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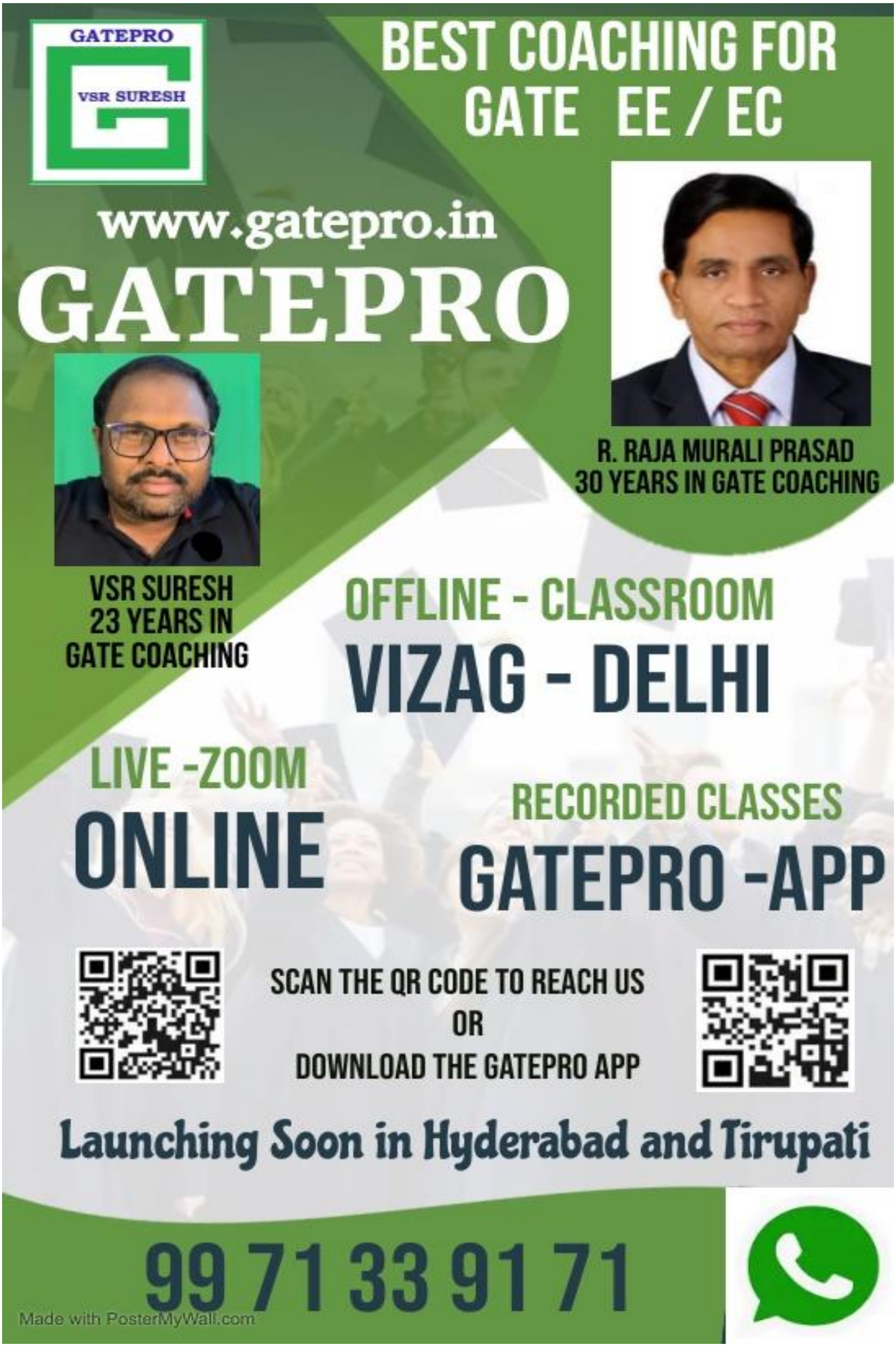
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Electronics and Communications Engg

NETWORK THEORY

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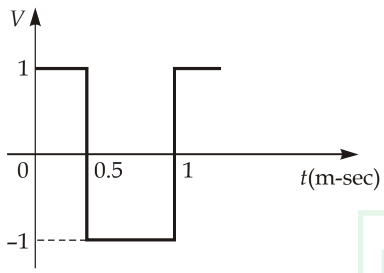
1 Basics of Network Analysis

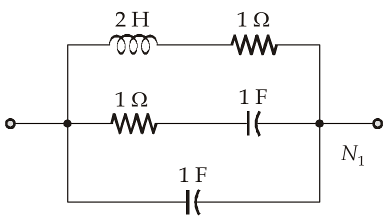
ELECTRONICS ENGINEERING
(GATE Previous Years Solved Papers)

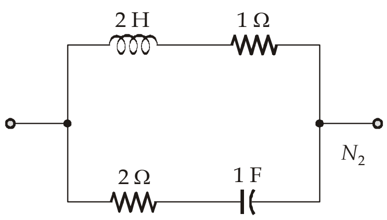
Q.1 A square waveform as shown in figure is applied across 1 mH ideal inductor. The current through the inductor is a ______ wave of ______ peak amplitude.

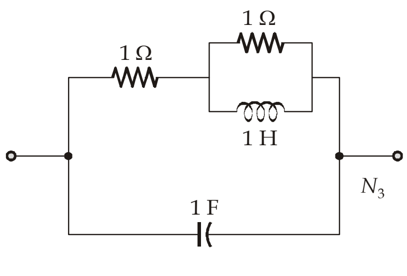


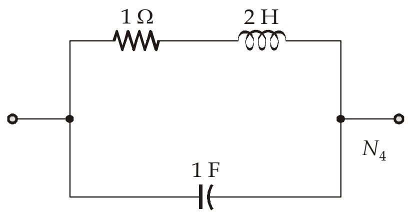
[EC-1987 : 2 Marks]

Q.2 Of the networks, N_1, N_2, N_3 and N_4 of figure, the networks having identical driving point function are









(a) N_1 and N_2 (b) N_2 and N_4
(c) N_1 and N_3 (d) N_1 and N_4

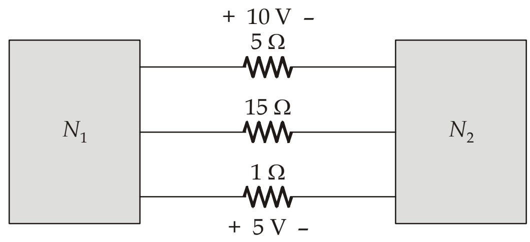
[EC-1992 : 2 Marks]

Q.3 A network contains linear resistors and ideal voltage sources. If values of all the resistors are doubled, then the voltage across each resistor is

(a) halved
(b) doubled
(c) increased by four times
(d) not changed

[EC-1993 : 2 Marks]

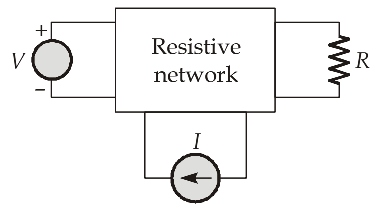
Q.4 The two electrical sub-networks N_1 and N_2 are connected through three resistors as shown in figure. The voltage across 5 Ω resistor and 1 Ω resistor are given to be 10 V and 5 V, respectively. Then voltage across 15 Ω resistor is



(a) –105 V (b) +105 V
(c) –15 V (d) +15 V

[EC-1993 : 2 Marks]

Q.5 A dc circuit shown in figure has a voltage source V, a current source I and several resistors. A particular resistor R dissipates a power of 4 Watts when V alone is active. The same resistor R dissipates a power of 9 Watts when I alone is active. The power dissipated by R when both sources are active will be



(a) 1 W (b) 5 W
(c) 13 W (d) 25 W

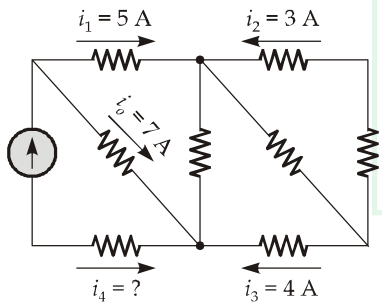
[EC-1993 : 1 Mark]

Q.6 Two 2 H inductance coils are connected in series and are also magnetically coupled to each other the coefficient of coupling being 0.1. The total inductance of the combination can be

(a) 0.4 H (b) 3.2 H
(c) 4.0 H (d) 4.4 H

[EC-1995 : 1 Mark]

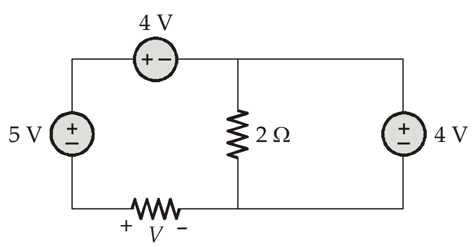
Q.7 The current i_4 in the circuit of figure is equal to



(a) 12 A (b) –12 A
(c) 4 A (d) None of these

[EC-1997 : 1 Mark]

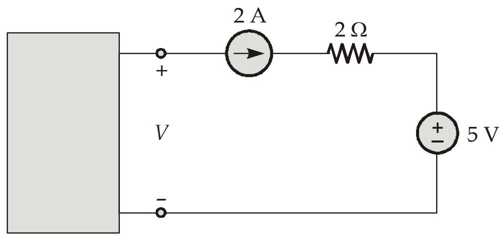
Q.8 The voltage V in figure is equal to



(a) 3 V (b) –3 V
(c) 5 V (d) None of these

[EC-1997 : 1 Mark]

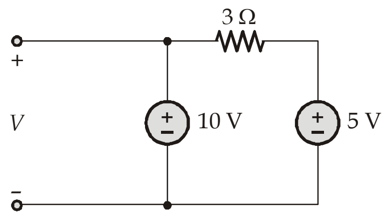
Q.9 The voltage V in figure is always equal to



(a) 9 V (b) 5 V
(c) 1 V (d) None of these

[EC-1997 : 1 Mark]

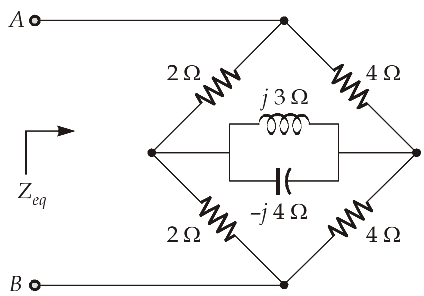
Q.10 The voltage V in figure is



(a) 10 V (b) 15 V
(c) 5 V (d) None of these

[EC-1997 : 1 Mark]

Q.11 In the circuit of figure the equivalent impedance seen across terminals A, B is

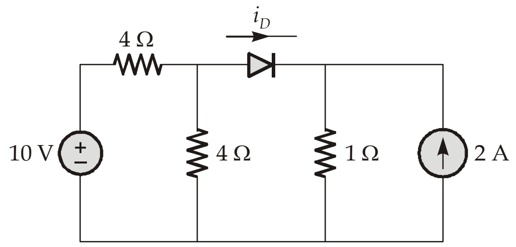


(a) $\left(\frac{16}{3}\right)\Omega$ (b) $\left(\frac{8}{3}\right)\Omega$

(c) $\left(\frac{8}{3}+12j\right)\Omega$ (d) None of the above

[EC-1997 : 2 Marks]

Q12 In the circuit shown in the figure the current i_D through the ideal diode (zero cut in voltage and zero forward resistance) equals



(a) 0 A (b) 4 A

(c) 1 A (d) None of these

[EC-1997 : 3 Marks]

Q.13 The nodal method of circuit analysis is based on

(a) KVL and Ohm's law

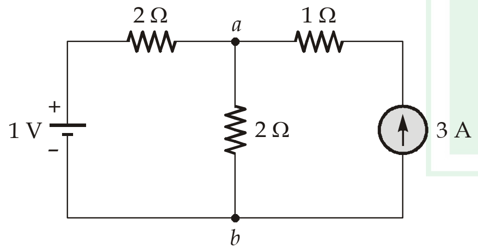
(b) KCL and Ohm's law

(c) KCL and KVL

(d) KCL, KVL and Ohm's law

[EC-1998 : 1 Mark]

Q.14 The voltage across the terminals '*a*' and '*b*' in figure is

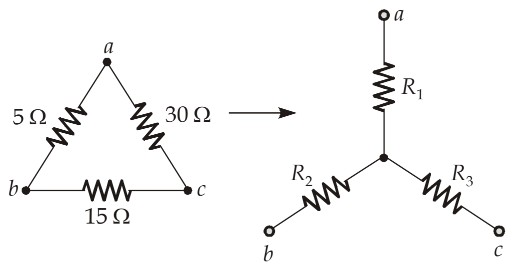


(a) 0.5 V (b) 3.0 V

(c) 3.5 V (d) 4.0 V

[EC-1998 : 1 Mark]

Q.15 A Delta-connected network with its Wye-equivalent is shown in figure. The resistance R_1, R_2 and R_3 (in Ω) are respectively

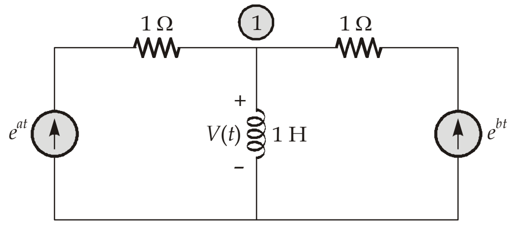


(a) 1, 5, 3 and 9 (b) 3, 9 and 1.5

(c) 9, 3 and 1.5 (d) 3, 1.5 and 9

[EC-1999 : 2 Marks]

Q.16 In the circuit of the figure, the voltage $v(t)$ is

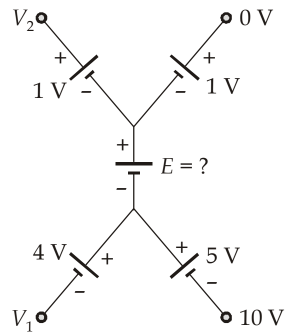


(a) $e^{at} - e^{bt}$ (b) $e^{at} + e^{bt}$

(c) $ae^{at} - be^{bt}$ (d) $ae^{at} + be^{bt}$

[EC-2000 : 1 Mark]

Q.17 In the circuit of the figure, the value of the voltage source *E* is

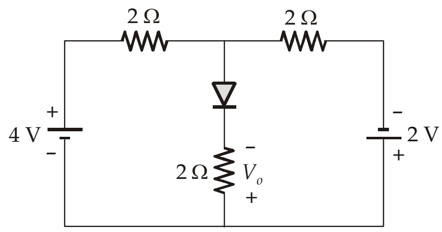


(a) –16 V (b) 4 V

(c) –6 V (d) 16 V

[EC-2000 : 1 Mark]

Q.18 For the circuit in the figure, the voltage V_o is

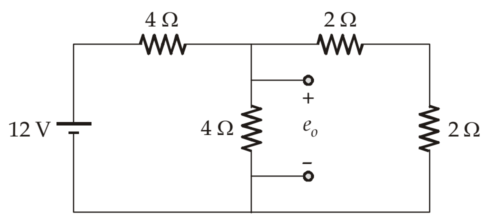


(a) 2 V (b) 1 V

(c) –1 V (d) None of these

[EC-2000 : 2 Marks]

Q.19 The voltage e_o in the figure is



(a) 2 V (b) $\frac{4}{3}$ V

(c) 4 V (d) 8 V

[EC-2000 : 1 Mark]

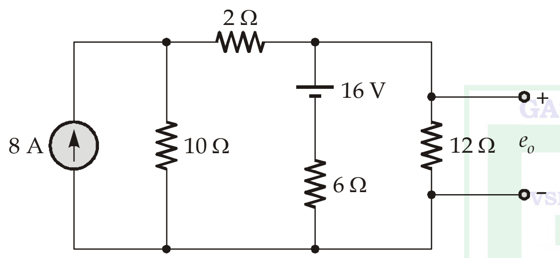
Q.20 If each branch of a delta circuit has impedance $\sqrt{3}Z$, then each branch of the equivalent Wye circuit has impedance.

