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CONTENTS

CHAPTER - 1
BASIC CONCEPTS

1.1INTRODUCTION
1.1.1 Charge

Charge can be classified as:
1. Stationary Charge
2. Dynamic Charge

1. Stationary Charge

Stationary charge does not result into electric current because the flow of current means charge moving with net rate across any cross section.

(i) Any electric circuit should always follow law of conservation of charge and law of conservation of energy.

(ii) Circuit theory is analysed always at low frequency and field theory always at high frequency.

(iii) Transit time effect is always neglected at low frequency because

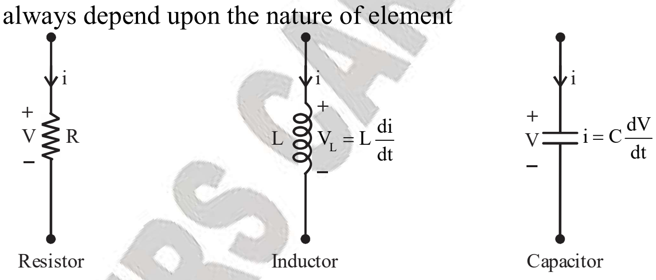
$T >> t_r$

Where T is time period of sinosdual signal

t_r is Transit Time (time taken by signal effect to travel from one point to another point).

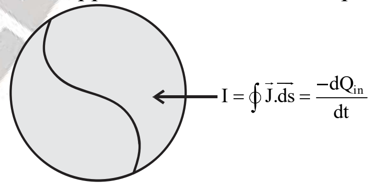
(iv) Elemental law is obeyed only at low frequency such as ohm's law. It is not applicable at high frequency because of distributed nature of element.

(v) Elemental law always depend upon the nature of element



For different Element, Different Form of Ohm's Law is present

(i) In time domain, the ohm's law are applicable and also in frequency domain.



Current flowing out of this body is given by equation of continuity as below

$$I = \oint \vec{J}.\vec{ds} = -\frac{dQ_{in}}{dt} \quad \ldots(i)$$

This equation gives the law of conservation of charge.

If $\frac{dQ_{in}}{dt} = 0$; means no rate of change of charge within body then eq.(i) become

WORKBOOK

Example 1. The waveform of the current through an inductor of 10H is shown in Fig. Sketch the waveform of the voltage across the inductor

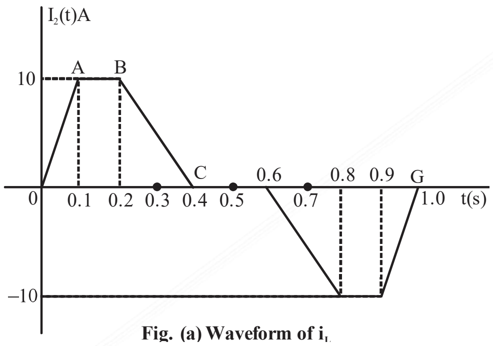


Fig. (a) Waveform of i_L

Solution.

The voltage across an inductor is

$$v_L = L\frac{di_L}{dt}$$

(a) Between 0 and 0.1 s (that is, for $0 < t < 0.1$), the derivative, $\frac{di_L}{dt}$, which is the slope of the i_L curve, is constant since $i_L(t)$ is linear

$$\frac{di_L}{dt} = \text{slope of line OA}$$

$$= \frac{OA}{AM} = \frac{10}{0.1} = 100\text{A/s} \text{ (constant)}$$

$\therefore\ v_L = L\frac{di_L}{dt} = 10\times 100 = 1000\text{V}$ (constant) for $0 < t < 0.1$

This constant value is plotted as a horizontal line ab in fig.

(b) For $0.1 < t < 0.2$s the current curve AB is horizontal, that is, its slope is zero

$$\therefore\ v_L = L\frac{di}{dt} = 10\times 0 = 0\text{V}$$

For $0.1 < t < 0.2$s

This is plotted as horizontal line cd in fig.

(c) For $0.2 < t < 0.4$s, the current curve is BC. The slope of BC is negative.

$$\therefore\ \frac{di_L}{dt} = \text{slope of line BC}$$

$$= \frac{BN}{NC} = \frac{10}{0.2} = -50\text{A/s}$$

$$\therefore\ v_L = L\frac{di_L}{dt} = 10\times 0 = 0 \text{ for } 0.4 < t < 0.6\text{s}$$

The voltage waveform in the range $0.4 < t < 0.6$s is by fh in Fig. (b)

(e) For $0.6 < t < 0.8$s , the current curve is DE. I has a negative slope given by

$$\frac{di_L}{dt} = -\frac{EP}{PD} = -\frac{10}{0.2} = -50\text{A/s}$$

$\therefore\ v_L = L\frac{di_L}{dt} = 10\times(-50) = -500\text{V}$ for $0.6 < t < 0.8$s

The voltage waveform in this range is show by km in fig.

(f) For $0.8 < t < 0.9$s, since the current curve EF is horizontal, $\frac{di_L}{dt} = 0$

$$\therefore\ v_L = L\frac{di_L}{dt} = 10\times 0 = 0\text{V}$$

This is shown by curve ℓ n in fig. 9b)

(g) for $0.9 < t < 1.0$s, the current curve FG has a slope

$$\frac{di_L}{dt} = \frac{FQ}{QG} = \frac{10}{0.1} = 100\text{A/s}$$

$$\therefore\ v_L = L\frac{di_L}{dt} = 10\times 100 = 1000\text{V}$$

This is shown by curve pq in Fig.(b)

Overall voltage waveform is shown below:

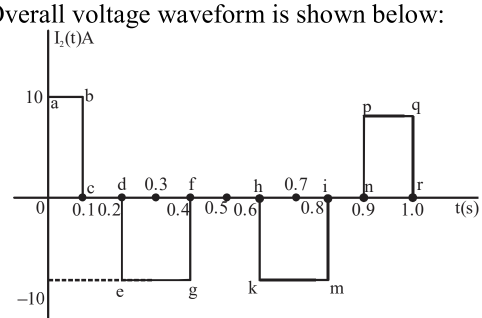
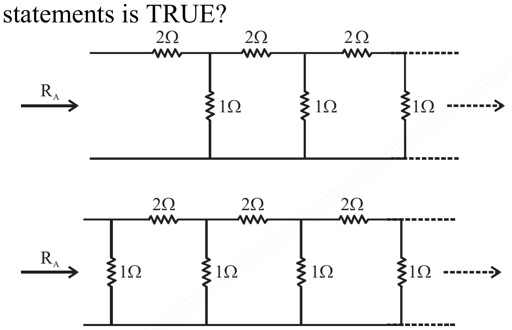


Fig. (b) Waveform of v_L

GATE QUESTIONS

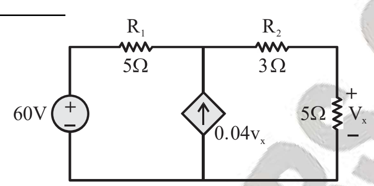
1. R_A and R_B are the input resistances of circuits as shown below. The circuits extend infinitely in the direction shown. Which one of the statements is TRUE?



[GATE - 2016]

(a) $R_A = R_B$ (b) $R_A = R_B = 0$
(c) $R_A < R_B$ (d) $R_B = R_A/(1+R_A)$

2. In the circuit shown in the figure, the magnitude of the current (in amperes) through R_2 is ______

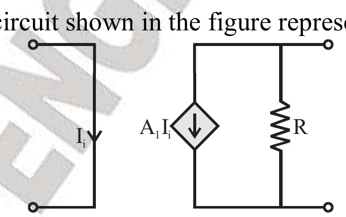


[GATE - 2016]

3. An incandescent lamp is marked 40W, 240V. If resistance at room temperature (26°C) is 120Ω, and temperature coefficient of resistance is 4.8×10^{-3}/°C, then its 'ON' state filament temperature in °C is approximately________

[GATE - 2014]

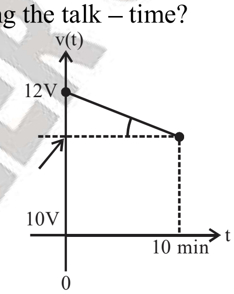
4. The circuit shown in the figure represents a



[GATE - 2014]

(a) Voltage controlled voltage source
(b) Voltage controlled current source
(c) Current controlled current source
(d) Current controlled voltage source

5. A fully charged mobile phone with a 12V battery is good for a 10 minute talk-time. Assume that during the talk – time the battery delivers a constant current of 2A and its voltage drops linearly from 12V to 10V as shown in the figure. How much energy does the battery deliver during the talk – time?

