC,

$$V = \frac{I_m}{\omega C}\sin(\omega t - 90^\circ) = X_C I_m \sin(\omega t - 90^\circ)$$

where $X_C = \frac{1}{\omega C}$ is the capacitive reactance. Voltage lags current by 90°.

Q-3: What is meant by an independent voltage source and an independent current source?

Answer:

- **Independent Voltage Source:**
  Maintains a specified voltage across its terminals regardless of the current drawn from it. Its output voltage is fixed (constant or time-varying) and independent of other circuit variables.
- **Independent Current Source:**
  Delivers a specified current through its terminals regardless of the voltage across it. Its output current is fixed and independent of other circuit variables.

Q-4: State Kirchhoff's Current Law (KCL).

Answer:

Kirchhoff's Current Law (KCL) states that the algebraic sum of currents entering and leaving a node (or junction) in an electrical circuit is zero.

$$\sum I_{\text{in}} = \sum I_{\text{out}} \text{or} \sum I_{\text{node}} = 0$$

This law is based on the principle of conservation of electric charge.

Q-5: State Kirchhoff's Voltage Law (KVL).

Answer:

Kirchhoff's Voltage Law states that the algebraic sum of all voltages around any closed loop in a circuit is zero:

$$\sum V_{\text{loop}} = 0$$

This is based on the conservation of energy.

Q-6: Define time constant of: (a) RL circuit (b) RC circuit

Answer:

- **(a) RL Circuit Time Constant (τ_L):**
  The time constant of an RL circuit is the time required for the current through the inductor to reach approximately 63.2% of its final steady-state value when a DC voltage is applied, or to decay to 36.8% of its initial value when the source is removed.

$$\tau_L = \frac{L}{R}(\text{seconds})$$

where L is the inductance in henries (H) and R is the resistance in ohms (Ω).

- **(b) RC Circuit Time Constant (τ_C):**
  The time constant of an RC circuit is the time required for the voltage across the capacitor to reach approximately 63.2% of its final charging voltage, or to decay to 36.8% of its initial voltage during discharging.

$$\tau_C = RC(\text{seconds})$$

where R is in ohms and C is in farads (F).

Q-7: Explain the behavior of inductor and capacitor under DC excitation.

Answer:

- **Inductor:**
  For DC (steady state), $\frac{dI}{dt} = 0$. From $V = L\frac{dI}{dt}$, voltage across the inductor becomes zero. Hence, it acts as a **short circuit**.
- **Capacitor:**
  For DC (steady state), $\frac{dV}{dt} = 0$. From $I = C\frac{dV}{dt}$, current through the capacitor becomes zero. Hence, it acts as an **open circuit**.

Q-8: Explain the procedure to analyze a DC circuit using Kirchhoff's laws.

Answer:

To analyze a DC circuit using Kirchhoff's laws:

1. **Identify all nodes, branches, and loops** in the circuit.
2. **Assign current variables** ($I_1, I_2, ...$) to each branch, choosing arbitrary directions.
3. **Apply Kirchhoff's Current Law (KCL)** at each node (except one) to write current equations.
4. **Apply Kirchhoff's Voltage Law (KVL)** to each independent closed loop. KVL states that the algebraic sum of all voltages around a closed loop is zero:

$$\sum V = 0$$

For each element:

- Resistor: $V = IR$ (voltage drop in direction of current).
- Voltage source: assign polarity signs.

5. **Solve the system of linear equations** for the unknown currents.
6. **Verify the solution** by checking power balance or using an alternative method (e.g., mesh/nodal analysis).

Q-9: State and explain the Superposition Theorem with necessary conditions.

Answer:

Statement:
In a linear circuit with multiple independent sources, the voltage across or current through any element is the algebraic sum of the responses caused by each independent source acting alone, while all other independent sources are turned off.

Conditions:

- The circuit must be **linear** (elements obey Ohm's law).
- Only applicable to **independent sources**; dependent sources remain unchanged.
- **Turning off sources:**
  - Voltage source → short circuit (0 V).
  - Current source → open circuit (0 A).

Q-10: State and explain Thevenin's Theorem.

Answer:

Thevenin's Theorem states that any linear two-terminal network containing independent sources, dependent sources, and resistances can be replaced by an equivalent circuit consisting of a single voltage source V_{th} (Thevenin voltage) in series with a single resistor R_{th} (Thevenin resistance).

Procedure to find Thevenin equivalent:

1. **Remove the load resistor** (if any) across the two terminals.
2. **Find V_{th}:** The open-circuit voltage across the terminals.
3. **Find R_{th}:**
   - Turn off all independent sources (voltage sources shorted, current sources opened).
   - Calculate the equivalent resistance seen from the terminals.
4. **Reconnect the load** to the Thevenin equivalent circuit for analysis.

Significance: Simplifies complex networks for easier analysis of load current, voltage, and power.