(a) $\frac{Z}{\sqrt{3}}$ (b) 3Z

(c) $3\sqrt{3}Z$ (d) $\frac{Z}{3}$

[EC-2000 : 1 Mark]

Q.21 The voltage e_o in the figure is

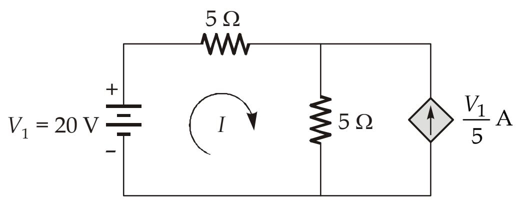


(a) 48 V (b) 24 V

(c) 36 V (d) 28 V

[EC-2001 : 2 Marks]

Q.22 The dependent current source shown in the figure,



(a) delivers 80 W

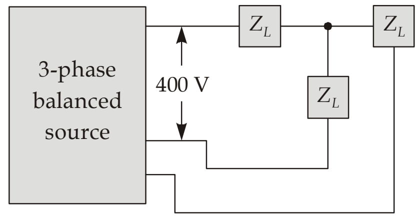
(b) absorbs 80 W

(c) delivers 40 W

(d) absorbs 40 W

[EC-2002 : 1 Mark]

Q.23 If the three-phase balanced source in the figure delivers 1500 W at a leading power factor 0.844, then the value of Z_L (in ohm) is approximately

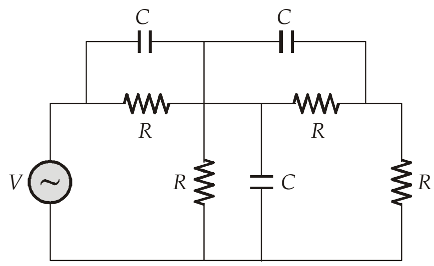


(a) 90∠32.44° (b) 80∠32.44°

(c) 80∠–32.44° (d) 90∠–32.44°

[EC-2002 : 2 Marks]

Q.24 The minimum number of equations required to analyze the circuit shown in the figure is



(a) 3 (b) 4

(c) 6 (d) 7

[EC-2003 : 1 Mark]

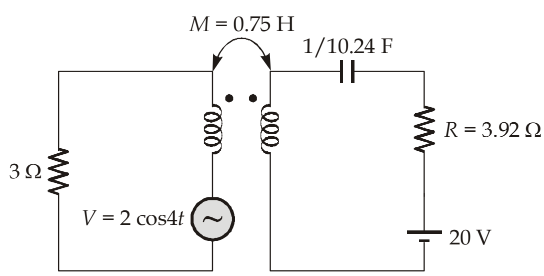
Q.25 Twelve 1 Ω resistances are used as edges to form a cube. The resistance between two diagonally opposite corners of the cube is

(a) $\frac{5}{6}$ Ω (b) 1 Ω

(c) $\frac{6}{5}$ Ω (d) $\frac{3}{2}$ Ω

[EC-2003 : 2 Marks]

Q.26 The current flowing through the resistance R in the circuit in the figure has the form P cos4t, where P is



(a) (0.18 + j0.72) (b) (0.46 + j1.90)

(c) –(0.18 + j1.90) (d) –(0.192 + j0.144)

[EC-2003 : 2 Marks]

Q.27 An ideal sawtooth voltage waveform of frequency 500 Hz and amplitude 3 V is generated by charging a capacitor of 2 μF in every cycle.

The charging requires

(a) constant voltage source of 3 V for 1 ms.

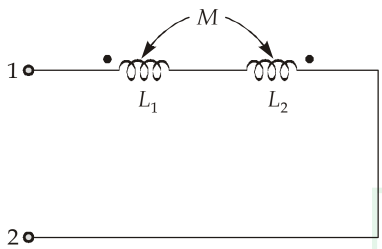
(b) constant voltage source of 3 V for 2 ms.

(c) constant current source of 3 mA for 1 ms.

(d) constant current source of 3 mA for 2 ms.

[EC-2003 : 2 Marks]

Q.28 The equivalent inductance measured between the terminals 1 and 2 for the circuit shown in the figure is

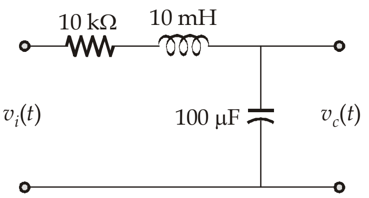


(a) $L_1 + L_2 + M$ (b) $L_1 + L_2 - M$

(c) $L_1 + L_2 + 2M$ (d) $L_1 + L_2 - 2M$

[EC-2004 : 1 Mark]

Q.29 For the circuit in the figure, the initial conditions are zero. Its transfer function $H(s) = \frac{V_c(s)}{V_i(s)}$ is,



(a) $\frac{1}{s^2 + 10^6 s + 10^6}$

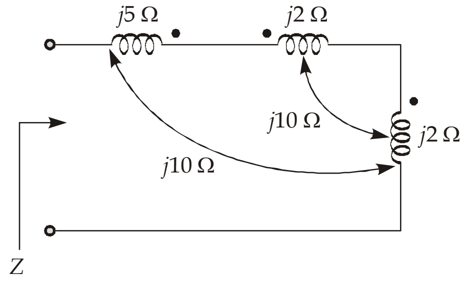
(b) $\frac{10^6}{s^2 + 10^3 s + 10^6}$

(c) $\frac{10^3}{s^2 + 10^3 s + 10^6}$

(d) $\frac{10^6}{s^2 + 10^6 s + 10^6}$

[EC-2004 : 2 Marks]

Q.30 Impedance Z as shown in the given figure is

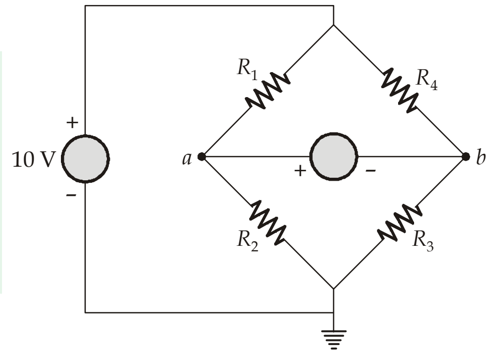


(a) $j29\ \Omega$ (b) $j9\ \Omega$

(c) $j19\ \Omega$ (d) $j39\ \Omega$

[EC-2005 : 2 Marks]

Q.31 If $R_1 = R_2 = R_4 = R$ and $R_3 = 1.1\ R$ in the bridge circuit shown in the figure, then the reading in the ideal voltmeter connected between 'a' and 'b' is

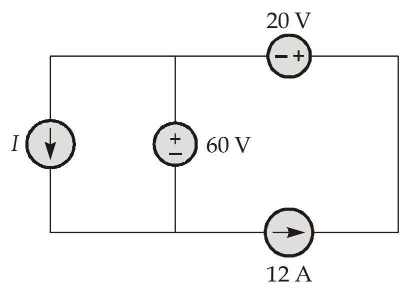


(a) 0.238 V (b) 0.138 V

(c) –0.238 V (d) 1 V

[EC-2005 : 2 Marks]

Q.32 In the interconnection of ideal sources shown in the figure, it is known that the 60 V source is absorbing power.

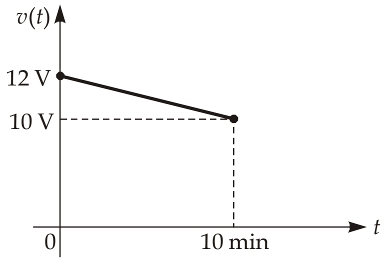


Which of the following can be the value of the current source I?

(a) 10 A (b) 13 A
(c) 15 A (d) 18 A

[EC-2009 : 1 Mark]

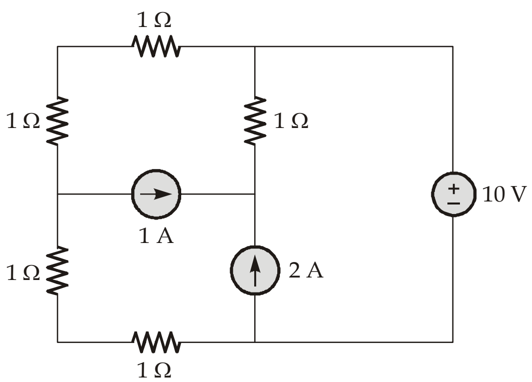
Q.33 A fully charged mobile phone with a 12 V battery is good for a 10 minute talk-time. Assume that, during the talk-time the battery delivers a constant current of 2 A and its voltage drops linearly from 12 V to 10 V as shown in the figure. How much energy does the battery deliver during this talk-time?



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

[EC-2009 : 1 Mark]

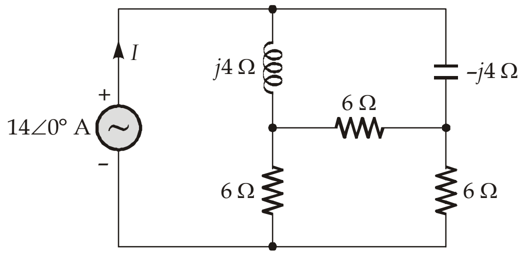
Q.34 In the circuit shown, the power supplied by the voltage source is



(a) 0 W (b) 5 W
(c) 10 W (d) 100 W

[EC-2010 : 2 Marks]

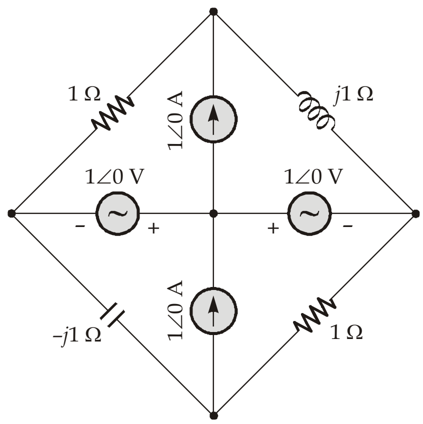
Q.35 In the circuit shown below, the current I is equal to



(a) 1.4∠0° A (b) 2.0∠0° A
(c) 2.8∠0° A (d) 3.2∠0° A

[EC-2011 : 2 Marks]

Q.36 In the circuit shown below, the current through the inductor is



(a) $\frac{2}{1+j}$ A (b) $\frac{-1}{1+j}$ A

(c) $\frac{1}{1+j}$ A (d) 0 A

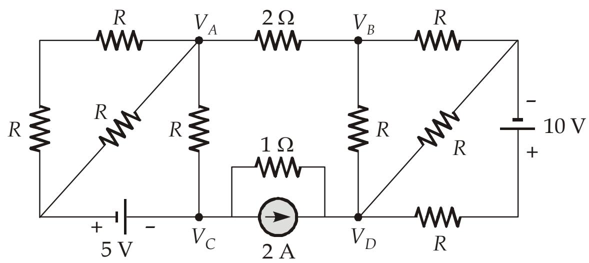
[EC-2012 : 1 Mark]

Q.37 The average power delivered to an impedance (4 – j3) Ω by a current 5 cos(100πt + 100) A is

(a) 44.2 W (b) 50 W
(c) 62.5 W (d) 125 W

[EC-2012 : 1 Mark]

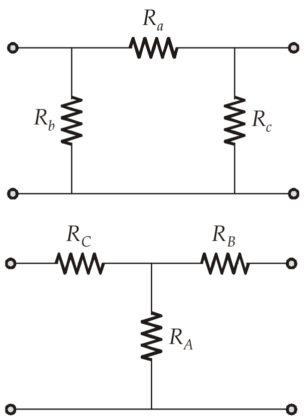
Q.38 If $V_A - V_B = 6$ V, then $V_C - V_D$ is



(a) –5 V (b) 2 V
(c) 3 V (d) 6 V

[EC-2012 : 2 Marks]

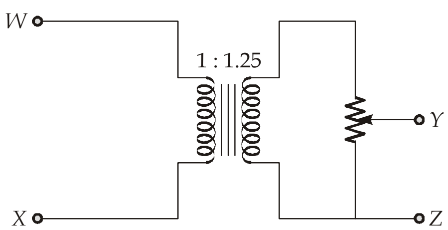
Q.39 Consider a delta-connection of resistors and its equivalent star-connection as shown below. If all elements of the delta-connection are scaled by a factor k, $k > 0$, the elements of the corresponding star equivalent will be scaled by a factor of



(a) k^2 (b) k
(c) $1/k$ (d) $\sqrt{k}$

[EC-2013 : 1 Mark]