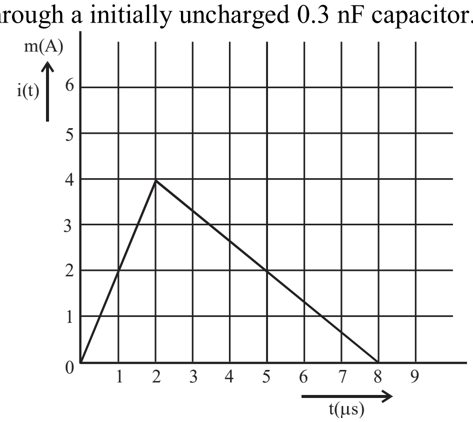


[GATE - 2009]

(a) 220 J (b) 12kJ
(c) 13.2 kJ (d) 14.4 J

Common data for Q. 6 & Q. 7

The current i(t) sketched in the figure flows through a initially uncharged 0.3 nF capacitor.



6. The charge stored in the capacitor at t = 5 μs, will be

[GATE - 2008]

(a) 8nC (b) 10 nC
(c) 13 nC (d) 16 nC

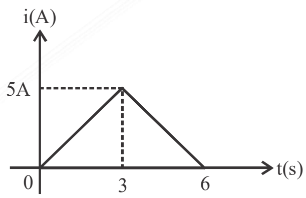
ESE OBJ QUESTIONS

1. A sinusoidal voltage waveform has frequency 50 Hz and RMS voltage 30 V. The equation representing the waveform is

[EC ESE - 2018]

(a) V = 30 sin 50t
(b) V = 60 sin 20t
(c) V = 42.42 sin 314 t
(d) V = 84.84 sin 314 t

2. A waveform, shown in the figure is applied to a resistor of 20Ω. The power dissipated in the resistor is



[EC ESE - 2018]

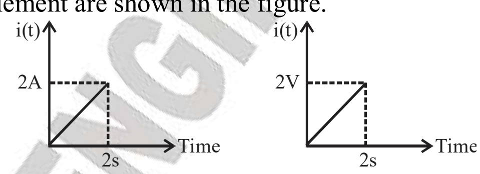
(a) 100 W (b) 600 W
(c) 900 W (d) 1000 W

3. The Kirchhoff's current law works on the principle of conservation of
1. Charge
2. Energy
3. Power
Which of the above is/are correct?

[EC ESE - 2018]

(a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

4. The voltage and current waveforms for an element are shown in the figure.

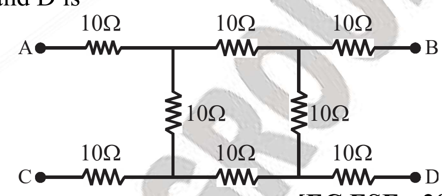


The circuit element and its value are

[EE ESE - 2017]

(a) Capacitor, 2F (b) Inductor, 2H
(c) Capacitor, 0.5F (d) Inductor, 0.5H

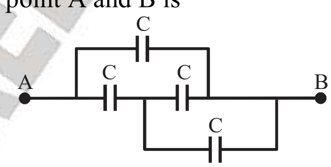
5. The equivalent resistance between the points A and D is



[EC ESE - 2015]

(a) 10Ω (b) 20 Ω
(c) 30 Ω (d) 40 Ω

6. The capacitance of each capacitor is C = 3μF in the figure shown. The effective capacitance between point A and B is



[EC ESE - 2015]

(a) 2μF (b) 3μF
(c) 4μF (d) 5μF

7. A network N consists of resistors, dependent and independent voltage and current sources. If the current in one particular resistance is 1A, it will be doubled if the values of all the

[EC ESE - 2014]

(a) Independent voltage sources are doubled.
(b) Independent current sources are doubled.
(c) Dependent and independent voltage and current sources are doubled
(d) Independent voltage and current sources are doubled

8. A voltage of 2000 V exists across 1cm insulating space between two parallel conducting plates. An electron of charge 1.6 $\times 10^{-19}$ coulomb is introduced into the space. The force on the electron is

[EC ESE - 2014]

(a) 18.2×10^{-26} N (b) 3.2×10^{-14} N
(c) 1.6×10^{-19} N (d) 4.5×10^{26} N

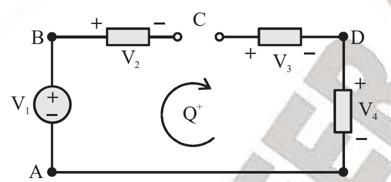
CHAPTER - 2
NETWORK LAWS

2.1 KIRCHOFF'S VOLTAGE LAW (KVL)
It states that algebraic sum of all voltages in a closed path or loop is zero

$$\sum_{loop} V = 0$$

For writing KVL start from any point in the loop and come to the same point via transversing the path of closed loop. While doing so take voltage rises as positive and voltage drops as negative then

Σ voltage rise + Σ voltage drops = 0



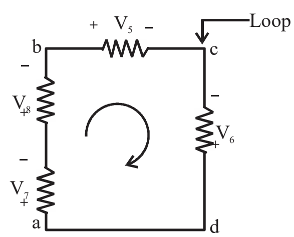
Q^+ positive is moving
A-B is energy is gained say W_1
B-C is energy lost say W_2
C-D is energy lost say W_3
D-A is energy lost say W_4
by consecration of energy
$W_1 = W_2 + W_3 + W_4$ or
$W_1 - W_2 - W_3 - W_4 = 0$

Divide by $Q = \frac{W_1}{Q} - \frac{W_2}{Q} - \frac{W_3}{Q} - \frac{W_4}{Q} = 0$

$\Rightarrow V_1 - V_2 - V_3 - V_4 = 0$

$\Sigma V = 0$ (In a loop)

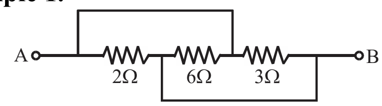
Example. KVL in this loop starting from a in clockwise direction is
$-V_7 - V_8 - V_5 + V_6 = 0$
$\Rightarrow V_6 = V_7 + V_8 + V_5$



The basis of the law is that if we start from a particular junction and go round the mesh till we come back to the starting point, then we must be at the same potential with which we started. Hence it means that all the sources of e.m.f. met on the way must necessarily be equal to the voltage drops in the resistances, every voltage being given its proper sign, plus or minus.

WORKBOOK

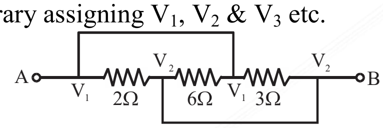
Example 1.



Find equivalent resistance across AB

Solution.

Arbitrary assigning V_1, V_2 & V_3 etc.



Potential difference (p.d.) across 2Ω resistance $= V_1 - V_2$

Potential difference (p.d.) across 6Ω resistance $= V_2 - V_1$

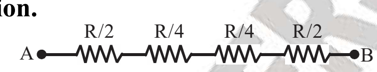
Potential difference (p.d.) across 3Ω resistance $= V_1 - V_2$

We will not consider sign of p.d. only magnitude is of concern, now because all the resistances have same p.d., they all are in parallel hence

$$\frac{1}{R_{AB}} = \frac{1}{2} + \frac{1}{6} + \frac{1}{3} \Rightarrow R_{AB} = 1\Omega$$

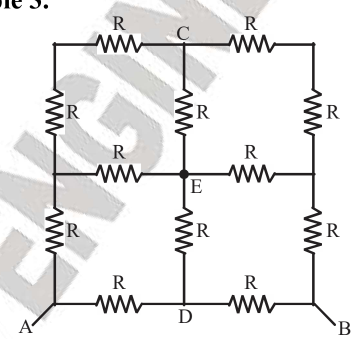
Example 2. Find R_{AB}.

