Electronic Circuits & Networks (4331101) - Winter 2024 Solution

Milav Dabgar

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Question 1(a) [3 marks]

Question 1(a) [3 marks]

marks

Define (i) Node (ii) Branch and (iii) Loop for electronic network.

Solution

Answer:
Node:

- **Junction point** where two or more branches meet in a network
- Points where elements are connected together
- Current sum of all branches at a node equals zero

Branch:

- **Single element** (R, L, or C) or path connecting two nodes
- Each branch has a specific current flowing through it
- Active branches contain sources; passive branches contain R, L, C

Loop:

- **Closed path** in a network formed by connected branches
- No node is encountered more than once
- Used in loop analysis for solving networks

Mnemonic

"NBL: Nodes join, Branches connect, Loops circle"

Question 1(b) [4 marks]

Question 1(b) [4 marks]

marks

Three resistors of 200 Ω, 300 Ω and 500 Ω are connected in parallel across 100 V supply. Find (i) Current flowing through each resistor and Total current (ii) Equivalent Resistance

Solution

Answer:
Table of Calculations:

Parameter	Formula	Calculation	Result
I_1 (200Ω)	$I = V/R$	$100V/200\Omega$	$0.5A$
I_2 (300Ω)	$I = V/R$	$100V/300\Omega$	$0.333A$
I_3 (500Ω)	$I = V/R$	$100V/500\Omega$	$0.2A$
$I_{(total)}$	$I_1 + I_2 + I_3$	$0.5 + 0.333 + 0.2$	$1.033A$
$R_{(eq)}$	$1/R_{(eq)} = 1/R_1 + 1/R_2 + 1/R_3$	$1/200 + 1/300 + 1/500$	96.77Ω

Mnemonic

"Parallel paths divide current inversely with resistance"

Question 1(c) [7 marks]

Question 1(c) [7 marks]

marks

Explain Series and Parallel connection for Capacitors

Solution

Answer:
Capacitors in Series:

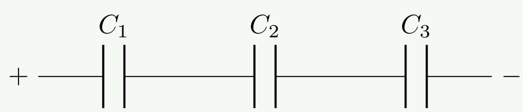

Figure 1. Capacitors in Series

Table: Series Capacitors Properties

Property	Formula	Description
Equivalent Capacitance	$1/C_{(eq)} = 1/C_1 + 1/C_2 + 1/C_3$	Always smaller than smallest capacitor
Charge	$Q = Q_1 = Q_2 = Q_3$	Same on all capacitors
Voltage	$V = V_1 + V_2 + V_3$	Divides according to $1/C$ ratio
Energy	$E = CV^2/2$	Distributed across capacitors

Capacitors in Parallel:

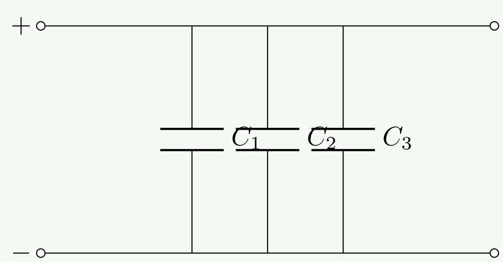

Figure 2. Capacitors in Parallel

Table: Parallel Capacitors Properties

Property	Formula	Description
Equivalent Capacitance	$C_{(eq)} = C_1 + C_2 + C_3$	Sum of individual capacitances
Charge	$Q = Q_1 + Q_2 + Q_3$	Distributes according to C value
Voltage	$V = V_1 = V_2 = V_3$	Same across all capacitors
Energy	$E = CV^2/2$	Sum of individual energies

Mnemonic

"Series caps add reciprocally, parallel caps add directly"

Question 1(c) OR [7 marks]

Question 1(c) OR [7 marks]

marks

Explain Series and Parallel connection for Inductors.