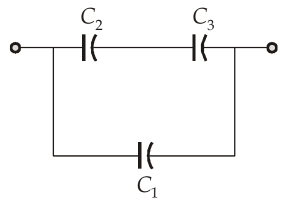
Q.40 The following arrangement consists of an ideal transformer and an attenuator which attenuates by a factor of 0.8. An ac voltage $V_{WX_1} = 100$ V is applied across WX to get an open-circuit voltage V_{YZ_1} across YZ. Next, an ac voltage $V_{YZ_2} = 100$ V is applied across YZ to get an open-circuit voltage V_{WX_2} across WX. Then, V_{YZ_1}/V_{WX_1}, V_{WX_2}/V_{YZ_2} are respectively,



(a) $\frac{125}{100}$ and $\frac{80}{100}$ (b) $\frac{100}{100}$ and $\frac{80}{100}$
(c) $\frac{100}{100}$ and $\frac{100}{100}$ (b) $\frac{80}{100}$ and $\frac{80}{100}$

[EC-2013 : 2 Marks]

Q.41 Three capacitors C_1, C_2 and C_3 whose values are 10 μF, 5 μF and 2 μF respectively, have breakdown voltages of 10 V, 5 V and 2 V respectively. For the interconnection shown below, the maximum safe voltage in volts that can be applied across the combination, and the corresponding total charge in μC stored in the effective capacitance across the terminals are, respectively

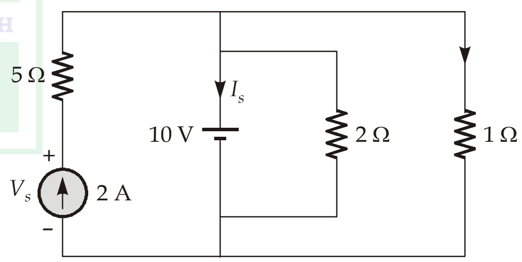


(a) 2.8 and 36 (b) 7 and 119
(c) 2.8 and 32 (d) 7 and 80

[EC-2013 : 2 Marks]

Common Data for Questions (42 and 43):

Consider the following figure:



Q.42 The current Is in amperes in the voltage source, and voltage V_s in volts across the current source respectively, are

(a) 13, –20 (b) 8, –10
(c) –8, 20 (d) –13, 20

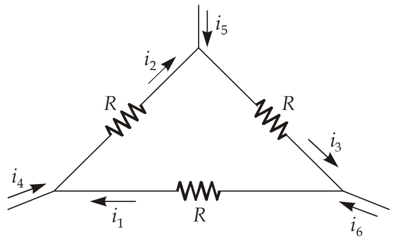
[EC-2013 : 2 Marks]

Q.43 The current in the 1 Ω resistor in amperes is

(a) 2 (b) 3.33
(c) 10 (d) 12

[EC-2013 : 2 Marks]

Q.44 Consider the configuration shown in the figure which is a portion of a larger electrical network.



For $R = 1\ \Omega$ and currents $i_1 = 2$ A, $i_4 = -1$ A, $i_5 = -4$ A, which one of the following is true?

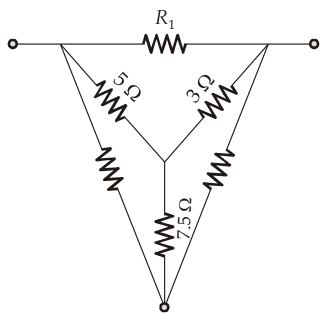
(a) $i_6 = 5$ A
(b) $i_3 = -4$ A
(c) data is sufficient to conclude that the supposed currents are impossible
(d) data is insufficient to identify the currents i_2, i_3 and i_6

[EC-2014 : 1 Mark]

Q.45 A Y-network has resistance of 10 Ω each in two of its arms, while the third arms has a resistance of 11 Ω in the equivalent Δ-network, the lowest value (in Ω) among the three resistances is __ .

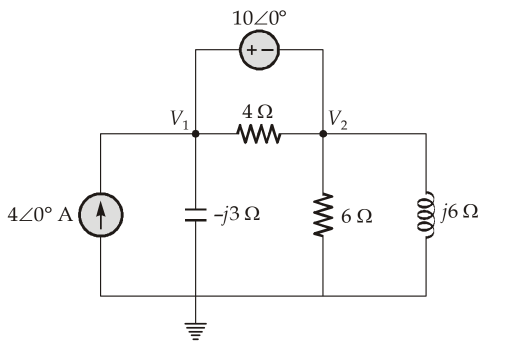
[EC-2014 : 2 Marks]

Q.46 For the Y-network shown in the figure, the value of R_1 (in Ω) in the equivalent Δ-network is ___ .



[EC-2014 : 2 Marks]

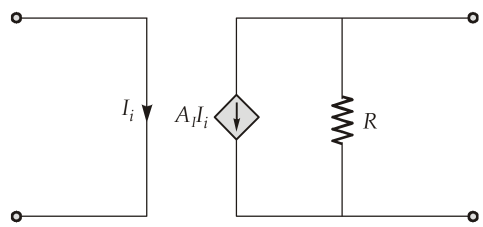
Q.47 In the circuit shown in the figure, the value of node voltage V_2 is



(a) $22 + j2$ V (b) $2 + j22$ V
(c) $22 - j2$ V (d) $2 - j22$ V

[EC-2014 : 2 Marks]

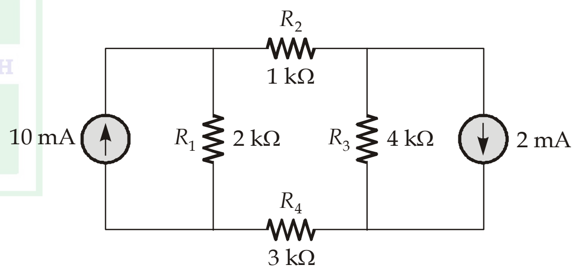
Q.48 The circuit shown in the figure represents a



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

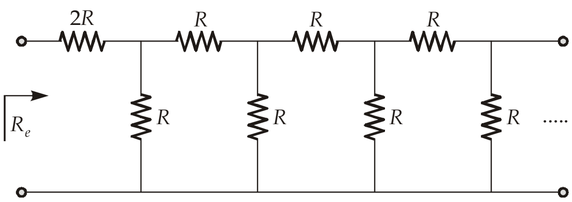
[EC-2014 : 1 Mark]

Q.49 The magnitude of current (in mA) through the resistor R_2 in the figure shown is _____ .



[EC-2014 : 1 Mark]

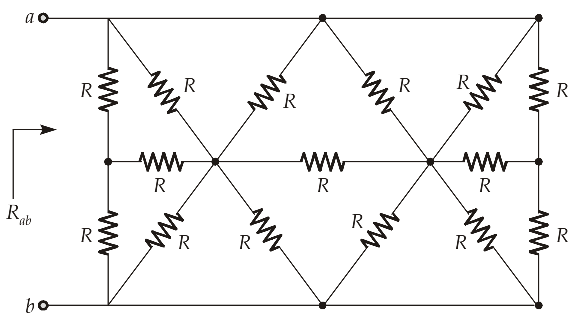
Q.50 The equivalent resistance in the infinite ladder network shown in the figure, is R_e.



The value R_e/R is ______ .

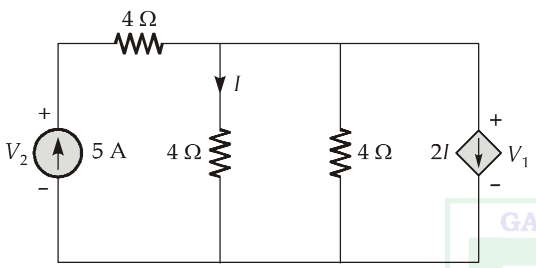
[EC-2014 : 2 Marks]

Q.51 In the network shown in the figure, all resistors are identical with $R = 300\ \Omega$. The resistance R_{ab} (in Ω) of the network is _____ .



[EC-2015 : 1 Mark]

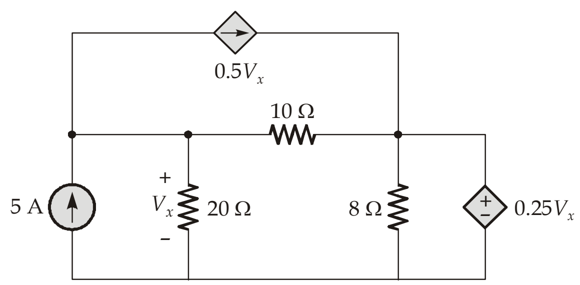
Q.52 In the given circuit, the values of V_1 and V_2 respectively are



(a) 5 V, 25 V (b) 10 V, 30 V
(c) 15 V, 35 V (d) 0 V, 20 V

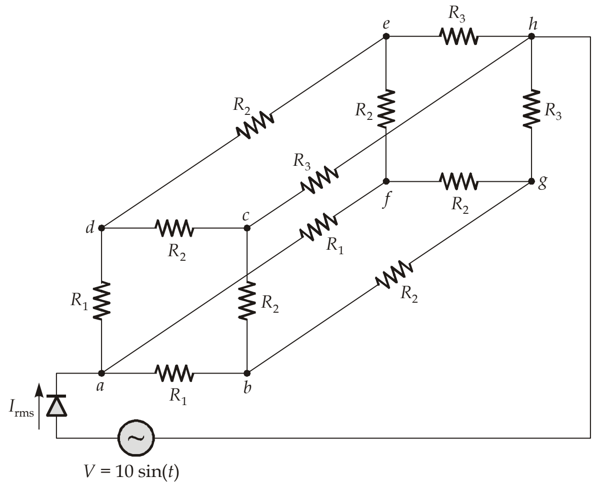
[EC-2015 : 1 Mark]

Q.53 In the circuit shown, the voltage V_x (in Volts) is ______ .



[EC-2015 : 1 Mark]

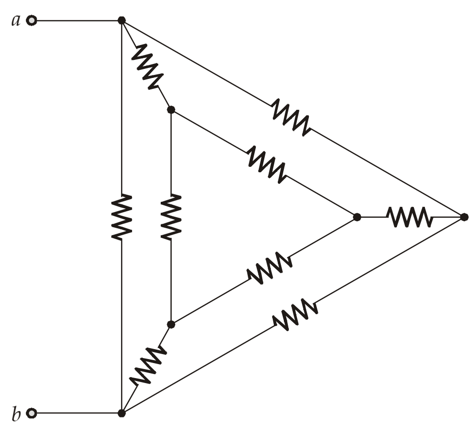
Q.54 An AC voltage source V = 10 sin(t) Volts is applied to the following network. Assume that, R_1 = 3 kΩ, R_2 = 6 kΩ and R_3 = 9 kΩ, and that the diode is ideal.



Rms current I_{rms} (in mA) through the diode is ______ .

[EC-2016 : 2 Marks]

Q.55 In the given circuit, each resistor has a value equal to 1 Ω.



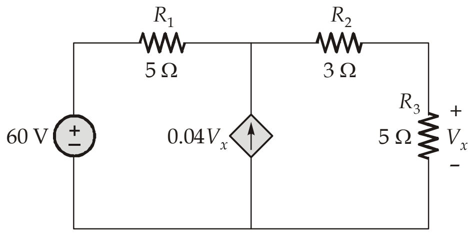
What is the equivalent resistance across the terminals 'a' and 'b'?

(a) $\frac{1}{6}$ Ω (b) $\frac{1}{3}$ Ω

(c) $\frac{9}{20}$ Ω (d) $\frac{8}{15}$ Ω

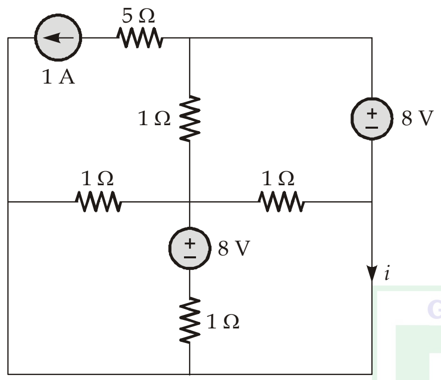
[EC-2016 : 2 Marks]

Q.56 In the circuit shown in the figure, the magnitude of the current (in Amperes) through R_2 is ____ .



[EC-2016 : 2 Marks]

Q.57 In the figure shown, the current 'i' (in Amperes) is ______ .

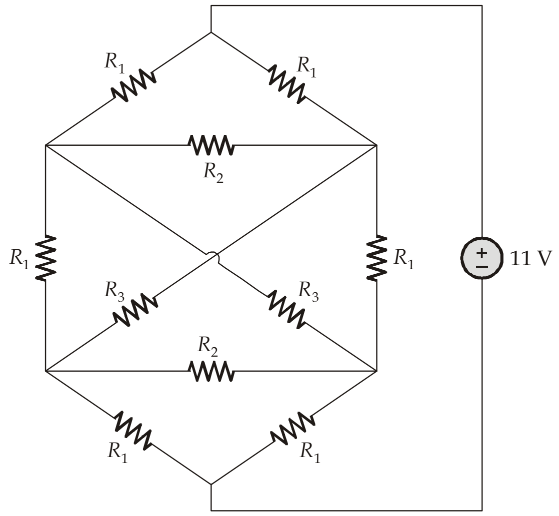


[EC-2016 : 2 Marks]

Q.58 A connection is made consisting of resistance A in series with a parallel combination of resistances B and C. Three resistors of value 10 Ω, 5 Ω, 2 Ω are provided. Consider all possible permutations of the given resistors into the positions A, B, C and identify the configurations with maximum possible overall resistance. The ratio of maximum to minimum values of the resistances (up to two decimal place) is _____ .

[EC-2017 : 1 Mark]

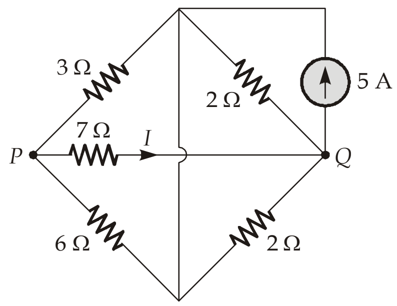
Q.59 Consider the network shown below with $R_1 = 1\ \Omega$, $R_2 = 2\ \Omega$ and $R_3 = 3\ \Omega$. The network is connected to a constant voltage source of 11 V.



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

[EC-2018 : 2 Marks]

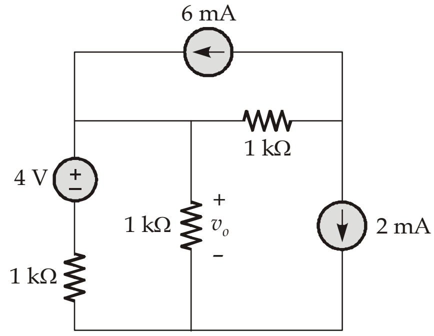
Q.60 Consider the circuit shown in the figure.