Solution.



$$\Rightarrow R_{AB} = \frac{R}{4} + \frac{R}{4} + \frac{R}{2} + \frac{R}{2} = \frac{3R}{2}$$

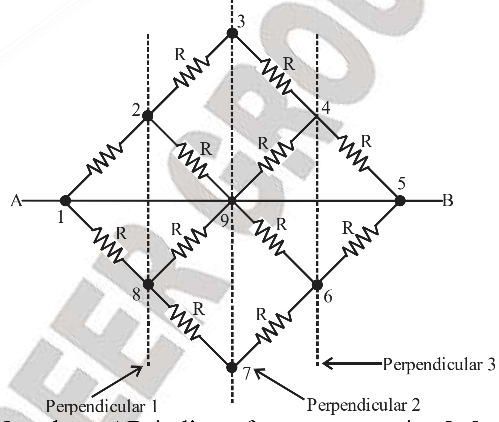
Example 3.



Find equivalent resistance between AB

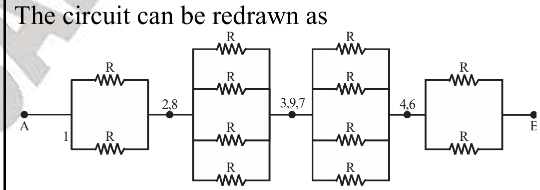
Solution.

All resistance are R Ω find R_{AB}



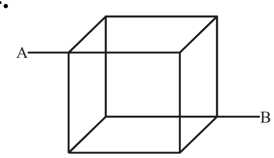
Now here AB is line of symmetry point 2 & 8 can be joined point 3, 9, 7 can be joined and point 2 & 6 can be joined.

The circuit can be redrawn as



In this problem AB is not line of symmetry however perpendicular bisector of AB that is CD is a line of symmetry. Hence points C, E & D are at same potentials hence R_{CE} & R_{ED} can be removed from the circuit.

Example 4.



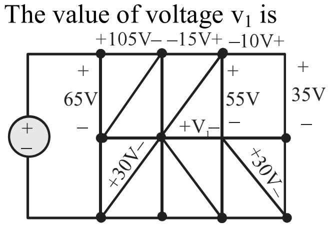
Find R_{AB} (equivalent resistance across diagonal of a cube)

Solution.

For solving such problems. Assume current I is entering at A then this i will come out of B then this current is distributed as per symmetry

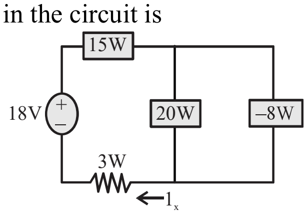
ASSIGNMENT

1. Consider the circuit graph shown in fig. Each branch of circuit graph represent a circuit element. The value of voltage v_1 is



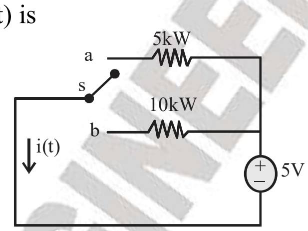
(a) –30 V (b) 25 V
(c) –20 V (d) 15 V

2. In the circuit of figure, power absorbed by the unknown elements are given. Then the current I_x in the circuit is



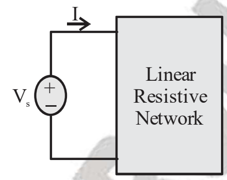
(a) 1.5 A (b) 6.0A
(c) 3.0A (d) None

3. In the circuit of figure, the ideal switch S alternatively stays at position A for 1 ms and at position B for 4 ms. The average value of current i(t) is



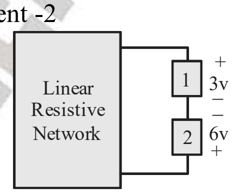
(a) 0.6 mA (b) 1.5mA
(c) 0.75 mA (d) 2.5 mA

4. If a resistor of 10Ω is placed in parallel with voltage source in the circuit of figure, the current i will be



(a) Increased
(b) Decreased
(c) Constant
(d) It is not possible to say

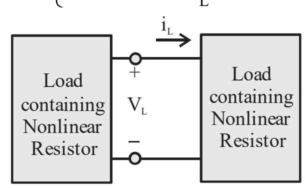
5. Two elements are connected in series as shown in figure. Element-1 supplies 36W of power. Element -2



(a) Absorbs 72W (b) Absorbs 36W
(c) Supplies 72W (d) Absorb 144W

6. The voltage v_L in figure is related to the current i_L according to

$$v_L = \begin{cases} 16 - 4i_L^2 & 0 \le i_L \le 2 \\ 0 & i_L > 2 \end{cases}$$

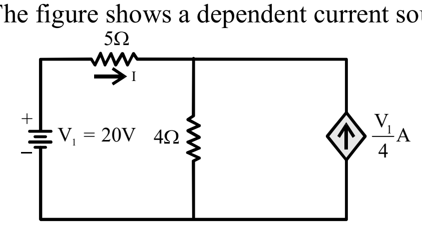


The value of i_L that maximizes the power absorbed by the load is
(a) 0A (b) 1.333A
(c) 2A (d) 1.155A

7. In the circuit shown in figure, the value of voltage v_0 is

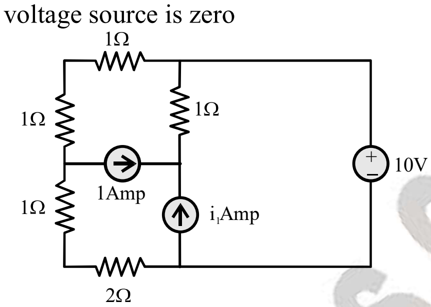
ASSIGNMENT

1. The figure shows a dependent current source.



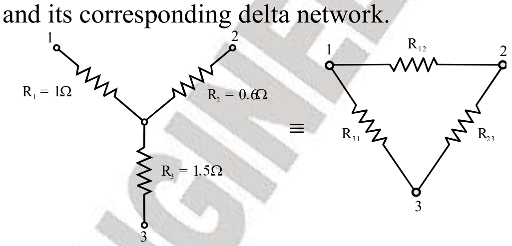
It
(a) Absorbs 80 W
(b) Delivers 80 W
(c) Absorbs 100w
(d) Delivers 100W

2. In the current shown ,the power supplied by the voltage source is zero



Current i_1 is
(a) 2A (b) 3A
(c) 1.6A (d) 4A

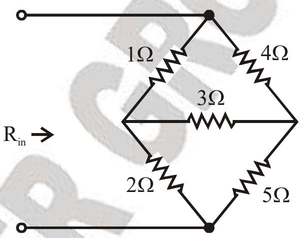
3. Following network shown is the star network and its corresponding delta network.



R_{12}, R_{23} and R_{31} are respectively
(a) 1.6Ω, 2.1Ω, 2.5Ω (b) 2.5Ω, 5Ω, 6Ω
(c) 2Ω, 3Ω, 4Ω (d) 2Ω, 3Ω, 5Ω

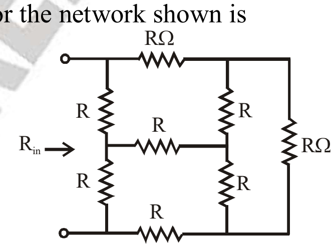
4. The rms value of the voltage function
$V = 50 + 100 \sin\omega t + 50 \sin 3\omega t$ is
(a) 91V (b) 93.5 V
(c) 102.6 V (d) 98.3 V