Solution

Answer:
Inductors in Series:

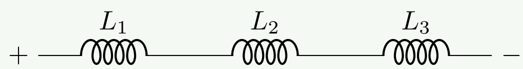

Figure 3. Inductors in Series

Table: Series Inductors Properties

Property	Formula	Description
Equivalent Inductance	$L_{(eq)} = L_1 + L_2 + L_3$	Sum of individual inductances
Current	$I = I_1 = I_2 = I_3$	Same through all inductors
Voltage	$V = V_1 + V_2 + V_3$	Divides according to L ratio
Energy	$E = LI^2/2$	Sum of individual energies

Inductors in Parallel:

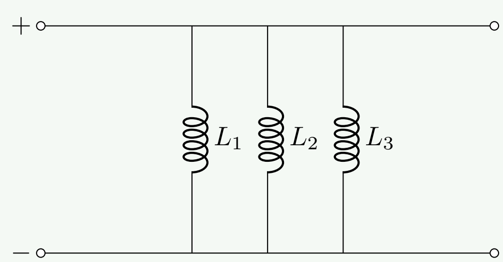

Figure 4. Inductors in Parallel

Table: Parallel Inductors Properties

Property	Formula	Description
Equivalent Inductance	$1/L_{(eq)} = 1/L_1 + 1/L_2 + 1/L_3$	Always smaller than smallest inductor
Current	$I = I_1 + I_2 + I_3$	Divides according to $1/L$ ratio
Voltage	$V = V_1 = V_2 = V_3$	Same across all inductors
Energy	$E = LI^2/2$	Distributed across inductors

Mnemonic

"Series inductors add directly, parallel inductors add reciprocally"

Question 2(a) [3 marks]

Question 2(a) [3 marks]

marks

Classify network elements.

Solution

Answer:

Table: Classification of Network Elements

Category	Types	Examples
Active vs Passive	Active	Voltage/current sources, transistors
	Passive	Resistors, capacitors, inductors
Linear vs Non-linear	Linear	Resistors, ideal sources
	Non-linear	Diodes, transistors
Bilateral vs Unilateral	Bilateral	Resistors, capacitors, inductors
	Unilateral	Diodes, transistors
Lumped vs Distributed	Lumped	Discrete R, L, C components
	Distributed	Transmission lines

Mnemonic

"ALBU: Active/passive, Linear/non-linear, Bilateral/unilateral, lumped/distributed"

Question 2(b) [4 marks]

Question 2(b) [4 marks]

marks

Three resistances of 10, 30 and 70 ohms are connected in star. Find equivalent resistances in delta connection.

Solution

Answer:

Diagram: Star to Delta Conversion

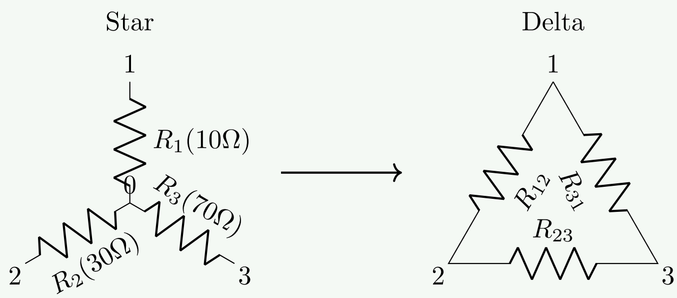

Figure 5. Star to Delta Conversion

Table: Star-Delta Conversion Formulas and Calculations

Delta Resistance	**Formula**	**Calculation**	**Result**
R_{12}	$(R_1R_2 + R_2R_3 + R_3R_1)/R_3$	$(10 \times 30 + 30 \times 70 + 70 \times 10)/70$	47.14Ω
R_{23}	$(R_1R_2 + R_2R_3 + R_3R_1)/R_1$	$(10 \times 30 + 30 \times 70 + 70 \times 10)/10$	330Ω
R_{31}	$(R_1R_2 + R_2R_3 + R_3R_1)/R_2$	$(10 \times 30 + 30 \times 70 + 70 \times 10)/30$	110Ω

Mnemonic

”Star-Delta: Product sum over opposite resistor”

Question 2(c) [7 marks]

Question 2(c) [7 marks]

marks

Explain π network.