The current 'I' flowing through the 7 Ω resistor between P and Q (Rounded off to 1 decimal place) is _______ A.

[EC-2021 : 1 Mark]

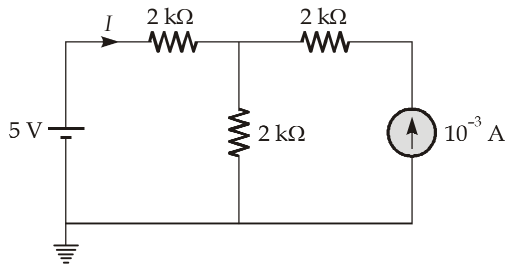
Q.61 Consider the circuit shown in the figure.



The value of V_o (Rounded off to one decimal place) is _______ Volt.

[EC-2021 : 1 Mark]

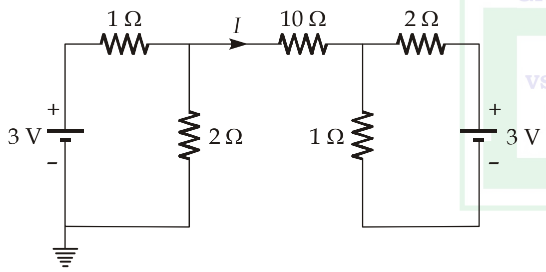
Q.62 The current 'I' in the circuit shown is _____ .



(a) 1.25×10^{-3} A (b) 0.75×10^{-3} A
(c) -0.5×10^{-3} A (d) 1.16×10^{-3} A

[EC-2022]

Q.63 Consider the circuit shown in the figure. The current 'I' flowing through the 10 Ω resistor is ________ .

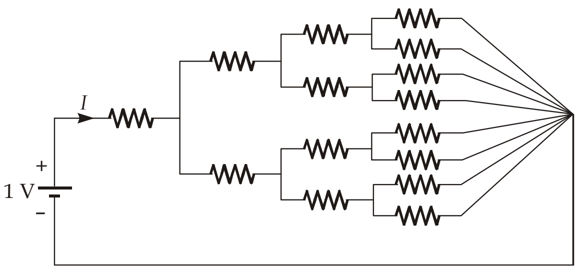


(a) 1 A (b) 0 A
(c) 0.1 A (d) –0.1 A

[EC-2022]

ELECTRICAL ENGINEERING
(GATE Previous Years Solved Papers)

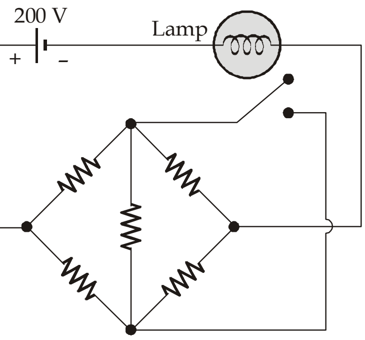
Q.1 All resistance in figure are 1 Ω each. The value of current 'I' is



(a) $\frac{1}{15}$ A (b) $\frac{2}{15}$ A
(c) $\frac{4}{15}$ A (d) $\frac{8}{15}$ A

[EE-1992 : 1 Mark]

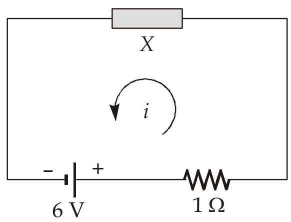
Q.2 All resistance in the circuit in figure are of (R Ω) each. The switch is initially open. What happens to the lamp's intensity when the switch is closed?



(a) Increases
(b) Decreases
(c) Remains same
(d) Answer depends on the value of R

[EE-1992 : 1 Mark]

Q.3 In the circuit shown in figure, X is an element which always absorbs power. During a particular operation, it sets up a current of 1 ampere in the possible that X can be absorb the same power P_x for another current i. Then the value of this current is



(a) $(3-\sqrt{14})$ A (b) $(3+\sqrt{14})$ A
(c) 5 A (d) None of these

[EE-1996 : 1 Mark]

Q.4 A practical current source is usually represented by

(a) a resistance in series with an ideal current source.

(b) a resistance in parallel with an ideal current source.

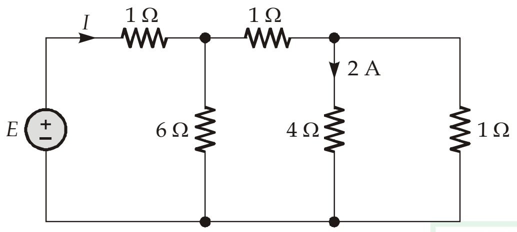
(c) a resistance in parallel with an ideal voltage source.

(d) none of these **[EE-1997 : 1 Mark]**

Q.5 A 10 Volt battery with an internal resistance of 1 Ω is connected across a non-linear load whose V-I characteristic is given by $7I = V^2 + 2V$. The current delivered by the battery is _______ A.

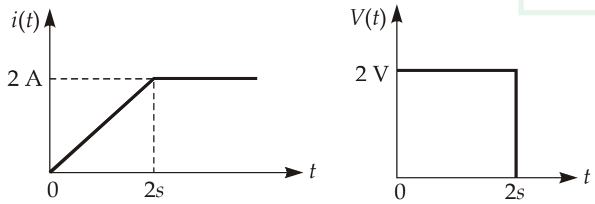
[EE-1997 : 1 Mark]

Q.6 The value of E and I for the circuit shown in figure, are _______ V and _______ A.



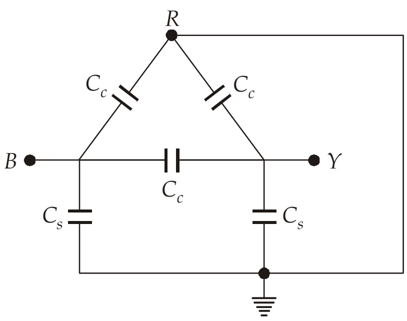
[EE-1997 : 2 Marks]

Q.7 The voltage and current waveforms for an element are shown in figure. The circuit element is ______ and its value is _______ .



[EE-1997 : 2 Marks]

Q.8 For the circuit shown in figure, the capacitance measured between terminals B and Y will be



(a) $C_c + \left(\frac{C_s}{2}\right)$ (b) $C_c + \left(\frac{C_c}{2}\right)$

(c) $\frac{(C_s + 3C_c)}{2}$ (d) $3\,C_c + 2\,C_s$

[EE-1999 : 1 Mark]

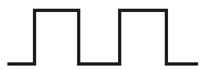
Q.9 When a resistor R is connected to a current source, it consumes a power of 18 W. When the same R is connected to a voltage source having the same magnitude as the current source, the power absorbed by R is 4.5 W. The magnitude of the current source and the value of R are

(a) $\sqrt{18}$ A and 1 Ω (b) 3 A and 2 Ω

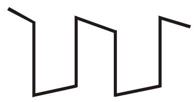
(c) 1 A and 18 Ω (d) 6 A and 0.5 Ω

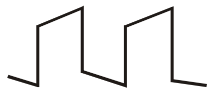
[EE-1999 : 2 Marks]

Q.10 When a periodic triangular voltage of peak amplitude 1 V and frequency 0.5 Hz is applied to a parallel combination of 1 Ω resistor and 1 F capacitance, the current through the voltage source has waveform.

(a) 

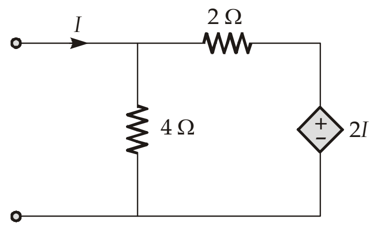
(b) 

(c) 

(d) 

[EE-1999 : 2 Marks]

Q.11 The circuit shown in the figure is equivalent to a load of



(a) $\frac{4}{3}\,\Omega$ (b) $\frac{8}{3}\,\Omega$

(c) $4\,\Omega$ (d) $2\,\Omega$

[EE-2000 : 2 Marks]

Q.12 Two incandescent light bulbs of 40 W and 60 W ratings are connected in series across the mains. Then,

(a) the bulbs together consume 100 W.

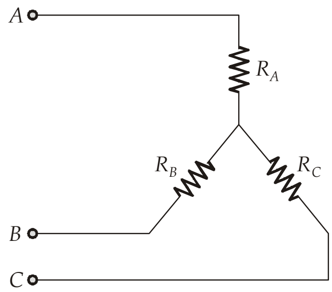
(b) the bulbs together consume 50 W.

(c) the 60 W bulb glows brighter.

(d) the 40 W bulb glows brighter.

[EE-2001 : 1 Mark]

Q.13 Consider the star network shown in figure. The resistance between terminals A and B with terminal C open is 6 Ω, between terminal B and C with terminal A open is 11 Ω, and between terminals C and A with terminal B open is 9 Ω. Then,



(a) $R_A = 4\,\Omega, R_B = 2\,\Omega, R_C = 5\,\Omega$

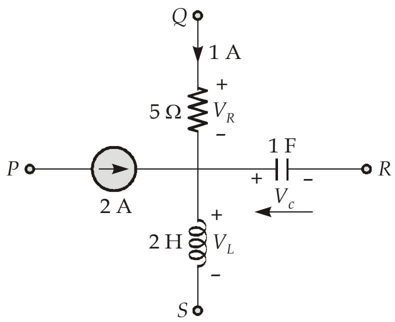
(b) $R_A = 2\,\Omega, R_B = 4\,\Omega, R_C = 7\,\Omega$

(c) $R_A = 3\,\Omega, R_B = 3\,\Omega, R_C = 4\,\Omega$

(d) $R_A = 5\,\Omega, R_B = 1\,\Omega, R_C = 10\,\Omega$

[EE-2001 : 2 Marks]

Q.14 A segment of a circuit shown in figure $V_R = 5$ V, $V_C = 4\sin 2t$. The voltage V_L is given by

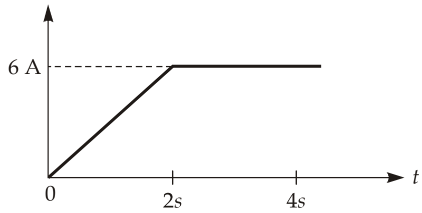


(a) $3 - 8\cos 2t$ (b) $32\sin 2t$

(c) $16\sin 2t$ (d) $16\cos 2t$

[EE-2003 : 1 Mark]

Q.15 Figure shows the waveform of the current passing through an inductor of resistance 1 Ω and inductance 2 H. The energy absorbed by the inductor in the first four second is

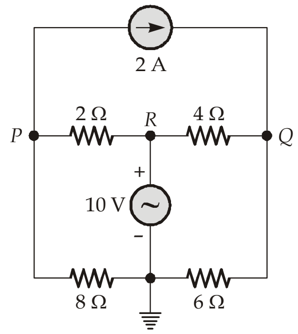


(a) 144 J (b) 98 J

(c) 132 J (d) 168 J

[EE-2003 : 1 Mark]

Q.16 In figure, the potential difference between points P and Q is

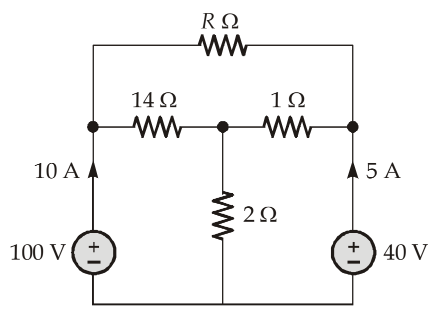


(a) 12 V (b) 10 V

(c) –6 V (d) 8 V

[EE-2003 : 2 Marks]

Q.17 In figure, the value of R is

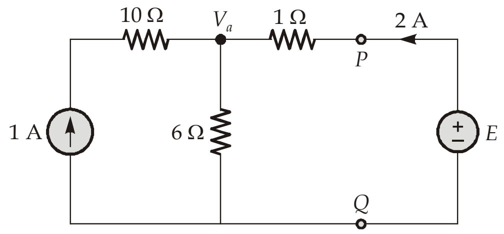


(a) 10 Ω (b) 18 Ω

(c) 24 Ω (d) 12 Ω

[EE-2003 : 2 Marks]

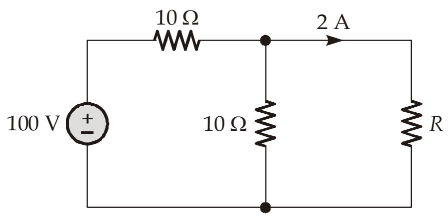
Q.18 In figure, the value of the source voltage is



(a) 12 V (b) 24 V
(c) 30 V (d) 44 V

[EE-2004 : 2 Marks]

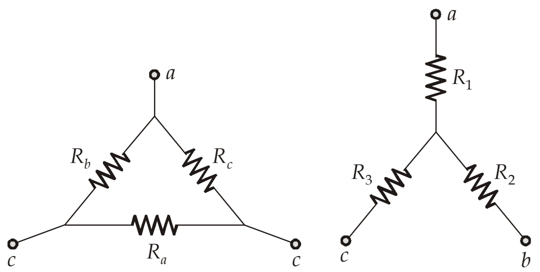
Q.19 In figure, the value of resistance R in Ω is



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

[EE-2004 : 2 Marks]

Q.20 In figure, R_a, R_b and R_c are 20 Ω, 10 Ω and 10 Ω respectively. The resistance R_1, R_2 and R_3 in Ω of an equivalent star-connection are



(a) 2.5, 5, 5 (b) 5, 2.5, 5
(c) 5, 5, 2.5 (d) 2.5, 5, 2.5

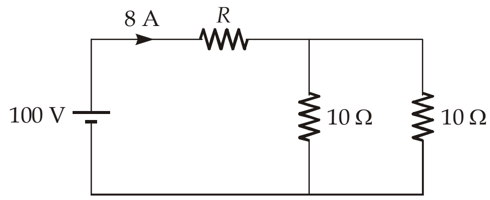
[EE-2004 : 2 Marks]

Q.21 The rms value of the current in the wire which carries a dc current of 10 A and a sinusoidal alternating current of peak value of 20 A is

(a) 10 A (b) 14.14 A
(c) 15 A (d) 17.32 A

[EE-2004 : 2 Marks]