5. The input resistance of the circuit shown below is



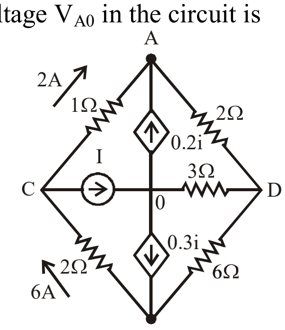
(a) 6Ω (b) 1.95 Ω
(c) 2.24 Ω (d) 3.36 Ω

6. R_{in} for the network shown is



Each R is 10Ω
(a) 10Ω (b) 15Ω
(c) 3Ω (d) 11.43Ω

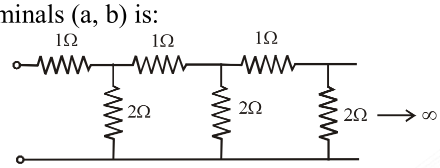
7. The voltage V_{A0} in the circuit is



(a) –0.4V (b) + 0.4V
(c) 1.6 V (d) 12 V

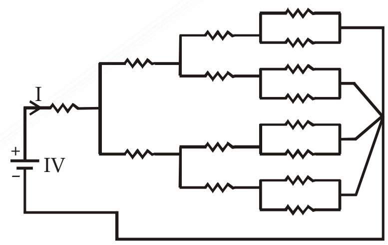
ASSIGNMENT

1. The equivalent resistance seen between the terminals (a, b) is:



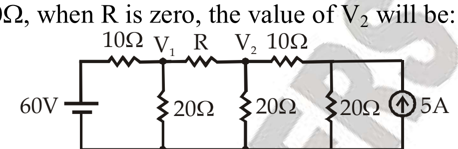
(a) 2Ω (b) 4Ω
(c) 1Ω (d) Not Possible

2. All the resistances in the figure are 1 Ω each. The value of I will be:



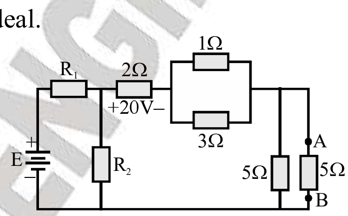
(a) 1/15 A (b) 2/15 A
(c) 4/15 A (d) 8/15 A

3. In the circuit below, V_1 = 40 V when R is 10Ω, when R is zero, the value of V_2 will be:



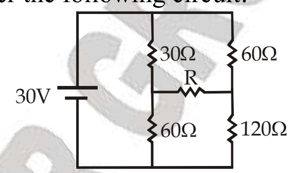
(a) 40V (b) 30V
(c) 20V (d) 10V

4. In the circuit shown below, the voltage across 2Ω resistor is 20V. The 5Ω resistor connected between the terminals A and B can be replaced by an ideal.



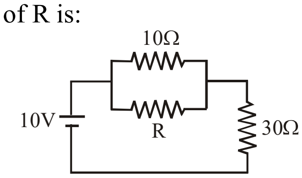
(a)Voltage source of 25V with +ve terminal upward
(b)Voltage source of 25V with +ve terminal downward
(c)Current source of 2A upward.
(d)Current source of 2A downward.

5. Consider the following circuit:



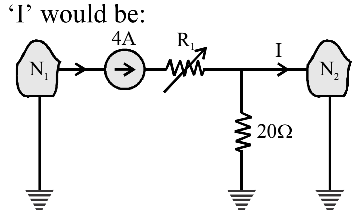
What is the power delivered to resistor in the above circuit?
(a) – 15 W
(b) 0W
(c) 15 W
(d) Cannot be determined unless the value of R is known.

6. In the circuit shown in the figure, the power dissipated in 30Ω resistor will be maximum if the value of R is:



(a) 30Ω (b) 16Ω
(c) 9Ω (d) Zero

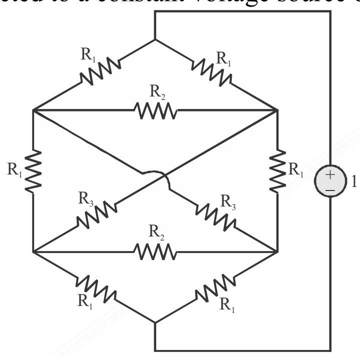
7. In the circuit shown in the figure, for R = 20Ω, the circuit 'I' is 2A. When R is 10Ω, the current 'I' would be:



8. In the figure below, the current of 1A flows through the resistance of:

GATE QUESTIONS

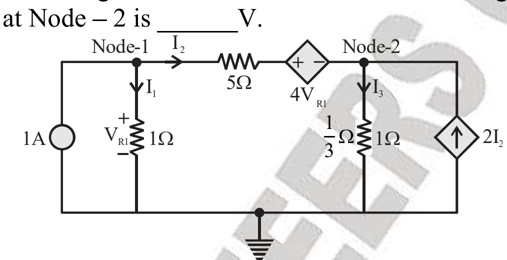
1. Consider the network shown below with R_1 = 1 Ω, R_2 = 2 Ω and R_3 = 3 Ω. The network is connected to a constant voltage source of 11 V.



The magnitude of the current (in amperes, accurate to two decimal places) through the source is __________

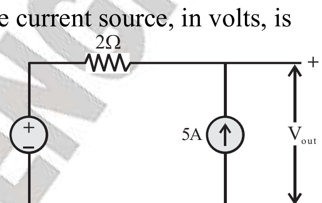
[GATE - 2018]

2. A circuit consisting of dependent and independent sources is shown in the figure. If the voltage at Node -1 is –1V, then the voltage at Node – 2 is ______V.



[GATE - 2017]

3. In the circuit shown below, the voltage and current sources are ideal. The voltage (V_{out}) across the current source, in volts, is

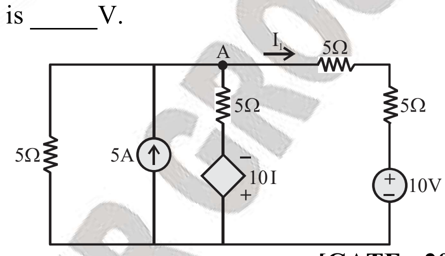


[GATE - 2016]

(a) 0 (b) 5

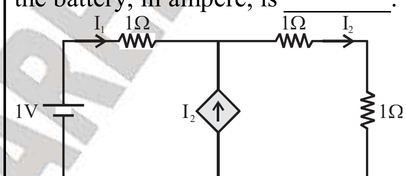
(c) 10 (d) 20

4. In the circuit shown below, the node voltage V_A is _____V.



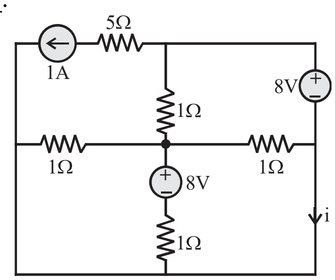
[GATE - 2016]

5. In the given circuit, the current supplied by the battery, in ampere, is ________.



[GATE - 2016]

6. In the figure shown, the current i (in ampere) is _____.



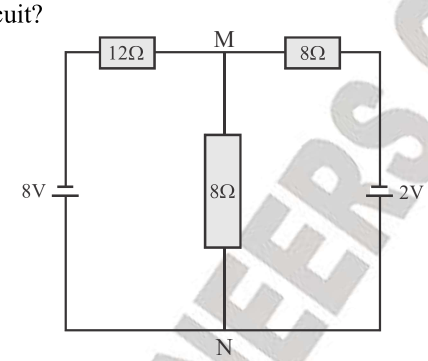
[GATE - 2016]

7. In the given circuit, each resistor has a value equal to 1Ω

ESE OBJ QUESTIONS

1. Statement I:
Two ideal current sources with currents I_1 and I_2 cannot be connected in parallel.
Statement II:
Superposition theorem cannot be applied to ideal current sources if these sources are connected in cascade.
[EC ESE - 2017]
Codes:
(a) Both Statement I and II are individually true and Statement II is the correct explanation of Statement I.
(b) Both Statement I and Statement II are individually true but Statement II is not the correct explanation of Statement I.
(c) Statement I is true but Statement II is false.
(d) Statement I is false but Statement II is true.