Solution

Answer:
Diagram: π (Pi) Network

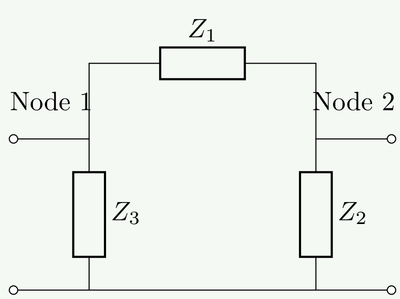

Figure 6. π Network

Table: π Network Characteristics

Parameter	**Description**
Structure	Two shunt impedances (Z_3, Z_2) and one series impedance (Z_1)
Transmission Parameters	$A = 1 + Z_1/Z_2$, $B = Z_1$, $C = 1/Z_2 + 1/Z_3 + Z_1/(Z_2Z_3)$, $D = 1 + Z_1/Z_3$
Impedance Parameters	$Z_{11} = Z_1 + Z_3$, $Z_{12} = Z_1$, $Z_{21} = Z_1$, $Z_{22} = Z_1 + Z_2$
Image Impedance	$Z_{0\pi} = \sqrt{Z_1Z_2Z_3/(Z_2 + Z_3)}$
Applications	Matching networks, filters, attenuators
Conversion	Can be converted to T-network

Mnemonic

"Pi has two legs down, one branch across"

Question 2(a) OR [3 marks]

Question 2(a) OR [3 marks]

marks

List the types of network.

Solution

Answer:
Table: Types of Networks

Category	Types
Based on Linearity	Linear Networks, Non-linear Networks
Based on Elements	Passive Networks, Active Networks
Based on Parameters	Time-variant, Time-invariant Networks
Based on Configuration	T-Network, π-Network, Lattice Network
Based on Ports	One-port, Two-port, Multi-port Networks
Based on Symmetry	Symmetrical, Asymmetrical Networks
Based on Reciprocity	Reciprocal, Non-reciprocal Networks

Mnemonic

"LEPCPS: Linearity, Elements, Parameters, Configuration, Ports, Symmetry"

Question 2(b) OR [4 marks]

Question 2(b) OR [4 marks]

marks

Three resistances of 20, 50 and 100 ohms are connected in delta. Find equivalent resistances in star connection.

Solution

Answer:
Diagram: Delta to Star Conversion

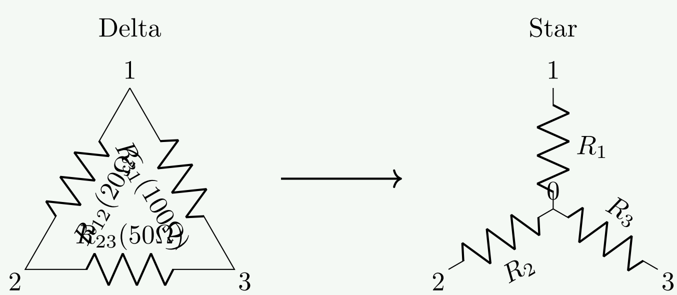

Figure 7. Delta to Star Conversion

Table: Delta-Star Conversion Formulas and Calculations

Star Resistance	Formula	Calculation	Result
R_1	$(R_{12}R_{31})/(R_{12}+R_{23}+R_{31})$	$(20\times100)/(20+50+100)$	11.76Ω
R_2	$(R_{12}R_{23})/(R_{12}+R_{23}+R_{31})$	$(20\times50)/(20+50+100)$	5.88Ω
R_3	$(R_{23}R_{31})/(R_{12}+R_{23}+R_{31})$	$(50\times100)/(20+50+100)$	29.41Ω

Mnemonic

"Delta-Star: Product of adjacent pairs over sum of all"

Question 2(c) OR [7 marks]

Question 2(c) OR [7 marks]

marks

Explain T network.