Q.22 In the figure given below the value of R is



(a) 2.5 Ω (b) 5.0 Ω
(c) 7.5 Ω (d) 10.0 Ω

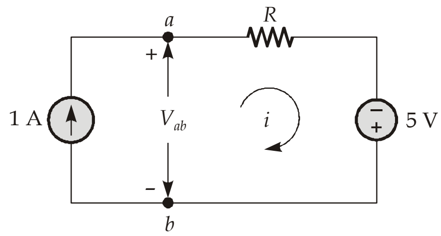
[EE-2005 : 1 Mark]

Q.23 A 3 V d.c. supply with an internal resistance of 2 Ω supplies a passive non-linear resistance characterized by the relation $V_{NL} = I_{NL}^2$. The power dissipated in the non-linear resistance is

(a) 1.0 W (b) 1.5 W
(c) 2.5 W (d) 3.0 W

[EE-2007 : 2 Marks]

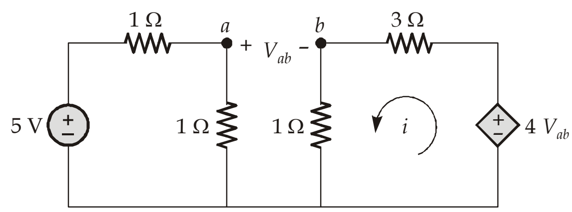
Q.24 Assuming ideal elements in the circuit shown below, the voltage V_{ab} will be



(a) –3 V (b) 0 V
(c) 3 V (d) 5 V

[EE-2008 : 2 Marks]

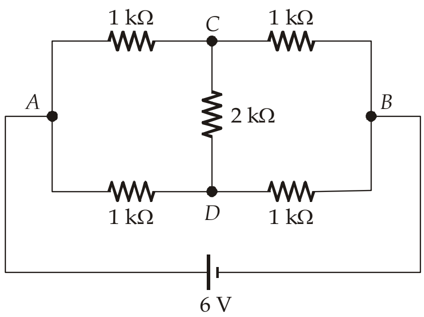
Q.25 In the circuit shown in the figure, the value of the current i will be given by



(a) 0.31 A (b) 1.25 A
(c) 1.75 A (d) 2.5 A

[EE-2008 : 2 Marks]

Q.26 The current through the 2 kΩ resistance in the circuit shown is



(a) 0 mA (b) 1 mA
(c) 2 mA (d) 6 mA

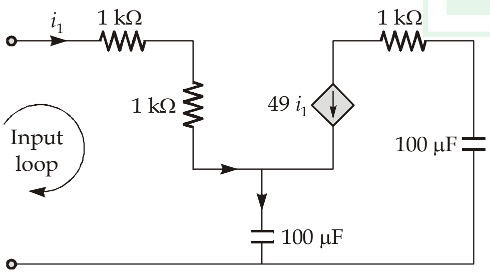
[EE-2009 : 1 Mark]

Q.27 How many 200 W/220 V incandescent lamps connected in series would consume the same total power as a single 100 W/220 V incandescent lamp?

(a) non possible (b) 4
(c) 3 (d) 2

[EE-2009 : 1 Mark]

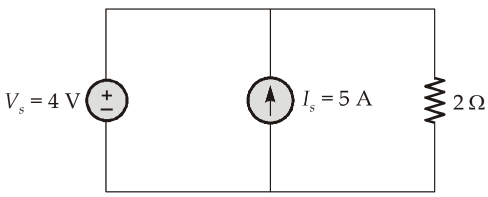
Q.28 The equivalent capacitance of the input loop of the circuit shown is



(a) 2 μF (b) 100 μF
(c) 200 μF (d) 4 μF

[EE-2009 : 2 Marks]

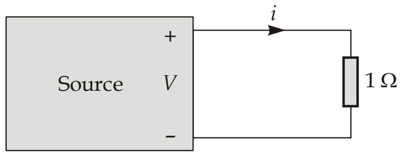
Q.29 For the circuit shown, find out the current flowing through the 2 Ω resistance. Also identify the changes to be made of double the current through the 2 Ω resistance.



(a) (5 A, Put $V_s = 20$ V)
(b) (2 A, Put $V_s = 8$ V)
(c) (5 A, Put $I_s = 10$ V)
(d) (7 A, Put $I_s = 12$ V)

[EE-2009 : 2 Marks]

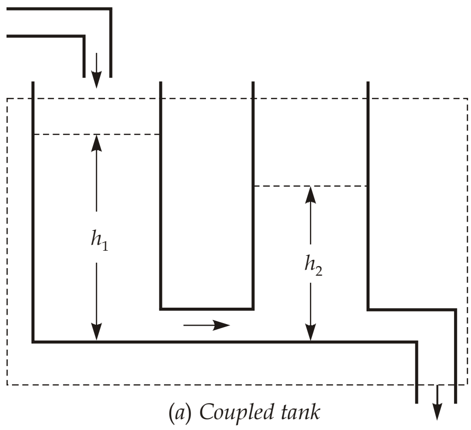
Q.30 As shown in the figure, a 1 Ω resistance is connected across a source that has a load line $v + i = 100$. The current through the resistance is



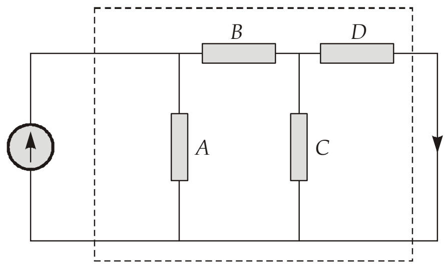
(a) 25 A (b) 50 A
(c) 100 A (d) 200 A

[EE-2010 : 1 Mark]

Q.31 If the electrical circuit of Fig. (b) is an equivalent of the coupled tank system of Fig. (a), then



(a) Coupled tank

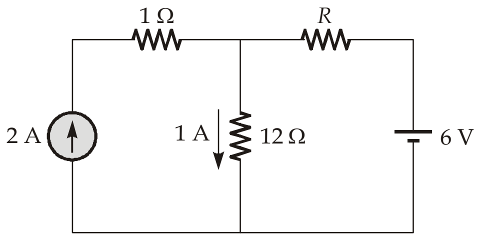


(b) Electrical equivalent

(a) *A*, *B* are resistance and *C*, *D* capacitances.
(b) *A*, *C* are resistance and *B*, *D* capacitances.
(c) *A*, *B* are capacitances and *C*, *D* resistances.
(d) *A*, *C* are capacitances and *B*, *D* resistances.

[EE-2010 : 1 Mark]

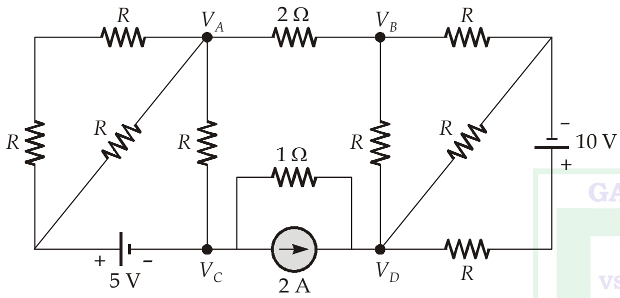
Q.32 If the 12 Ω resistor draws a current of 1 A as shown in the figure, the value of resistance R is



(a) 4 Ω (b) 6 Ω
(c) 8 Ω (d) 18 Ω

[EE-2010 : 2 Marks]

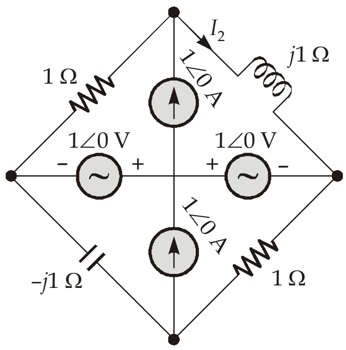
Q.33 If $V_A - V_B = 6$ V, then $V_C - V_D$ is



(a) –5 V (b) 2 V
(c) 3 V (d) 6 V

[EE-2012 : 2 Marks]

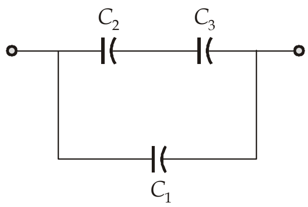
Q.34 In the circuit shown below, the current through the inductor is



(a) $\frac{2}{1+j}$ A (b) $\frac{-1}{1+j}$ A
(c) $\frac{1}{1+j}$ A (d) 0 A

[EE-2012 : 1 Mark]

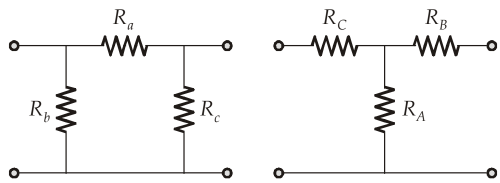
Q.35 Three capacitors C_1, C_2 and C_3 whose values are 10 μF, 5 μF and 2 μF respectively have breakdown voltages of 10 V, 5 V and 2 V respectively. For the interconnection shown below, the maximum safe voltage in volts that can be applied across the combination, and the corresponding total charge in μC stored in the effective capacitance across the terminals are, respectively



(a) 2.8 and 36 (b) 7 and 119
(c) 2.8 and 32 (d) 7 and 80

[EE-2013 : 2 Marks]

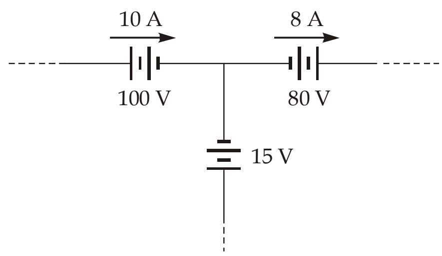
Q.36 Consider a delta-connection of resistors and its equivalent star-connection as shown below. If all elements of the delta-connection are scaled by a factor k, $k > 0$, the elements of the corresponding star equivalent will be scaled by a factor of



(a) k^2 (b) 5
(c) $\frac{1}{k}$ (d) $\sqrt{k}$

[EE-2013 : 1 Mark]

Q.37 The three circuit elements shown in the figure are part of an electric circuit. The total power absorbed by the three circuit elements in watts is _______ .



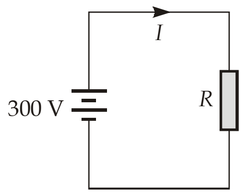
[EE-2014 : 1 Mark]

Q.38 An incandescent lamp is marked 40 W, 240 V. If resistance at room temperature (26°C) is 120 Ω, and temperature coefficient of resistance is 4.5×10^{-3}/°C, then its 'ON' state filament temperature in °C is approximately _______ .

[EE-2014 : 2 Marks]

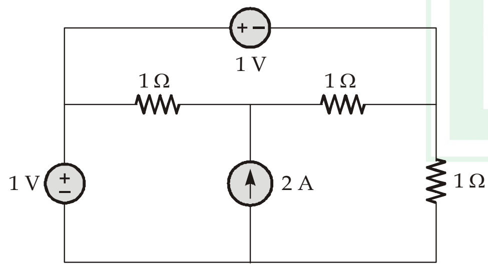
Q.39 In the figure, the value of resistor R is $\left(25+\frac{I}{2}\right)\Omega$, where I is the current in amperes.

The current I is _______ .



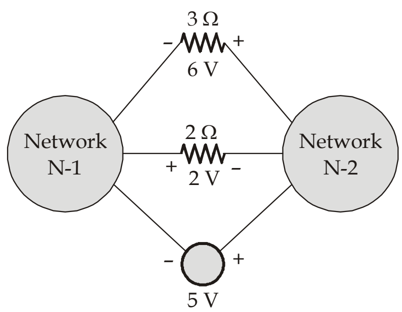
[EE-2014 : 2 Marks]

Q.40 The power delivered by the current source, in the figure, is _______ .



[EE-2014 : 2 Marks]

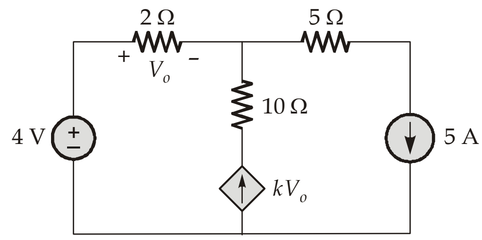
Q.41 The voltages developed across the 3 Ω and 2 Ω resistors shown in the figure are 6 V and 2 V respectively, with the polarity as marked. What is the power (in Watt) delivered by the 5 V voltage source?



(a) 5 (b) 7
(c) 10 (d) 14

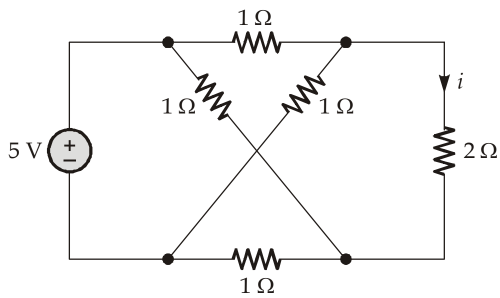
[EE-2015 : 1 Mark]

Q.42 In the given circuit, the parameter 'k' is positive, and the power dissipated in the 2 Ω resistor is 12.5 W. The value of 'k' is _______ .



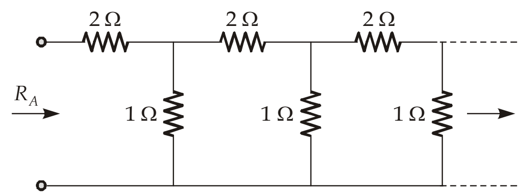
[EE-2015 : 2 Marks]

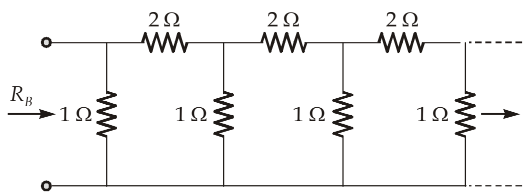
Q.43 The current i (in Ampere) in the 2 Ω resistor of the given network is _______ .



[EE-2015 : 1 Mark]

Q.44 R_A and R_B are the input resistance of circuits as shown below. The circuits extend infinitely in the direction shown. Which one of the following statements is true?