2. What is the current through the 8Ω resistance connected across terminals, M and N in the circuit?



[EE ESE - 2017]
(a) 0.34 A from M to N
(b) 0.29 A from M to N
(c) 0.29 A from n to M
(d) 0.34 A from N to M

3. Consider the following statements:
1. Flaming's rule is used where induced e.m.f is due to flux cutting.
2. Leng'z law is used when the induced e.m.f is due to change in flux linkages.
3. Lenz's law is direct consequence of the law of conservation of energy.
Which of the above statements are correct?
[EC ESE - 2017]
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

4. Consider the following factors:
1. Number of turns of the coil
2. Length of the coil
3. Rea of cross-section of the coil
4. permeability of the core
On which of the above factors does inductance, depend ?
[EC ESE - 2017]
(a) 1, 2 and 3 only (b) 1, 3 and 4 only
(c) 1, 2, 3, and 4 (d) 2 and 4 only

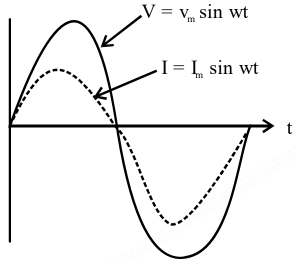
5. Consider a packet switched network based on a virtual circuit mode of switching. The delay jitter for the packets of a session from the source node to the destination node is/are
1. Always zero
2. Non-zero
3. For some networks, zero
Select the correct answer using the code given below.
[EC ESE - 2017]
(a) 1 (b) 2 only
(c) 3 only (d) 2 and 3

6. A network in which all the elements are physically separable is called a
[EC ESE - 2017]
(a) Distributed network
(b) Lumped network
(c) Passive network
(d) Reactive network

7. For the active network shown in figure, the value of V/I is

CHAPTER - 3
A.C ANALYSIS

3.1 AC THROUGH PURE OHMIC RESISTANCE ALONE



$v = V_m \sin\omega t$

$v = iR$

$i = \frac{V_m}{R}\sin\omega t$

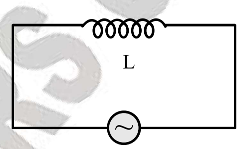
Current is max when sin wt = 1

i.e. $I_m = \frac{V_m}{R}$

$\therefore\ i = I_m \sin\omega t$

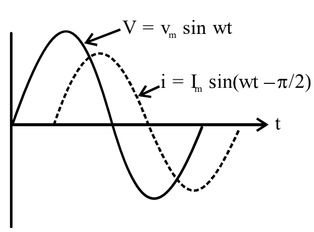
3.2 AC THROUGH PURE INDUCTANCE ALONE

Whenever an alternating voltage is applied to a purely inductive coil, a back emf is produced due to the self-inductance of the coil



$v = L\frac{di}{dt}$

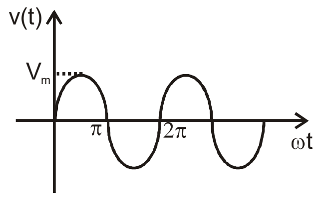
$V_m \sin\omega t = \frac{Ldi}{dt} \Rightarrow di = \frac{v_m}{L}\sin\omega t dt$



$i = \frac{V_m}{L}\int \sin\omega t dt$

WORKBOOK

Example 1. Average and RMS value of full sine wave



$$v(t) = v_m \sin\omega t$$

$$v_{av} = \frac{v_m}{2\pi}\int_0^{2\pi} v_m \sin\omega t \; d(\omega t) = 0$$

Average value of full cycle of sine and cosine is zero.

Average value for half cycle

$$v_{av} = \frac{v_m}{\pi}\int_0^{\pi} v_m \sin\omega t \; d(\omega t)$$

$$= \frac{V_m}{\pi}\left[-\cos\omega t\right]_0^{\pi} = \frac{V_m}{\pi}\left[-\cos\pi + \cos 0\right] = \frac{2V_m}{\pi}$$

RMS value

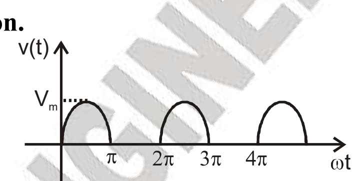
$$V_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} V_m^2 \sin^2\omega t \; d(\omega t)}$$

$$= V_m\sqrt{\frac{1}{\pi}\int_0^{\pi}\frac{1}{2}(1-\cos 2\omega t)\; d(\omega t)}$$

$$= \frac{V_m}{\sqrt{2}}$$

Example 2. Find average and RMS value of half wave rectified sine wave

Solution.



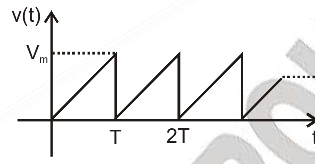
Average value

$$V_{av} = \frac{1}{2\pi}\int_0^{\pi} V_m \sin\omega t \; d(\omega t) = \frac{V_m}{\pi}$$

$$V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} V_m^2 \sin^2\omega t \; d(\omega t)} = \frac{V_m}{2}$$

Example 3. Find out average and RMS value of saw tooth wave form

Solution.



$$v(t) = \frac{V_m}{T}\times t \text{ for } 0 < t < T$$

Average value

$$V_{av} = \frac{1}{T}\int_0^{T}\frac{V_m}{T} t\, dt$$

$$= \frac{V_m}{T^2}\frac{t^2}{2}\Big|_0^T = \frac{V_m}{2}$$

RMS value $V_{rms} = \sqrt{\frac{1}{T}\int_0^T \frac{V_m^2}{T^2} t^2\, dt}$

$$= \sqrt{\frac{V_m^2}{T^3}\int_0^T t^2\, dt}$$

$$= \sqrt{\frac{V_m^2}{T^3}\frac{t^3}{3}\Big|_0^T} = \frac{V_m}{\sqrt{3}}$$

Example 4. Given $i_1(t) = 4\cos(\omega t + 30°)$ A and $i_2(t) = 5\sin(\omega t - 20°)$ A, find their sum.

Solution.

$$I_1 = 4\angle 30^\circ$$

$$i_2 = 5\cos\left(\omega t - 20^\circ - 90^\circ\right)$$

$= 5\cos\left(\omega t - 110^\circ\right)$ And its phasor is

$$I_2 = 5\angle -110^\circ$$

$$I = I_1 + I_2$$

$$= 4\angle 30^\circ + 5\angle -110^\circ$$

$$= 3.464 + 2j - 1.71 - j4.698$$

$$= 1.754 - j2.698$$

$$= 3.218\angle -56.97^\circ \text{ A}$$

Transforming this to time domain, we get

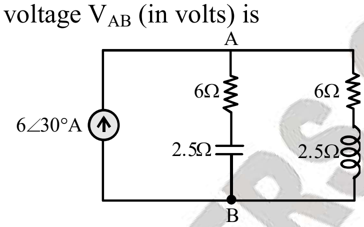
ASSIGNMENT

1. The current flowing through a circuit-containing passive elements like R, L or C is I = 15.5 sin (2500t – 145°) with voltage source V = 311 sin (2500t + 170°). The impedance Z is
(a) $20 \angle -25^{o}\ \Omega$ (b) $20 \angle 25^{o}\ \Omega$
(c) $20 + j20\Omega$ (d) $14.14 - j14.14\ \Omega$

2. There is a pure element in series with R = 25Ω which causes the current to lag the voltage by 20°. It is _____ if frequency is 400 Hz.
(a) 35 μF capacitor (b) 3.6 mH inductor
(c) 25μF capacitor (d) 2 mH inductor

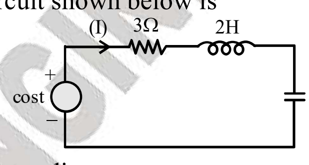
3. There is a pure element in series with R = 50Ω which causes the current to lead the voltage by 30°. It is _______ if frequency is 500 Hz.
(a) 11 μF capacitor (b) 22 μF capacitor
(c) 1.2mH (d) 2.4mH inductor

4. In the AC network shown in the figure. The phasor voltage V_{AB} (in volts) is



(a) $7 \angle 30^{o}$ (b) $6 \angle 30^{o}$
(c) $21 \angle 30^{o}$ (d) $11 \angle 30^{o}$

5. The differential equation for the current i(t) in the circuit shown below is



(a) $2\frac{d^2i}{dt^2} + 3\frac{di}{dt} + i(t) = -\sin t$

9. The value of L in the given circuit to keep power factor zero is

(b) $2\frac{d^2i}{dt^2} + 3\frac{di}{dt} + i(t) = \sin t$

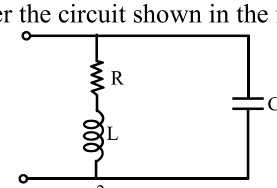
(c) $2\frac{d^2i}{dt^2} + 3\frac{di}{dt} + i(t) = \cos t$

(d) $2\frac{d^2i}{dt^2} + 3\frac{di}{dt} + i(t) = -\cos t$

Common Data for Q.6 & Q.7
Given below is the current and applied voltage in a series connection of two pure circuit elements.
V = 150 sin (314 t + 10°) volts
i = 15 sin (314 t – 53.4°) amperes