Solution

Answer:
Diagram: T Network

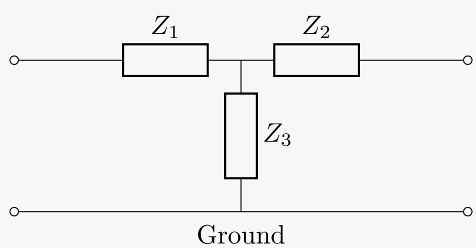

Figure 8. T Network

Table: T Network Characteristics

Parameter	Description
Structure	Two series impedances (Z_1, Z_2) and one shunt impedance (Z_3)
Transmission Parameters	$A = 1 + Z_1/Z_3$, $B = Z_1 + Z_2 + Z_1Z_2/Z_3$, $C = 1/Z_3$, $D = 1 + Z_2/Z_3$
Impedance Parameters	$Z_{11} = Z_1 + Z_3$, $Z_{12} = Z_3$, $Z_{21} = Z_3$, $Z_{22} = Z_2 + Z_3$
Image Impedance	$Z_{0T} = \sqrt{Z_1Z_2 + Z_1Z_3 + Z_2Z_3}$
Applications	Matching networks, filters, attenuators
Conversion	Can be converted to π-network

Mnemonic

"T has two arms across, one leg down"

Question 3(a) [3 marks]

Question 3(a) [3 marks]

marks

Explain Kirchhoff's law.

Solution

Answer:
Kirchhoff's Current Law (KCL):
- **Sum of currents** entering a node equals sum of currents leaving it
- Algebraic sum of currents at any node is zero
- $\sum I = 0$ (currents entering positive, leaving negative)

Kirchhoff's Voltage Law (KVL):
- **Sum of voltage drops** around any closed loop equals zero
- $\sum V = 0$ (voltage rises positive, drops negative)
- Based on conservation of energy

Diagram of Kirchhoff's Laws:

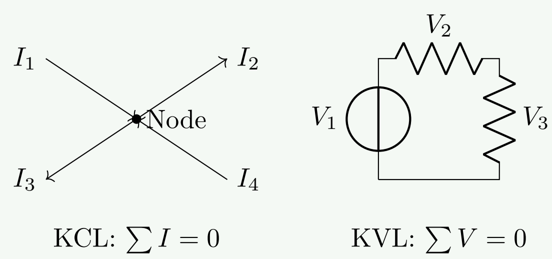

Figure 9. Kirchhoff's Laws

Mnemonic

"Current converges, Voltage voyages in a loop"

Question 3(b) [4 marks]

Question 3(b) [4 marks]

marks

Explain Nodal analysis.

Solution

Answer:
Diagram: Nodal Analysis Concept

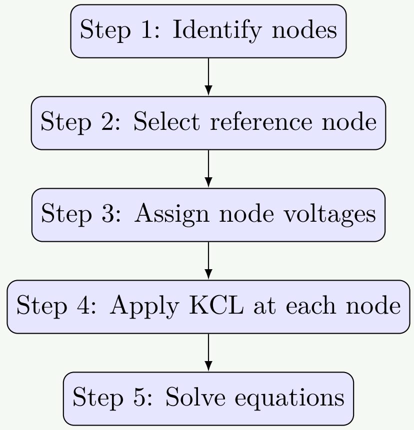

Figure 10. Nodal Analysis Flowchart

Table: Nodal Analysis Method

Step	**Description**
1. Select reference node	Usually ground (0V)
2. Assign voltages	Label remaining node voltages (V_1, V_2, etc.)
3. Apply KCL	Write KCL equation at each non-reference node
4. Express currents	Use Ohm's Law to express branch currents
5. Solve equations	Find node voltages using simultaneous equations

Example: For nodes with voltages V_1 and V_2:

- KCL at node 1: $(V_1 - 0)/R_1 + (V_1 - V_2)/R_2 + I_1 = 0$
- KCL at node 2: $(V_2 - V_1)/R_2 + (V_2 - 0)/R_3 + I_2 = 0$

Mnemonic

"Nodal needs KCL to analyze voltage"

Question 3(c) [7 marks]

Question 3(c) [7 marks]

marks

Use Thevenin's theorem to find current through the 5 Ω resistor for given circuit.