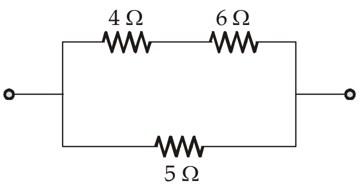


(a) $R_A = R_B$ (b) $R_A = R_B = 0$

(c) $R_A < R_B$ (d) $R_B = \dfrac{R_A}{(1+R_A)}$

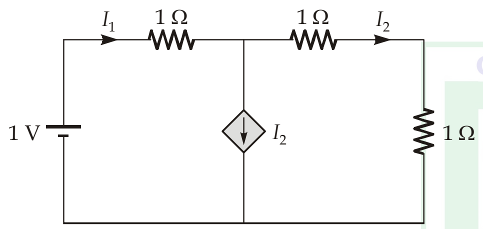
[EE-2016 : 1 Mark]

Q.45 In the portion of a circuit shown, if the heat generated in 5 Ω resistance is 10 calories/sec, then heat generated by the 4 Ω resistance, in calories per second, is _______ .



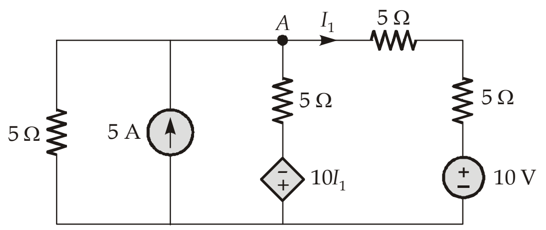
[EE-2016 : 1 Mark]

Q.46 In the given circuit, the current supplied by the battery, in ampere, is ________ .



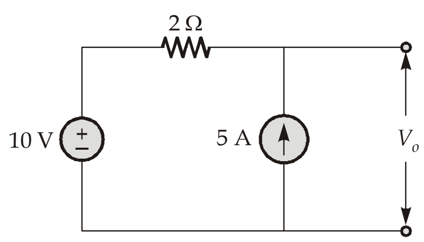
[EE-2016 : 1 Mark]

Q.47 In the circuit shown below, the node voltage V_A is _______ V.



[EE-2016 : 2 Marks]

Q.48 In the circuit shown below, the voltage and current sources are ideal. The voltage (V_{out}) across the current source (in Volts), is ______ .

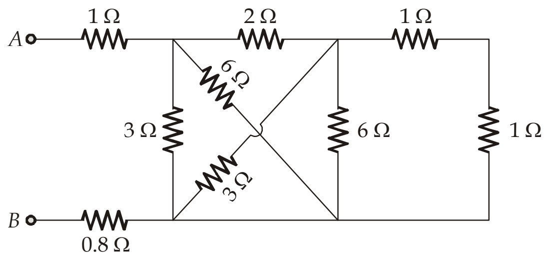


(a) 0 (b) 5

(c) 10 (d) 20

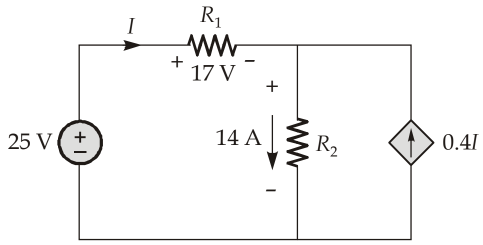
[EE-2016 : 1 Mark]

Q.49 The equivalent resistance between the terminals A and B is _______ Ω.



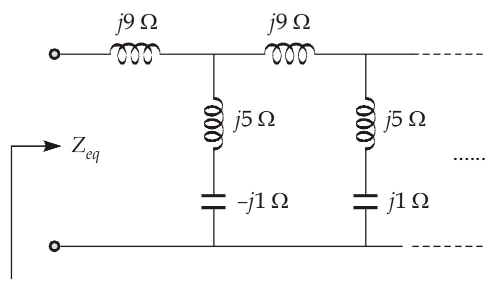
[EE-2017 : 1 Mark]

Q.50 The power supplied by the 25 V source in the figure shown below is ______ W.



[EE-2017 : 1 Mark]

Q.51 The equivalent impedance Z_{eq} for the infinite ladder circuit shown in the figure is

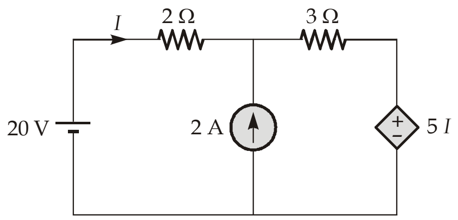


(a) $j12$ Ω (b) $-j12$ Ω

(c) $j13$ Ω (d) 13 Ω

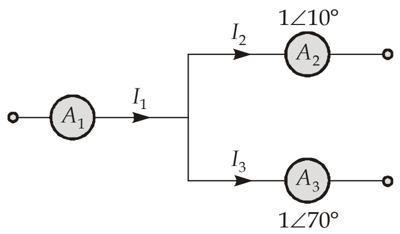
[EE-2018 : 2 Marks]

Q.52 The current I flowing in the circuit shown below in amperes (Round off to one decimal place) is _________ .



[EE-2019 : 1 Mark]

Q.53 Currents through ammeters A_2 and A_3 in the figure are $1\angle 10°$ and $1\angle 70°$ respectively. The reading of the ammeter A_1
(Rounded off to 3 decimal places) is ______ A.



[EE-2020 : 1 Mark]

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Electronics & Electrical Engineering

GATE Previous Years Solved Paper

Answers & Explanations

Answers

EC Basics of Network Analysis

1. (0.5)	**2.** (c)	**3.** (d)	**4.** (a)	**5.** (d)	**6.** (d)	**7.** (b)	**8.** (a)
9. (d)	**10.** (a)	**11.** (b)	**12.** (c)	**13.** (b)	**14.** (c)	**15.** (d)	**16.** (d)
17. (a)	**18.** (d)	**19.** (c)	**20.** (a)	**21.** (d)	**22.** (a)	**23.** (d)	**24.** (a)
25. (a)	**26.** (*)	**27.** (d)	**28.** (d)	**29.** (d)	**30.** (b)	**31.** (c)	**32.** (a)
33. (c)	**34.** (a)	**35.** (b)	**36.** (c)	**37.** (b)	**38.** (a)	**39.** (b)	**40.** (b)
41. (c)	**42.** (d)	**43.** (c)	**44.** (a)	**45.** (29.09)	**46.** (10)	**47.** (d)	**48.** (c)
49. (2.8)	**50.** (2.62)	**51.** (100)	**52.** (a)	**53.** (8)	**54.** (1)	**55.** (d)	**56.** (5)
57. (–1)	**58.** (2.143)	**59.** (8)	**60.** (0.5)	**61.** (1)	**62.** (b)	**63.** (b)	

Solutions

EC Basics of Network Analysis

1. Sol.

Triangular wave, 0.5 ampere peak,

$$i_L = \frac{1}{L}\int V dt$$

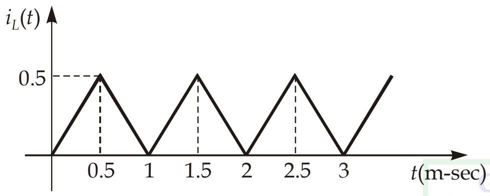
So, the current through inductor is the integration of the applied voltage across the inductor.

Integration of square wave is a triangular wave.

So, the current through the inductor is a **triangular wave**.

Now, $v(t) = u(t) - 2u(t-0.5) + 2u(t-1) + ...$

$\therefore$ $i_L(t) = r(t) - 2r(t-0.5) + 2r(t-1) + ...$



$$I_p = 0.5 \text{ A}$$

5. (c)

N_1:

$$Y_1(s) = s + \frac{1}{2s+1} + \frac{1}{\frac{1}{s}+2}$$

$$Y_1(s) = \frac{2s^2+2s+1}{2s+1}$$

N_2:

$$Y_2(s) = \frac{1}{2s+1} + \frac{1}{2+\frac{1}{s}} = \frac{1+s}{2s+1}$$

N_3:

$$Y_3(s) = s + \frac{1}{1+\frac{1}{1+\frac{1}{s}}} = s + \frac{1+s}{s+1+s}$$

$$Y_3(s) = \frac{2s^2+2s+1}{2s+1}$$

N_4:

$$Y_4(s) = s + \frac{1}{2s+1} = \frac{2s^2+2s+1}{2s+1}$$

So, N_1 and N_3 networks having identical driving point function.

3. (d)

If all resistors are doubled then the current get halved,

$$I' = \frac{I}{2}$$

$$R' = 2R$$

$$V' = \frac{I}{2}\cdot 2R = IR = V$$

4. (a)

Current through 5 Ω resistor,

$$i_5 = \frac{10}{5} = 2 \text{ Amp.}$$

Current through 1 Ω resistor,

$$i_1 = \frac{5}{1} = 5 \text{ Amp.}$$

So, the current through 15 Ω resistor,

$$i_{15} = -(i_1 + i_5)$$
$$= -(5+2) = -7 \text{ Amp.}$$

Voltage across 15 Ω resistor,

$$V_{15} = 15(i_{15})$$
$$= 15(-7) = -105 \text{ V}$$

5. (d)

$$P_1 = 4 \text{ W}, \quad P_2 = 9 \text{ W}$$

From superposition theorem,

$$P = (\sqrt{P_1} + \sqrt{P_2})^2$$

$$= (\sqrt{4} + \sqrt{9})^2$$

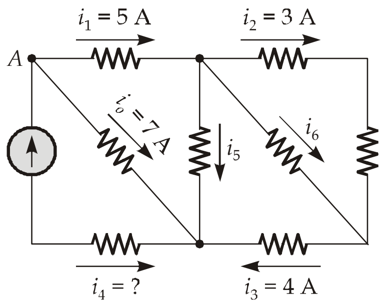
$$P = (2+3)^2 = 25 \text{ W}$$

6. (d)

$$L = L_1 + L_2 \pm 2M$$
$$= L_1 + L_2 \pm 2k\sqrt{L_1 L_2}$$

$$L = 2 + 2 \pm 2(0.1)\sqrt{2\times 2}$$
$$= 4 \pm 0.4$$
$$L = 3.6 \text{ H and } 4.4 \text{ H}$$

7. **(b)**



Apply KCL at node A,

$$i_0 + i_1 + i_4 = 0$$
$$7 + 5 + i_4 = 0$$
$$i_4 = -12 \text{ A}$$

8. **(a)**

Apply KVL,

$$V + 5 - 4 - 4 = 0$$
$$V = 3 \text{ V}$$

9. **(d)**

$$V = V_{2\text{ A}} + 2 \times 2 + 5$$
$$= V_{2\text{ A}} + 9$$

Since, the voltage of 2 A current source is not known. So, it is not possible to find the value of voltage V.

10. **(a)**

Voltage in parallel is always equal.

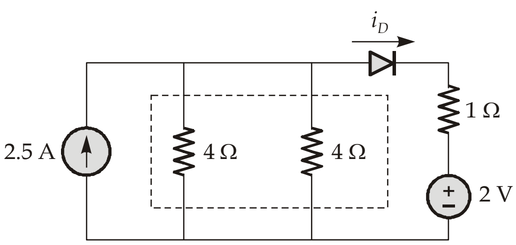
11. **(b)**

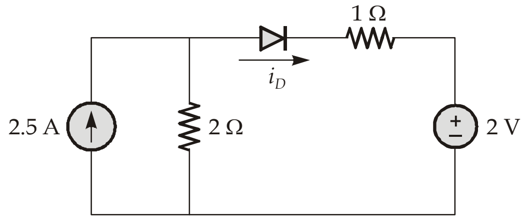
The bridge is balanced,

$$Z_{eq} = (2||4) + (2||4)$$

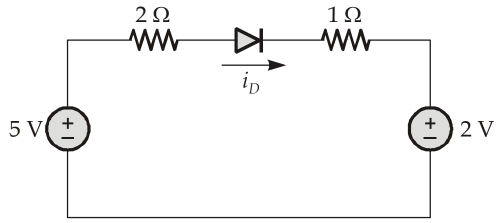
$$Z_{eq} = \frac{2\times4}{2+4} + \frac{2\times4}{2+4} = \frac{4}{3} + \frac{4}{3} = \frac{8}{3}\ \Omega$$

12. **(c)**





Using source transformation,



$$i_D = \frac{5-2}{2+1} = \frac{3}{3} = 1 \text{ Amp.}$$

13. **(b)**

The nodal or mesh method is based on KCL and Ohm's law.

14. **(c)**

Apply superposition theorem:

For 1 Volt source,

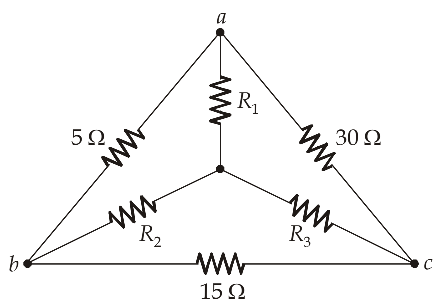
$$V_{ab_1} = 1 \times \frac{2}{2+2}$$
$$= 0.5 \text{ V}$$

For 3 A source,

$$V_{ab_3} = 3 \times \left(\frac{2}{2+2}\right) \times 2 = 3 \text{ V}$$

$$V_{ab} = V_{ab_1} + V_{ab_3}$$
$$= 0.5 + 3 = 3.5 \text{ V}$$

15. **(d)**



$$R_1 = \frac{5 \times 30}{5 + 30 + 15} = 3$$

$$R_2 = \frac{15\times5}{50} = 1.5$$

$$R_3 = \frac{15\times30}{50} = 9$$

16. (d)

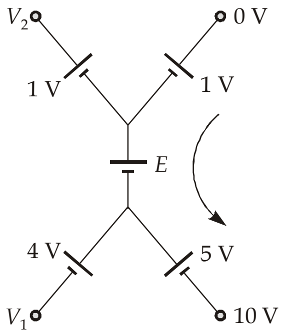
Applying KCL at the node (1),

$$e^{at} + e^{bt} = i_L(t)$$

$$\Rightarrow \quad v(t) = L\frac{d}{dt}[e^{at} + e^{bt}]$$

$$v(t) = ae^{at} + be^{bt}$$

17. (a)



$$0 - 1 - E - 5 - 10 = 0$$

$$E = -16 \text{ V}$$

18. (d)

Since diode is forward bias it is taken as short-circuit.