6. The circuit contains a
(a) Resistance of 5Ω and capacitor of 1μF
(b) Resistance of 4.47 Ω and inductor of 0.028 H
(c) Resistance of 6.7Ω and capacitor of 0.01 μF
(d) Resistance of 10Ω and inductor of 0.021 H

7. Consider the circuit shown in the figure

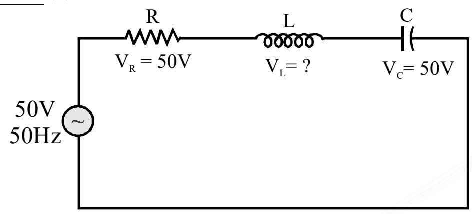


In the circuit $4R^2C = 3L$, the resonance frequency ω_0 is
(a) $\sqrt{LC}$ (b) $\frac{1}{\sqrt{LC}}$
(c) $\frac{1}{2\pi\sqrt{LC}}$ (d) $\frac{1}{2\sqrt{LC}}$

8. A voltage V is represented as V = 50 sin(ωt + 30°) – 25 sin(3ωt – 60°) + 16 sin (5ωt + 45°)V R.M.S. value of the voltage is
(a) 41 volt (b) 41.11 volt
(c) 91 volt (d) 58.14 volt

GATE QUESTIONS

1. A series R-L-C circuit is excited with a 50v, 50Hz sinusoidal source. The voltages across the resistance and the capacitance are shown in the figure. The voltage across the inductor (V_L) is _____V.

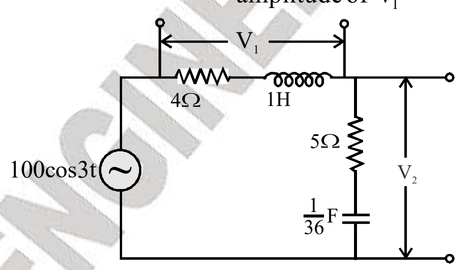


[GATE - 2017]

2. A connection is made consisting of resistance A is series with a parallel combination of resistance B and C. Three resistors of value 10Ω, 5Ω, 2Ω are provided. Consider all possible permutations of the given resistors into the positions A, B, C and identify the configuration with maximum possible overall resistance; and also the ones with minimum possible overall resistance; and also the ones with minimum possible overall resistance. The ratio of maximum to minimum values of the resistances (up to second decimal place) is ____

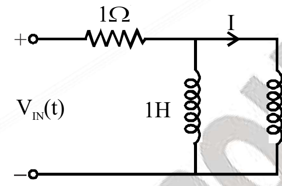
[GATE - 2017]

3. The figure shows an RLC circuit excited by the sinusoidal voltage 100cos (3t) Volts, where t is in seconds. The ratio $\frac{\text{amplitude of } V_2}{\text{amplitude of } V_1}$ is __



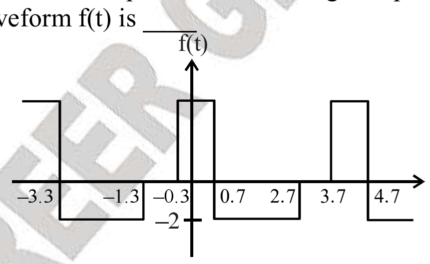
[GATE - 2017]

4. In the circuit shown, the positive angular frequency ω (in radians per second) at which the magnitude of the phase difference between the voltages V_1 and V_2 equals $\frac{\pi}{4}$ radians, is ___.



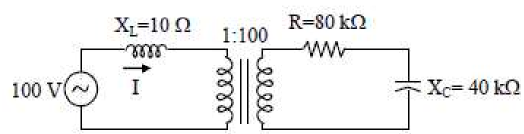
[GATE - 2017]

5. The mean square value of the given periodic waveform f(t) is ____



[GATE - 2017]

6. The following figure shows the connection of an ideal transformer with primary to secondary turns ratio of 1:100. The applied primary voltage is 100V (rms), 50 Hz, AC. The rms value of the current I, in ampere, is ________.



[GATE - 2016]

7. A resistance and a coil are connected in series and supplied from a single phase, 100 V, 50 Hz ac source as shown in the figure below. The rms values of plausible voltages across the resistance (V_R) and coil (V_C) respectively, in volts, are

ESE OBJ QUESTIONS

1. A two-element series circuit is connected across an AC source given by $e = 200\sqrt{2}\sin(314t + 20)V$. The current is then found to be $i = 10\sqrt{2}\cos(314t - 25)V$. The parameters of the circuit are

[EE ESE - 2017]

(a) R = 20 Ω and C = 160μF
(b) R = 14.14 Ω and C = 225 μF
(c) L = 45 mH and C = 225 μF
(d) L = 45 mH and C = 160 μF

2. Two resistors of 5Ω and 10Ω and an inductor L are connected in series across a 50 cos ωt voltage source. If the power consumed by the 5Ω resistor is 10W, the power factor of the circuit is

[EE ESE - 2017]

(a) 1.0 (b) 0.8
(c) 0.6 (d) 0.4

3. Statement (I): One series RC circuit and the other series RL circuit are connected in parallel across at ac supply. The circuit exhibits two reasonance when L is variable.
Statement (II): The circuit has two values of l for which the imaginary part of the input admittance of the circuit is zero.

[EE ESE - 2017]

(a)Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b)Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)
(c)Statement (I) is true but Statement (II) is false.
(d)Statement (I) is false but Statement (II) is true

4. One of the basic characteristics of any steady state sinusoidal response of a linear R-L-C circuit with constant R, L and C values is

[EC ESE - 2017]

(a)The output remains sinusoidal with its frequency being the same as that of the source
(b)The output remains sinusoidal with its frequency differing from that of the source
(c)The output amplitude equals the soruce amplitude
(d)The phase angle difference between the source and the output is always zero.

5. Three identical impedances are first connected in delta across a 3-phase balanced supply. If the same impedances are now connected in star across the same supply, then

[EC ESE - 2017]

(a)The phase current will be one – third
(b)The line current will be one – third
(c)The power consumed will be one –third
(d)The power consumed will be halved

6. A voltage v(t) = 173 sin (314t + 10°) is applied to a circuit. It causes a current flow described by

$$i(t) = 14.14 \sin(314t - 20°)$$

The average power delivered is nearly

[EC ESE - 2017]

(a) 2500 W (b) 2167 W
(c) 1500 W (d) 1060 W

7. Consider the following statements respect to a parallel R-L-C circuit:
1.The bandwidth of the circuit
2.The bandwidth of the circuit remain same if L is increased .
3.At resonance, input impedance is a real quantity.
4.At resonance, the magnitude of the input impedance attains its m inimum value.
Which of the above statements are correct?

[EC ESE - 2017]

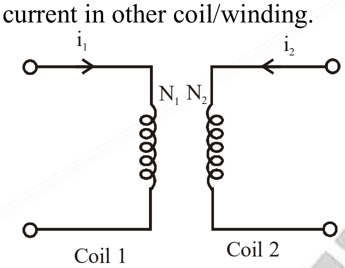
(a) 1, 2 and 4 (b) 1, 3 and 4

CHAPTER - 4
MAGNETICALLY COUPLED CIRCUIT

4.1 INTRODUCTION

When two circuits are so placed that a portion of the magnetic flux produced by one links with the turns of both, they are said to be mutually coupled magnetically. This effect is characterized by mutually inductance (M)

Mutual Inductance (M) is the property of magnetic coupling showing an induction of voltage in one coil/winding by a change of current in other coil/winding.



In the above figure two coils 1 and 2 with turns N_1 and N_2 are placed close to each other so that part of flux of one coil links with other coil too. The current i_1 in coil 1 produces flux ϕ_1. Some part of ϕ_1 links only with coil 1 let this is ϕ_{11} this is known as self flux or leakage flux of coil 1. ϕ_{12} is the flux which links with both the coils. ϕ_{12} is called mutual flux. Similarly current i_2 in coil 2 produces ϕ_2 which has ϕ_{22} and ϕ_{21} as its components. ϕ_{22} links only with coil 2 and ϕ_{21} links with both coils.