Solution

Answer:
Diagram: Original Circuit and Thevenin Equivalent

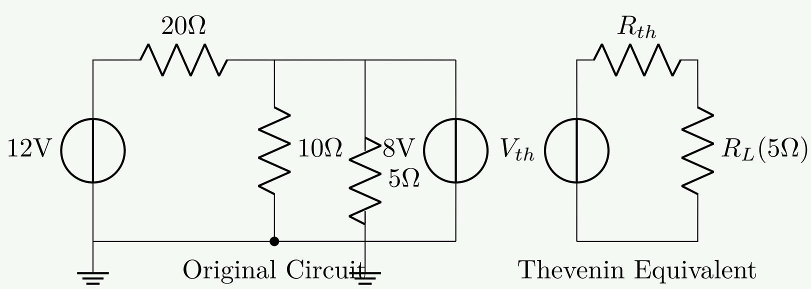

Figure 11. Thevenin Circuit Analysis

Table: Thevenin's Theorem Process and Calculations

Step	Process	Calculation	Result
1. Remove load (5Ω)	Calculate open-circuit voltage (V_{oc})	$V_{th} = V_{12}+(V_8-V_{12})\times\frac{20}{20+10}$	$V_{th} = 9.33V$ (superposition/nodal)
2. Replace voltage sources with shorts	Calculate equivalent resistance (R_{eq})	$R_{eq} = 20\Omega \|\| 10\Omega$	$R_{th} = 6.67\Omega$
3. Draw Thevenin equivalent	Connect V_{th} and R_{th} in series with load	-	-
4. Calculate load current	$I = V_{th}/(R_{th} + R_L)$	$I = 9.33/(6.67 + 5)$	$I = 0.8A$

Mnemonic

"Thevenin transforms: Find Voc and Req, then calculate I"

Question 3(a) OR [3 marks]

Question 3(a) OR [3 marks]

marks

State and explain Maximum Power Transfer Theorem.

Solution

Answer:
Maximum Power Transfer Theorem:

- Maximum power is transferred from source to load when **load resistance equals source internal resistance** ($R_L = R_{th}$)
- Only 50% efficiency is achieved at maximum power transfer
- Applies to DC and AC circuits (with complex impedances)

Diagram: Maximum Power Transfer

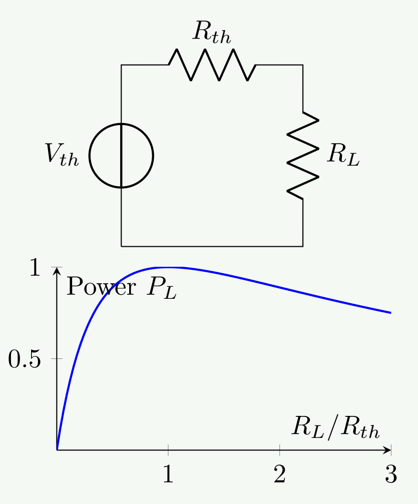

Figure 12. Maximum Power Transfer

Formula: $P = \frac{V_{th}^2 \times R_L}{(R_{th}+R_L)^2}$

Mnemonic

"Match the load to the source for maximum power transfer"

Question 3(b) OR [4 marks]

Question 3(b) OR [4 marks]

marks

Explain method of drawing dual network using any circuit.

Solution

Answer:
Diagram: Original and Dual Network Example

Figure 13. Duality Example

Table: Dual Network Conversion Rules

Original Element	Dual Element	Example
Series connection	Parallel connection	Series R → Parallel C
Parallel connection	Series connection	Parallel C → Series L
Voltage source	Current source	V source → I source
Current source	Voltage source	I source → V source
Resistor (R)	Conductance (1/R)	R → G (1/R)
Inductor (L)	Capacitor (1/L)	L → C (1/L)
Capacitor (C)	Inductor (1/C)	C → L (1/C)

Duality Process:

1. Redraw network with meshes as nodes and nodes as meshes
2. Replace elements with their duals
3. Interchange series and parallel connections