Applying KCL,

$$\frac{V-4}{2} + \frac{V}{2} + \frac{V+2}{2} = 0$$

$$3V = 2$$

$$\Rightarrow \quad V = \frac{2}{3}$$

$$\Rightarrow \quad V_o = -V = -\frac{2}{3}$$

19. (c)

Applying KCL,

$$\frac{e_0 - 12}{4} + \frac{e_0}{4} + \frac{e_0}{4} = 0$$

$$\Rightarrow \quad 3e_o = 12$$

$$\therefore \quad e_o = 4 \text{ V}$$

20. (a)

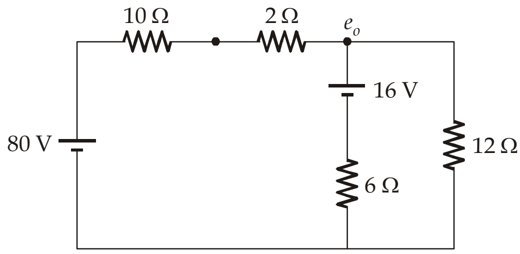
$$Z_\Delta = 3Z_Y$$

$$\Rightarrow \quad \sqrt{3}\,Z_\Delta = 3Z_Y$$

$$Z_Y = \frac{Z_\Delta}{\sqrt{3}}$$

21. (d)

Applying source conversion,



$$\frac{e_0 - 80}{12} + \frac{e_0}{12} + \frac{e_0 - 16}{6} = 0$$

$$4e_o = 112$$

$$e_o = \frac{112}{4} = 28 \text{ V}$$

22. (a)

Applying KVL,

$$20 - 5I - 5\left(I + \frac{V_1}{5}\right) = 0$$

$$20 - 10I - 20 = 0$$

$$\Rightarrow \quad I = 0$$

$\therefore$ Only dependent source acts,

$$\frac{V_1}{5} = 4 \text{ A}$$

$$\text{Power delivered} = I^2R$$

$$= 16 \times 5 = 80 \text{ W}$$

23. (d)

$$3V_pI_p\cos\theta = 1500$$

$$3\left(\frac{V_L}{\sqrt{3}}\right)\left(\frac{V_L}{\sqrt{3}Z_L}\right)\cos\theta = 1500$$

$$Z_L = \frac{V_L^2 \cdot \cos\theta}{1500}$$

$$= \frac{400^2 \times 0.844}{1500} = 90\ \Omega$$

$$\theta = \cos^{-1}(0.844) = 32.44$$

As power factor is leading, load is capacitive so angle will be negative,

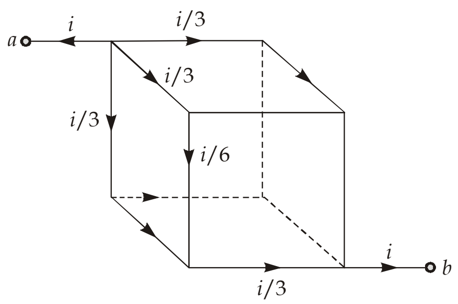
$$\theta = -32.44°$$

24. (a)

As voltage at 1 node is known.

$\therefore$ using nodal analysis only 3 equations required.

25. (a)



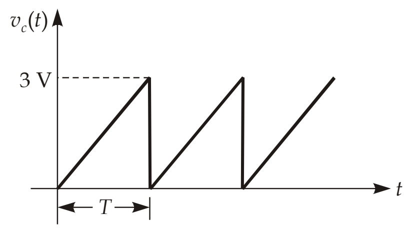
$$V_{ab} = \frac{i}{3}\times 1 + \frac{i}{6}\times 1 + \frac{i}{3}\times 1$$

$$\Rightarrow \quad R_{eq} = \frac{V_{ab}}{i} = \frac{5}{6}\,\Omega$$

26. (*)

Question is incomplete.

27. (d)



$$v_c(t) = \frac{1}{C}\int_0^T i\,dt$$

Here, $T = \frac{1}{t} = \frac{1}{500} = 2$ m-sec

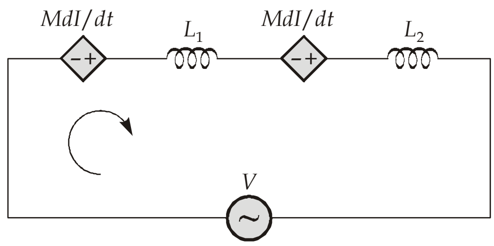
$C = 2\,\mu F$

$$\Rightarrow \quad 3 = \frac{i}{2\,\mu F}T$$

$$i = \frac{3\times 2\,\mu F}{T} = \frac{3\times 2\,\mu F}{2\text{ m-sec}} = 3\text{ mA}$$

Hence, the charging requires constant current source of 3 mA for 2 m-sec.

28. (d)



If current enters the dotted terminals of coil 1 then a voltage is developed across coil 2 whose higher potential is at dotted terminals,

$$V = \frac{-MdI}{dt} + \frac{L_1 dI}{dt} - \frac{MdI}{dt} + L_2\frac{dI}{dt}$$

$$= (L_1 + L_2 - 2M)\frac{dI}{dt}$$

$$V = L_{eq}\frac{dI}{dt}$$

29. (d)

$$H(s) = \frac{1/sC}{R + sL + \frac{1}{sC}} = \frac{1}{s^2LC + sCR + 1}$$

$$H(s) = \frac{1}{10^{-6}s^2 + s + 1} = \frac{10^6}{s^2 + 10^6 s + 10^6}$$

30. (b)

$$X = X_1 + X_2 + X_3 + 2X_m - 2X_m$$

$= (j5 + j2 + j2 + j20 - j20)\ \Omega$

$= j9\,\Omega$ (one additive and other subtractive)

31. (c)

$V_a = 5$ $\quad (R_1 = R_2)$

$$V_b = \frac{R_3}{R_3 + R_4}\times 10 = \frac{1.1}{2.1}\times 10$$

$V = V_a - V_b = -0.238$ V

32. (a)

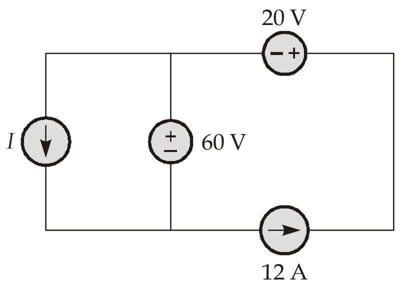
Since, the power is absorbed by 60 V source,

$I' = 12 - I$

$\Rightarrow \quad I' > 0$

$12 - I > 0$

$I < 12$ A

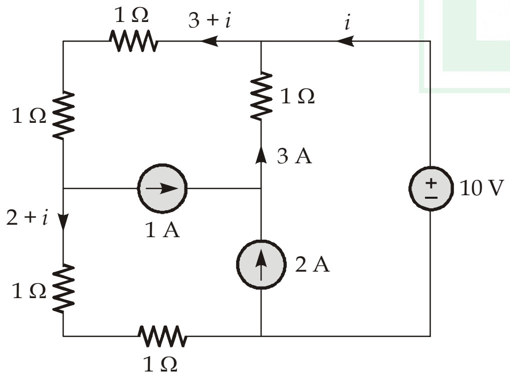


33. (c)

$$P = VI$$
$$\text{Energy} = P \cdot t$$
$$I = 2\text{ A} \quad \text{(Given)}$$
$$V \cdot t = \text{Area under } V - t \text{ curve}$$
$$V \cdot t = \left(\frac{1}{2} \times 2 \times 600\right) + (10 + 600)$$
$$= 600 + 6000$$
$$V \cdot t = 6600$$
$$E = (6600) \times 2 = 13200 = 13.2$$

kJ

34. (a)



Applying KVL in outer loop,

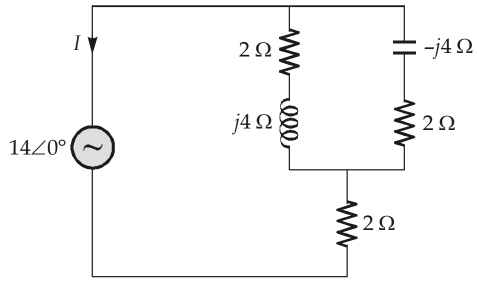
$$(3 + i)\,2 + (2 + i)\,2 = 10$$
$$\Rightarrow \quad 6 + 2i + 4 + 2i = 10$$
$$\Rightarrow \quad 4i = 0$$
$$\Rightarrow \quad i = 0$$

Power supplied by the voltage across,

$$P = Vi$$
$$= 10 \times 0 = 0\text{ W}$$

35. (b)

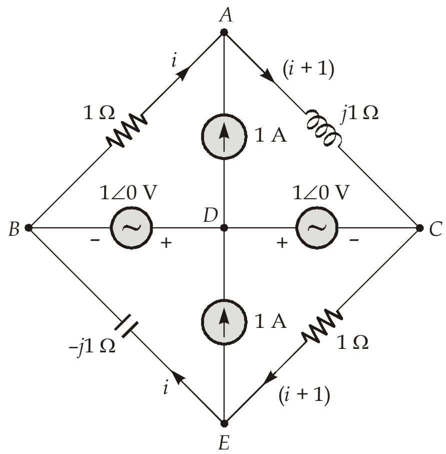
Converting delta into star, the circuit can be redrawn as below:



Equivalent impedance of the circuit,

$$Z = (2 + j4)\,||\,(2 - j4) + 2$$
$$\Rightarrow \quad Z = \frac{4 + 16}{4} + 2 = 7\ \Omega$$
$$\therefore \text{ Current,} \quad I = \frac{14\angle 0^\circ}{7} = 2\angle 0^\circ\text{ A}$$

36. (c)



According to KCL at node D there will be no current in voltage sources.

According to KCL at node A current through inductor will be

$$i_1 = i + 1 \quad \text{...(1)}$$

Applying KVL in loop $ACDBA$ we have

$$1 \times i + (i + 1)\,j1 + 1\angle 0 - 1\angle 0 = 0$$
$$i + (i + 1)\,j = 0$$
$$(1 + j)\,i = -j$$
$$i = \frac{-j}{1 + j} \quad \text{...(2)}$$

Therefore from (1) and (2) we have,

$$i_1 = i + 1 = \frac{-j}{j + 1} + 1$$
$$i_1 = \frac{1}{1 + j}$$

37. (b)

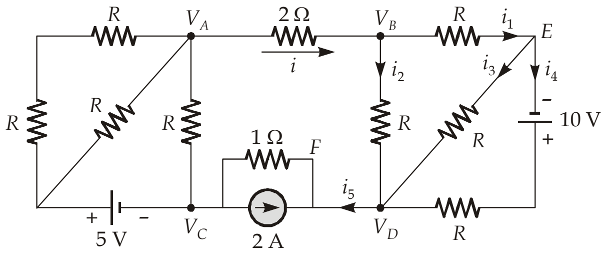
Average power is same as rms power,

$$P = I_{\text{rms}}^2 R = \left(\frac{5}{\sqrt{2}}\right)^2 \times 4$$

$$= \frac{25}{2} \times 4 = 50 \text{ W}$$

Note : Power is consumed only by resistance i.e. by real part of impedance.

38. (a)



$$i = \frac{V_A - V_B}{2} = \frac{6}{2}$$

$$= 3 \text{ A} \qquad \text{...(i)}$$

$$i_5 = 3 \text{ A}$$

KCL at node *F*, we have,

$$i_6 + 2 + i_5 = 0$$

$$i_6 = -2 - i_5$$

$$i_6 = -5 \text{ A}$$

So, $V_C - V_D = 1 \times i_6 = -5 \text{ V}$

39. (b)

$$R_A = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$R'_a = kR_a$$

$$R'_b = kR_b$$

$$R'_c = kR_c$$

$$R'_A = \frac{kR_b \cdot kR_c}{kR_a + kR_b + kR_c}$$

$$= \frac{k^2 R_b R_c}{k(R_A + R_b + R_c)}$$

$$= k \times \frac{R_b R_c}{R_a + R_b + R_c}$$

$$R'_A = kR_A$$

40. (b)

$$V_{YZ_1} = 100 \times 1.25 \times 0.8$$

$$= 100 \text{ V}$$

In second case, when 100 V is applied at *YZ* terminals, this whole 100 V will appear across the secondary winding.

Hence, $V_{WX_2} = \frac{100}{1.25} = 80 \text{ V}$

$$\Rightarrow \quad \frac{Y_{YZ_1}}{Y_{WX_1}} = \frac{100}{100}, \frac{V_{WX_2}}{V_{YZ_2}} = \frac{80}{100}$$

41. (c)

$$Q = CV$$

$$Q_1 = C_1V_1 = 10 \times 10^{-6} \times 10 = 100 \text{ μC}$$

$$Q_2 = C_2V_2 = 5 \times 10^{-6} \times 5 = 25 \text{ μC}$$

$$Q_3 = C_3V_3 = 2 \times 10^{-6} \times 2 = 4 \text{ μC}$$

Capacitors C_2 and C_3 are in series.

In series charge in same.

So, the maximum charge on C_2 and C_3 will be minimum of $(Q_2, Q_3) = \min(25 \text{ μC}, 4 \text{ μC}) = 4 \text{ μC} = Q_{23}$.