Now the voltage induced in coil 2 by change in current of coil 1 i_1

$$v_{21} = M_{21}\frac{di_1}{dt}$$

However by Faraday's Law

$$v_{21} = N_2\frac{d\phi_{12}}{dt}$$

$$\Rightarrow M_{21} = N_2\frac{d\phi_{12}}{di_1}$$

$$\Rightarrow M_{21} = N_2\frac{d\phi_{12}}{di_1}$$

If air is the medium between two coils, then magnetization is linear and

$$\frac{d\phi_{12}}{di_1} = \frac{\phi_{12}}{i_1}$$

Hence $M_{21} = \dfrac{N_2\phi_{12}}{i_1}$

Similarly $M_{12} = \dfrac{N_1\phi_{21}}{i_2}$

Since the reluctance of both the fluxes i.e. ϕ_{12} & ϕ_{21} is same M_{12} & M_{21} are equal say $M_{12} = M_{21} = M$.

WORKBOOK

Example 1. The number of turns in two coupled coils are 600 and 1200 respectively. When a current of 4A flows in coil 1, the total flux in this coil is 0.5m Wb and the flux linking coil 2 is 0.4m Wb. Determine L_1, L_2, M and k.

Solution.

$$L_1 = \frac{\phi_1 N_1}{I_1} = \frac{0.5\times10^{-3}\times600}{4} = 0.075H$$

Since the self inductance is direction proportional to the square of the number of turns $L \propto N^2$ and

$$\frac{L_1}{L_2} = \frac{N_1^2}{N_2^2}$$

$$L_2 = \left(\frac{N_2}{N_1}\right)^2 \times L_1$$

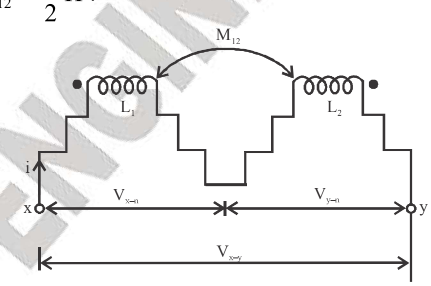
$$= \left(\frac{1200}{600}\right)^2 \times 0.075 = 0.3H$$

$$M = \frac{N_2\phi_{12}}{L_1} = \frac{1200\times0.4\times10^{-3}}{4} = 0.12H$$

$$k = \frac{\phi_{12}}{\phi_1} = \frac{0.4}{0.5} = 0.8$$

Alternatively, $k = \dfrac{M}{\sqrt{L_1L_2}} = \dfrac{0.12}{\sqrt{0.075\times0.3}} = 0.8$

Example 2. With reference to fig. Find $\nu_{x\text{-}y}$, if $\dfrac{di}{dt} = 300A/sec$. Assume L_1 = L_2 = 1H and $M_{12} = \dfrac{1}{2}H$.



Solution.

Applying KVL in the respective loops,

$$v_{x-n} = L_1\frac{di}{dt} - M_{12}\frac{di}{dt}$$

[As the coils are electrically in series, hence, the same current I passes through the coils; M is negative]

Or $v_{x-n} = \dfrac{di}{dt} - 0.5\dfrac{di}{dt} = 0.5\dfrac{di}{dt}$ … (i)

Similarly, $v_{y-n} = L_2\dfrac{di}{dt} - M_{12}\dfrac{di}{dt}$

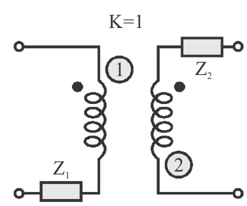
$= 1.\dfrac{di}{dt} - 0.5\dfrac{di}{dt} = 0.5\dfrac{d}{dt}$ … (ii)

$$\therefore\ \nu_{x-y} = \nu_{x-n} + \nu_{y-n}$$

$$= 0.5\frac{di}{dt} + 0.5\frac{di}{dt} = \frac{di}{dt}$$

i.e., $|\nu_{x-y}| = 300V$

Example 3. Two impedances Z_1 and Z_2 are connected in series with the primary and secondary winding of an ideal transformer where the primary coil has J2Ω and the secondary coil has j3Ω reactance. Find the mutual reactance and inductance if ω = 100 rad/sec.



Solution.

In ideal transformer , K = 1

$$\therefore\ M = \sqrt{L_1L_2}$$

i..e, $X_M = \sqrt{X_1X_2}$

X_1 is reactance of primary coil

X_2 is reactance of secondary coil

X_M is mutual reactance

i.e. $X_M = \sqrt{j2\times j3} = j2.45\Omega$

but X = 2πfL

CHAPTER - 5
NETWORK THEOREMS

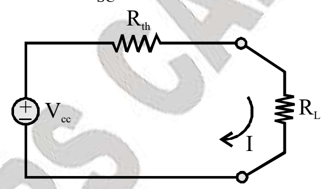
5.1 THEVENIN'S THEORM
Any two terminal bilateral linear circuit can be replaced by an equivalent circuit consisting of a voltage source and a series resistor.

5.1.1 Steps for Solving a Network using Thevenin's Theorem
1. Remove the load resistor (R_L) and find the open circuit voltage (V_{oc}) across the open circuited load terminals.
2. Find the Thevenin's resistance (R_{TH})

1. If Circuit contains only Independent Sources
Deactivate the constant sources (for voltage source remove it by short circuit and for the current source remove it by open circuit) and find the internal resistance (R_{TH}) of the source side looking through the open circuited load terminals.

2. For the circuits containing dependent sources in addition to or in absence of independent sources
Find V_{OC} by open circuiting the load terminals. Then short the load terminals and find the short circuit current (I_{SC}) through the shorted terminals.

Thevenin's resistance is given as: $R_{TH} = \frac{V_{OC}}{I_{SC}}$



(i) Obtain thevenin's equivalent circuit by placing R_{TH} in series with V_{OC}
(ii) Reconnect R_L across the load terminals.

5.1.2 Thevenin's Equivalent Network
$$I(\text{Load current}) = \frac{V_{OC}}{R_{TH} + R_L}$$

If only dependent sources are present in circuit, $R_{Th} = \frac{V_{test}}{1_{test}}; I_{test} = 1A$

V_{test} is calculated across the load by short circuiting it, and current of 1A flows through the short circuited branch as I_{test}. Then $R_{TH} = V_{test}$

Dividing equation (ii) by equation (i)

$$3 = \sqrt{\frac{624 + C_S}{60.4 + C_S}}$$

$\Rightarrow \quad 543.6 + 9C_S = 624 + C_S$

$\Rightarrow \quad 8C_S = 80.4$

$\Rightarrow \quad C_S = 10.05 \text{ pF}$

Sol. 9. (a)

In an L-C function,

(i) Poles and zeros are alternate on $j\omega$ axis.

(ii) There is either a pole or a zero at origin and infinity.

(iii) The highest and lowest powers of s in numerator and denomenator can differ at the most by 1.

CHAPTER - 7

LAPLACE TRANSFORMATION AND ITS APPLICATION IN CIRCUIT ANALYSIS

7.1 LAPLACE TRANSFORMATION

The Laplace transformation of a function $f(t)$ is defined as

$$F(s) = Lf(t) = \int_0^{\infty} f(t)e^{-st}dt$$

Where as in complex frequency
s being the intermediate or transformation variable.