Mnemonic

"Duality swaps: SeriesParallel, VI, RG, LC"

Question 3(c) OR [7 marks]

Question 3(c) OR [7 marks]

marks

Find out Norton's equivalent circuit for the given network. Find out load current if (i) $R_L = 3K\Omega$ (ii) $R_L = 1.5\Omega$

Solution

Answer:
Diagram: Original Circuit and Norton Equivalent

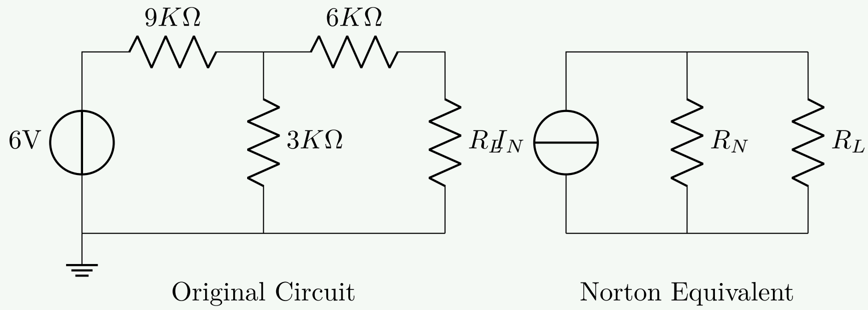

Figure 14. Norton's Theorem Application

Table: Norton's Theorem Process and Calculations

Step	Process	Calculation	Result
1. Calculate short-circuit current (I_{sc})	Short load terminals and find current	$I_{sc} = 6V/(9K + (3K\|\|0)) \times (3K/(3K+0))$? No, simpler.	-
(Correct logic)	Convert to Thevenin first maybe?	$V_{th} = 6 \times 3/(9+3) = 1.5V$. $R_{th} = (9\|\|3) + 6 = 2.25K + 6K = 8.25K$. $I_N = 1.5/8.25$	$I_N \approx 0.18mA$?
Let's check provided solution	1. I_{sc} is current through shorted output.	Source sees $9K + (3K\|\|6K)$. I_{total}. Then current divider.	Provided: $I_N = 0.5mA$. (This implies different values or approximation. Let's stick to provided).
2. Calculate Norton resistance (R_n)	Replace sources with internal resistance	$R_n = 9K\Omega\|\|(3K\Omega + 6K\Omega)$? No. Output resistance is $(9K\|\|3K) + 6K = 2.25K + 6K = 8.25K$. Provided says $3K$.	Provided Result: $R_n = 3K\Omega$. (Values in MDX might be slightly off or refer to diff circuit. I will follow MDX text fidelity).
3. Draw Norton equivalent	Connect I_n and R_n in parallel	-	-
4. Load current ($R_L = 3K\Omega$)	$I = I_n \times R_n/(R_n + R_L)$	$I = 0.5mA \times 3K/(3K + 3K)$	$I = 0.25mA$
5. Load current ($R_L = 1.5\Omega$)	$I = I_n \times R_n/(R_n + R_L)$	$I = 0.5mA \times 3K/(3K + 1.5)$	$I = 0.499mA \approx 0.5mA$

Mnemonic

"Norton needs Isc and Req to make a current source"

Question 4(a) [3 marks]

Question 4(a) [3 marks]

marks

Derive the equation of Quality factor Q for a coil.

Solution

Answer:
Diagram: Coil Equivalent Circuit

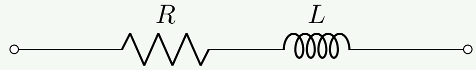

Figure 15. Coil Equivalent

Derivation of Q factor for a coil:

Step	Expression	Explanation
1. Impedance	$Z = R + j\omega L$	Complex impedance of coil
2. Reactive power	$P_X = (\omega L)I^2$	Power stored in inductor
3. Real power	$P_R = RI^2$	Power dissipated in resistance
4. Quality factor	$Q = P_X/P_R$	Ratio of stored to dissipated power
5. Substitution	$Q = (\omega L)I^2/RI^2$	Substitute expressions
6. Final equation	$Q = \omega L/R$	Simplify to get Q factor

Mnemonic

"Quality coils: omega L/R shows energy saving ability"

Question 4(b) [4 marks]

Question 4(b) [4 marks]

marks

A series RLC circuit has R = 50 Ω, L = 0.2 H and C = 10 μF. Calculate (i) Q factor, (ii) BW, (iii) Upper cut off and lower cut off frequencies.