11. State and explain Norton's Theorem.

Statement

Norton's Theorem states that:

*Any linear bilateral network with voltage/current sources and resistances can be replaced by a single **current source (I_N)** in **parallel** with a single **resistance (R_N)** across the load terminals.*

Explanation

Step 1 – Remove load
Remove the load resistor across which current/voltage is to be found. Mark the open terminals as A and B.

Step 2 – Find I_N (Norton current)
Short terminals A and B. The current flowing through this short circuit is **I_N**.

Step 3 – Find R_N (Norton resistance)
Deactivate all independent sources:

- Replace voltage sources with short circuits.
- Replace current sources with open circuits.
  Then calculate equivalent resistance between A and B.
  (R_N = R_th from Thevenin)

Step 4 – Draw Norton equivalent circuit
A current source **I_N** in parallel with **R_N**, with load connected across A and B.

Step 5 – Calculate load current
Using current division:

$$I_L = I_N \times \frac{R_N}{R_N + R_L}$$

Limitations

- Applicable only to **linear** circuits.
- Not valid for circuits with mutual inductance or non-linear elements.

Relation with Thevenin

$$I_N = \frac{V_{th}}{R_{th}}, R_N = R_{th}$$

Q-12: Derive the formula for Star–Delta and Delta–Star transformations.

Answer:

Delta to Star Transformation:

Given Delta resistances R_{AB}, R_{BC}, R_{CA}, the equivalent Star resistances are:

$$R_A = \frac{R_{AB}R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$
$$R_B = \frac{R_{AB}R_{BC}}{R_{AB} + R_{BC} + R_{CA}}$$
$$R_C = \frac{R_{BC}R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$

Star to Delta Transformation:

Given Star resistances R_A, R_B, R_C, the equivalent Delta resistances are:

$$R_{AB} = R_A + R_B + \frac{R_A R_B}{R_C}$$
$$R_{BC} = R_B + R_C + \frac{R_B R_C}{R_A}$$
$$R_{CA} = R_C + R_A + \frac{R_C R_A}{R_B}$$

Derivation Outline:
Equate resistances between pairs of terminals in both configurations under open-circuit conditions, solve the resulting equations.

Q-13: Derive the expression for current growth in an RL circuit when a DC voltage is applied.

Answer:

Given:
RL series circuit with resistance R, inductance L, DC voltage V applied at $t = 0$.

To Find: $i(t)$

Formula:
KVL:

$$V = iR + L\frac{di}{dt}$$

Solution:
Rearrange:

$$L\frac{di}{dt} + Ri = V$$

Homogeneous solution: $i_h = Ae^{-(R/L)t}$
Particular solution: $i_p = V/R$
Complete solution:

$$i(t) = \frac{V}{R}\left(1 - e^{-(R/L)t}\right)$$

where time constant $\tau = L/R$.

Final Answer:

$$\boxed{i(t) = \frac{V}{R}\left(1 - e^{-t/\tau}\right)}$$

Q-14: Derive the expression for voltage across capacitor in an RC circuit during charging.

Answer:

Circuit: A DC voltage source V_s in series with resistor R and capacitor C (initially uncharged).

Applying KVL:

$$V_s = iR + v_c$$

where $i = C\frac{dv_c}{dt}$.

Substitute:

$$V_s = RC\frac{dv_c}{dt} + v_c$$

Rearrange:

$$\frac{dv_c}{dt} = \frac{V_s - v_c}{RC}$$

Solve first-order differential equation with initial condition $v_c(0) = 0$:

$$\int_0^{v_c} \frac{dv_c}{V_s - v_c} = \frac{1}{RC}\int_0^t dt$$

$$-\ln(V_s - v_c)\,|_0^{v_c} = \frac{t}{RC}$$

$$\ln\left(\frac{V_s}{V_s - v_c}\right) = \frac{t}{RC}$$

$$v_c(t) = V_s\left(1 - e^{-t/(RC)}\right)$$

Thus, the voltage across the capacitor during charging is:

$$\boxed{v_c(t) = V_s\left(1 - e^{-t/\tau}\right)} \text{ where } \tau = RC.$$

Q-15: Compare Thevenin's and Norton's Theorems.

Answer:

Aspect	**Thevenin's Theorem**	**Norton's Theorem**
Equivalent circuit	Voltage source V_{th} in series with R_{th}	Current source I_N in parallel with R_N
V_{th}	Open-circuit voltage at terminals	Same as Thevenin voltage
I_N	Short-circuit current at terminals	—
Resistance	$R_{th} = R_N$ (same)	$R_N = R_{th}$
Conversion	$V_{th} = I_N R_{th}$	$I_N = V_{th}/R_{th}$
Use case	Simplifies analysis for maximum power transfer, load voltage	Useful for parallel load analysis, load current

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