7.1.1 Laplace Transform of a Derivative $\left[\frac{df(t)}{dt}\right]$

$$Lf'(t) = sF(s) - f(0+)$$

7.1.2 Laplace Transform of an Integral $\int f(t)dt$

$$L\left(\int f(t)dt\right) = \frac{1}{s}\int f(t)dt \Big|_{0+} + \frac{1}{s}F(s)$$

$$\left[\int f(t)\Big|_{0+} \text{ gives the value of the integral at } t = 0+\right]$$

7.1.3 Frequency Shifting

$$L\left(e^{at}f(t)\right) = F(s-a)$$

$$L\left(e^{-at}f(t)\right) = F(s+a)$$

7.2 LAPLACE TRANSFORM OF COMMON FORCING FUNCTIONS

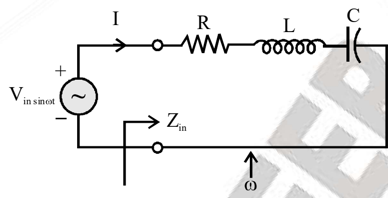
$f(t)$	F(s)	$f(t)$	F(s)
u(t)	$\frac{1}{s}$	$e^{-\alpha t}t^n$	$\frac{\lfloor n}{(s+\alpha)^{n+1}}$
$e^{-\alpha t}$	$\frac{1}{s+\alpha}$	$e^{-\alpha t}\sin\omega t$	$\frac{\omega}{(s+\alpha)^2+\omega^2}$
$\sin\omega t$	$\frac{\omega}{s^2+\omega^2}$	$e^{-\alpha t}\cos\omega t$	$\frac{s+a}{(s+\alpha)^2+\omega^2}$
$\cos\omega t$	$\frac{\omega}{s^2+\omega^2}$	$\delta(t)$	1
t	$\frac{1}{s^2}$	Sinh θt	$\frac{\theta}{s^2-\theta^2}$

CHAPTER - 8
RESONANCE

8.1 RESONANCE

Resonance in electrical circuits consisting of passive and active elements represents a particular state of the circuit when the current or voltage in the circuit is maximum or minimum with respect to the magnitude of excitation at a particular frequency, the circuit impedance being either minimum of maximum at the power factor unity.
The phenomenon of resonance is observed in both series or parallel a.c. circuits comprising of R, L and C and excited by an a.c. source.

8.2 SERIES RESONANCE

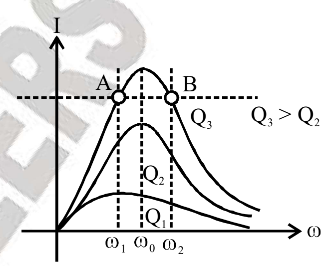


$$Z_{in} = \frac{V}{I} = R + j(\omega L - \frac{1}{\omega c})$$

For resonance V & I must be in same phase
So for some frequency $\omega = \omega_0$

$$Z_{in} = R + j_0 \Rightarrow \omega_0 L - \frac{1}{\omega_0 C} = 0 \Rightarrow \omega_0 = \frac{1}{\sqrt{LC}}$$

$$I = \frac{V}{|z|} = \frac{V}{\sqrt{R^2 + (\omega L - 1/\omega c)^2}} \quad \text{at } \omega_0,\ I = \frac{V}{R}$$



Points A & B are half power or 3dB points because $20\log_{10}\left(\frac{1}{2}\right)$ = 3dB

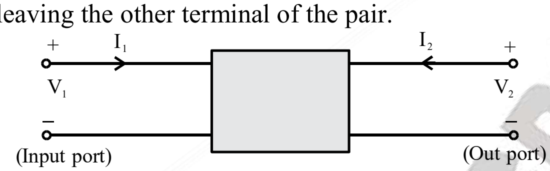
Band width of circuit $\Delta\omega$ = BW = $\omega_2 - \omega_1$
Quality factor

$$Q_0 = 2\pi\left[\frac{\text{Max energy stored}}{\text{Total energy last per perior}}\right]$$

$$Q_0 = 2\pi\left[\frac{\omega_L + \omega_C}{P_R T}\right]$$

CHAPTER - 9
TWO PORT NETWORKS

9.1 INTRODUCTION
The terminal pair is called as a ″port″. If the current entering one terminal of a pair is equal and opposite to the current leaving the other terminal of the pair.



9.2 TWO-PORT NETWORK
A two-port network is shown, by which we observe that a two-port network is represented by a black box with four variables, namely, two voltages (V_1, V_2) and two currents (I_1, I_2) which are available for measurements and are relevant for the analysis of two port networks. Of these four variables which two variable may be considered `independent` and which two `dependent` is generally decided by the probable under consideration

Two Port Parameters			
Name	**Express**	**In terms of**	**Matrix Equation**
Open circuit impedance [Z]	V_1, V_2	I_1, I_2	$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$
Short-circuit admittance [Y]	I_1, I_2	V_1, V_2	$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$
Transmission or Chain [T] or [ABCD]	V_1, I_2	V_2, I_2	$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$
Inverse Transmission [T’]	V_2, I_2	$V_1, -I_1$	$\begin{bmatrix} V_2 \\ I_2 \end{bmatrix} = \begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} \begin{bmatrix} V_1 \\ -I_1 \end{bmatrix}$
Hybrid (h)	V_1, I_2	I_1, V_2	$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$
Inverse hybrid (g)	I_1, V_2	V_1, I_2	$\begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} g_{11} & h_{12} \\ g_{21} & h_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}$

9.3 OPEN CIRCUIT IMPEDANCE (Z) PARAMETERS
Expressing two-port voltages in terms of two-port currents

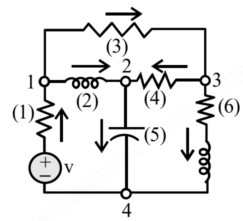
$$(V_1, V_2) = f(I_1, I_2)$$

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} \text{ or } [V] = [Z][I]$$

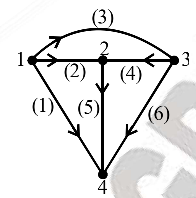
CHAPTER - 10
GRAPH THEORY

10.1 IMPORTANT DEFINITIONS

1. Graph: It is the collection of nodes and Branch of a network.



(A)



(B)

2. Branch: Each oriented line segment of the graph is called branch.

3. Node: The end point of a branch is called node.

4. Incident Branch: Branch whose end fall on a node is called incident branch.

5. Connected and Non-Connected Graph
If there exists a path between every pair of nodes of a graph, then the graph is called connected graph, otherwise graph is called non-connected graph.

6. Degree of Node: Degree of Node is the number of branches incident on the node.

7. Subgraph: A portion of graph is called subgraph

8. Path: Path is transverse from one node to another node

9. Loop: Loop is a collection of branches in a graph which form a closed path.

10. Tree: The collection of minimum no. of branches connecting all the nodes of a graph without making a loop.
A single graph can have many no. of trees.
The no. of trees for a given graph= n – 1
where $n \rightarrow$ no. of nodes

11. Twig: Branch of a tree is called a twig.

12. Cotree: Remaining part of a graph after removal of twigs is called cotree. It is collection of links.

13. Links: are the branches removed from the graph to make a tree.
Total no. of branch of a graph are given by $b = (n-1) + L$
n is no. of nodes
L is No. of links
No. of twigs = (n – 1) = no. of KCL equation

CHAPTER - 11
NETWORK FUNCTIONS

11.1 INTRODUCTION
The basic definition of one port and two port network being discussed earlier, here we will discuss about the transform of excitation and response along with their relations. A network function exhibits the relationship between the transform of the source or excitation to the transform of the response for a electrical network. Further to this, we will discuss the stability of the network function mathematically formulating the network function mathematically formulating the network function through "pole-zero" concept.

11.2 DRIVING POINT IMPEDANCE AND ADMITTANCE
The driving point impedance of a one port network is defined as

$$Z(s) = \frac{V(s)}{I(s)} \qquad \ldots \text{(i)}$$

While the driving point admittance is given as

$$Y(s) = \frac{I(s)}{V(s)} \qquad \ldots \text{(ii)}$$

For the one port network
Similarly, for the two port network, the driving point impedance and admittance at port 1 is defined as

$$Z_{11}(s) = \frac{V_1(s)}{I_1(s)} \qquad \ldots\text{(iii)}$$

and $Y_{11}(s) = \dfrac{I_1(s)}{V_1(s)}$ … (iv)

While the driving point impedance and admittance at the port 2 are designated as

$$Z_{22}(s) = \frac{V_2(s)}{I_2(s)} \qquad \ldots\text{(iv(a))}$$

and $Y_{22}(s) = \dfrac{I_2(s)}{V_2(s)}$ … (v)

11.3 TRANSFER IMPEDANCE AND ADMITTANCE
Transfer impedance is defined as the ratio of transform voltage at output port to the transformed current at the input port of a two port network.

This gives, $Z_{12}(s) = \dfrac{V_2(s)}{I_1(s)}$ … (vi)

In a similar way, the transfer admittance is defined as the ratio of current transform at output port to the voltage transform at the input port. It is given as

$$Y_{12}(s) = \frac{I_2(s)}{V_1(s)} \qquad \ldots\text{(vii)}$$