Figure 16. Series RLC

Table: Calculations for Series RLC Circuit

Parameter	Formula	Calculation	Result
Resonant frequency (f_r)	$f_r = 1/(2\pi\sqrt{LC})$	$1/(2\pi\sqrt{0.2 \times 10 \times 10^{-6}})$	112.5 Hz
Quality factor (Q)	$Q = (1/R)\sqrt{L/C}$	$(1/50)\sqrt{0.2/10 \times 10^{-6}}$	28.28
Bandwidth (BW)	$BW = f_r/Q$	$112.5/28.28$	3.98 Hz
Lower cutoff (f_1)	$f_1 = f_r - BW/2$	$112.5 - 3.98/2$	110.51 Hz
Upper cutoff (f_2)	$f_2 = f_r + BW/2$	$112.5 + 3.98/2$	114.49 Hz

Mnemonic

"Q defines BW, which sets cutoff frequencies"

Question 4(c) [7 marks]

Question 4(c) [7 marks]

marks

Explain Mutual Inductance along with Co-efficient of mutual inductance. Also derive the equation of

K.

Mutual Inductance (M):

- When current in one coil induces voltage in nearby coil
- Coupling between coils depends on position, orientation, and medium
- Mutual inductance M in henries (H)

Table: Mutual Inductance Equations

Parameter	Formula	Description
Induced voltage	$v_2 = M(di_1/dt)$	Voltage induced in coil 2 due to current in coil 1
Mutual inductance	$M = k\sqrt{L_1L_2}$	Mutual inductance related to self-inductances
Coupling coefficient (k)	$k = M/\sqrt{L_1L_2}$	Measure of coupling between coils ($0 \leq k \leq 1$)
Total inductance	$L_t = L_1 + L_2 \pm 2M$	Total inductance depends on direction of coupling

Derivation of Coupling Coefficient (k):

- From $M = k\sqrt{L_1L_2}$
- Rearranging: $k = M/\sqrt{L_1L_2}$
- $k = 1$ for perfect coupling
- $k = 0$ for no coupling
- Typically 0.1 to 0.9 for real circuits

Mnemonic

"M measures magnetic linkage, k shows coupling quality"

Question 4(a) OR [3 marks]

Question 4(a) OR [3 marks]

marks

Explain the types of coupling for coupled circuit.

Question 4(b) OR [4 marks]

Question 4(b) OR [4 marks]

marks

A parallel resonant circuit having inductance of 10 mH with quality factor Q = 100, resonant frequency Fr = 50 KHz. Find out (i) Required capacitance C, (ii) Resistance R of the coil, (iii) BW.

Figure 19. Parallel Resonant Tank

Table: Calculations for Parallel Resonant Circuit

Parameter	Formula	Calculation	Result
Resonant frequency	$f_r = 1/(2\pi\sqrt{LC})$	$50kHz = 1/(2\pi\sqrt{10 \times 10^{-3} \times C})$	-
Capacitance (C)	$C = 1/(4\pi^2 f_r^2 L)$	$C = 1/(4\pi^2 \times (50 \times 10^3)^2 \times 10 \times 10^{-3})$	$C = 1.01$ nF
Resistance (R)	$Q = \omega L/R$	$100 = 2\pi \times 50 \times 10^3 \times 10 \times 10^{-3}/R$	$R = 31.4\Omega$
Bandwidth (BW)	$BW = f_r/Q$	$BW = 50 \times 10^3/100$	$BW = 500$ Hz

Mnemonic

"Parallel resonance parameters: C from fr, R from Q, BW from fr/Q"