In series the equivalent capacitance of C_2 and C_3 is

$$C_{23} = \frac{C_2C_3}{C_2 + C_3} = \frac{5 \times 2}{5 + 2} = \frac{10}{7} \text{ μF}$$

So, the equivalent voltage,

$$V_{23} = \frac{Q_{23}}{C_{23}} = \frac{4 \times 10^{-6}}{\frac{10}{7} \times 10^{-6}}$$

$$= \frac{28}{10} = 2.8 \text{ V}$$

In parallel, the voltage is same,

$$V_1 = V_{23} = 2.8 \text{ V}$$

Charge in capacitor C_1,

$$Q_1 = C_1V_1$$

$$= 10 \times 10^{-6} \times 2.8$$

$$= 28 \text{ μC}$$

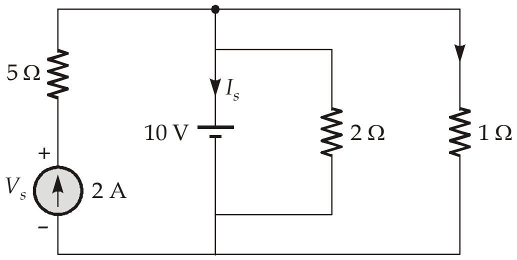
In parallel, the total charge,

$$Q = Q_1 + Q_{23}$$

$$Q = 4 + 28$$

$$Q = 32 \text{ μC}$$

42. (d)



Voltage across 1 Ω resistance,

$$V_1 = 10 \text{ V}$$

Current through 1 Ω resistance,

$$I_1 = \frac{10}{1} = 10 \text{ Amp.}$$

Voltage across 2 Ω resistance,

$$V_2 = 10 \text{ V}$$

Current through 2 Ω resistance,

$$I_2 = \frac{10}{2} = 5 \text{ Amp.}$$

Apply KCL at node A,

$$-2 + I_s + I_2 + I_1 = 0$$
$$I_s = 2 - I_1 - I_2 = 2 - 10 - 5$$
$$I_s = -13 \text{ Ampere}$$

Voltage at node A,

$$V_A = 10 \text{ V}$$
$$V_s - 10 = 10 \text{ V}$$
$$V_s = 10 + 10 = 20 \text{ V}$$

43. (c)

The current in the 1 Ω resistor,

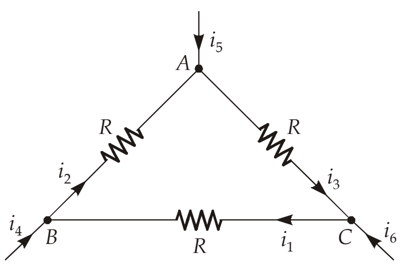
$$I_1 = \frac{10}{1} = 10 \text{ Ampere}$$

44. (a)

Given data: $i_1 = 2$ A, $i_4 = -1$ A, $i_5 = -4$ A

$R = 1\ \Omega$

To calculate, $i_6 = ?$



Using KVL at all the three nodes we get

At node A,

$$i_5 - i_3 + i_2 = 0 \quad \text{...(i)}$$

At node B,

$$i_4 + i_1 - i_2 = 0 \quad \text{...(ii)}$$

At node C,

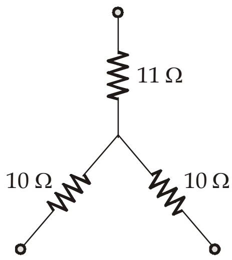
$$i_6 + i_3 - i_1 = 0 \quad \text{...(iii)}$$

By putting the value of i_3 and i_2 from equation (i) and (ii) in equation (iii) we get,

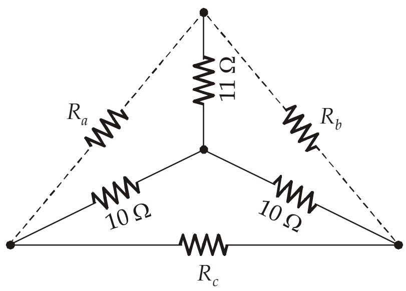
$$i_6 + (i_2 + i_5) - i_1 = 0$$
$$i_6 + (i_1 + i_4 + i_5) - i_1 = 0$$
$$\therefore \quad i_6 + (2 - 1 - 4) - 2 = 0$$
$$i_6 = 5 \text{ A}$$

45. Sol.

According to the question,



The equivalent Δ-network of the above Y-network is,



Here,

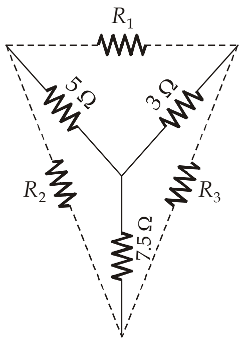
$$R_a = 10 + 11 + \frac{10 \times 11}{10} = 32\ \Omega$$

$$R_b = 10 + 11 + \frac{10 \times 11}{10} = 32\ \Omega$$

$$R_c = 10 + 10 + \frac{10 \times 10}{11} = 29.09\ \Omega$$

Hence, the lowest value among the three resistances is 29.09 Ω.

46. Sol.



Using star-delta conversions:

The value of R_1 is given by

$$= 5+3+\frac{5\times 3}{7.5}=10$$

47. (d)

Using the concepts of super node, we get

$$V_1 - V_2 = 10\angle 0° \quad ...(i)$$

$$= \frac{V_1}{-3j}+\frac{V_2}{6j}+\frac{V_2}{6}=4\angle 0° \quad ...(ii)$$

$$= \frac{-2V_1+V_2+jV_2}{6j}=4\angle 0° \quad ...(iii)$$

From equation (i) and (iii),

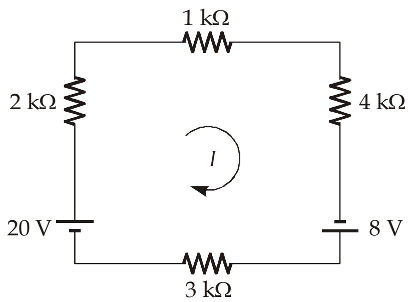
$$V_2 = \frac{20+j24}{(-1+j)}=\frac{31.241\angle 50.194}{\sqrt{2}\angle 135°}$$

$$= 22.091\angle -84.806$$

or, $V_2 = 2 - 22j$

49. Sol.

Using source transformation, we get,



Applying KVL in above circuit, we get,

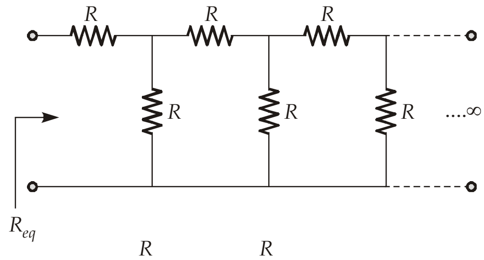
$$20 - 2I - I - 4I + 8 - 3I = 0$$

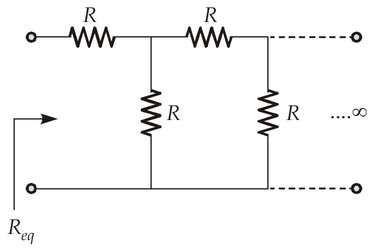
or, $28 = 10I$

or, $I = 2.8$ mA

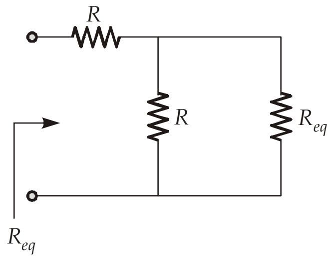
50. Sol.

For an infinite ladder network, if all the resistance are comprises of same value R, then,





or,

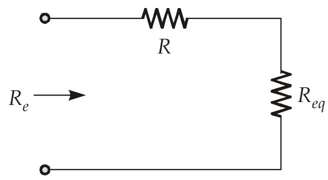


$$\therefore \quad R_{eq} = R+\frac{R\cdot R_{eq}}{R+R_{eq}} \quad ...(i)$$

After solving equation (i) we get,

$$R_{eq} = \left(\frac{1+\sqrt{5}}{2}\right)R \quad ...(ii)$$

From the given question, the circuit can be redraw as,



$$\therefore \quad R_e = R + R_{eq} \quad ...(iii)$$

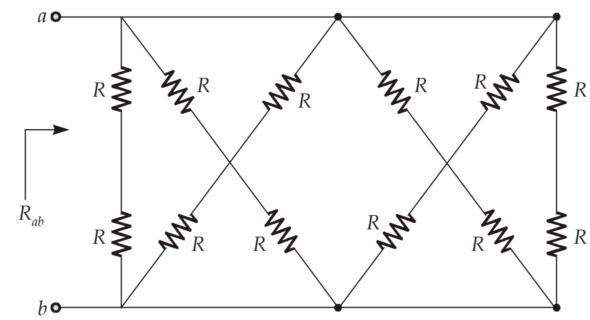
From equation (ii) and (iii) we get,

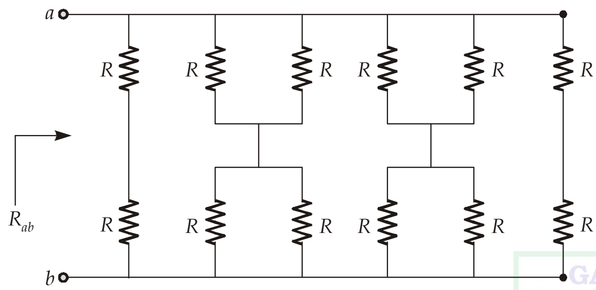
$$R_e = R+\left(\frac{1+\sqrt{5}}{2}\right)R = 2.618\,R \quad ...(iv)$$

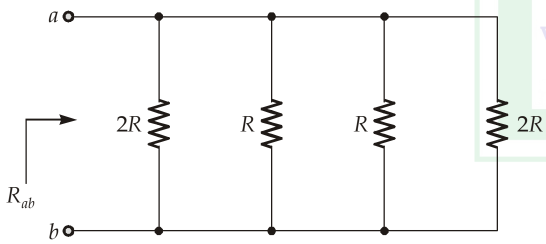
or, $$\frac{R_e}{R} = 2.618 = 2.62$$

51. Sol.

Modifying the given circuit,



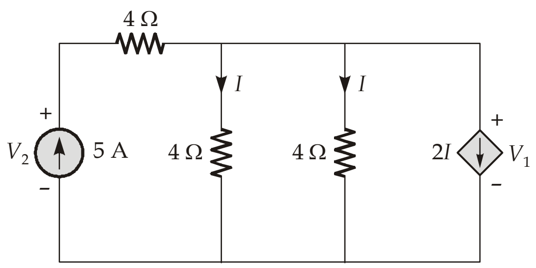




$$R_{ab} = \left(\frac{1}{2R}+\frac{1}{R}+\frac{1}{R}+\frac{1}{2R}\right)^{-1}$$

$$= \frac{R}{3} = \frac{300}{3} = 100\ \Omega$$

52. (a)



Current flowing through both the parallel 4 Ω will be I.

So, $V_2 = 4(I + I + 2I) + 4I$ (By KVL)

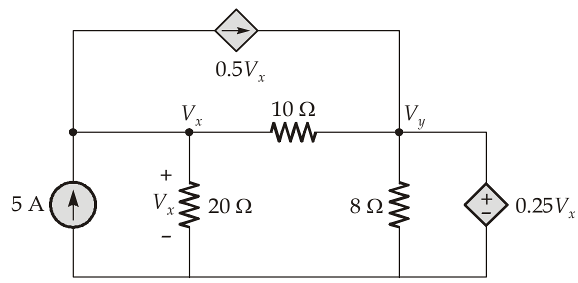
$I + I + 2I = 5$ (By KCL)

$$I = \frac{5}{4}\ \text{A}$$

$$V_2 = 4\times5+\frac{4\times5}{4} = 25\ \text{V}$$

$$V_1 = 4I = \frac{4\times5}{4} = 5\ \text{V}$$

53. Sol.



$$\frac{V_x}{20}+\frac{V_x-V_y}{10}+0.5V_x = 5\ \text{A}$$

$$V_x\left[\frac{1}{20}+\frac{1}{10}+0.5\right] = 5+\frac{V_y}{10}$$

$13V_x = 100 + 2V_y$ ...(i)

and also, $V_y = 0.25\,V_x$ ...(ii)

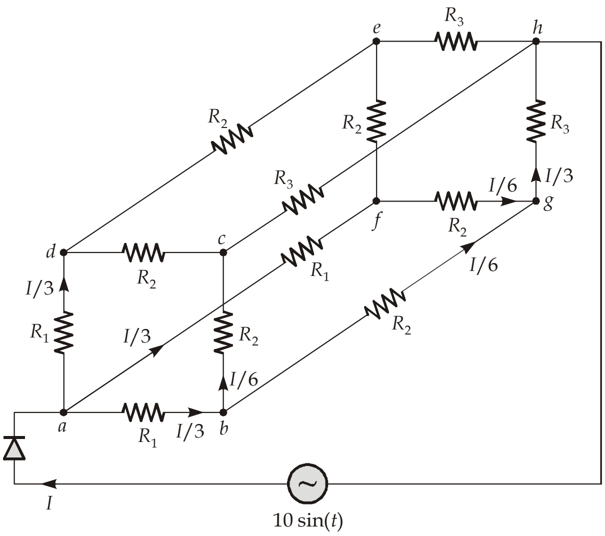
Solving equations (i) and (ii), we have

$52V_y = 100 + 2V_y$

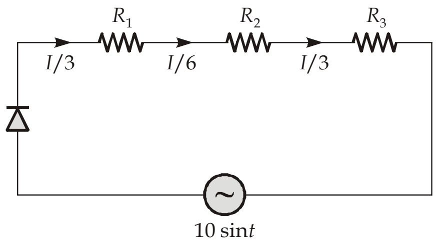
$\Rightarrow$ $50V_y = 100 \Rightarrow V_y = 2$ V

$V_x = 4V_y = 8$ V

54. Sol.



The equivalent resistance across terminal *ah* (outer loop) is,



$$V = \frac{1}{3}\times 3\text{ k}\Omega + \frac{I}{6}\times 6\text{ k}\Omega + \frac{I}{3}\times 9\text{ k}\Omega = 5I$$

or, $\frac{V}{I} = 5\text{ k}\Omega$

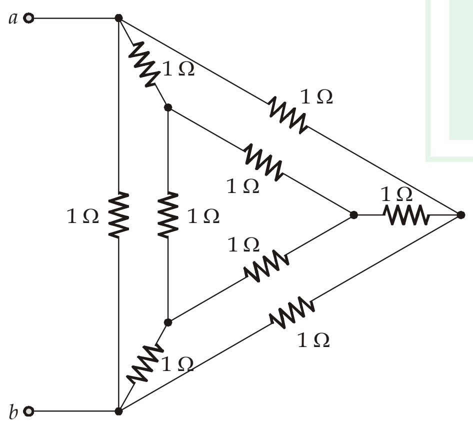
For half wave rectifier,

$$I_{\text{rms}} = \frac{I_m}{(2)} = \frac{10\sin t}{5\text{ k}\Omega} = 2\sin t\text{ mA}$$

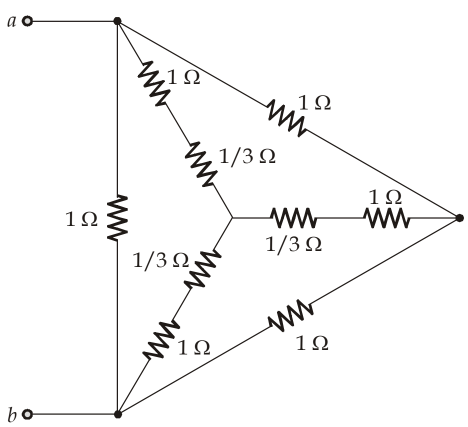
$$\therefore \quad I_{\text{rms}} = \frac{I_m}{2} = 1\text{ mA}$$

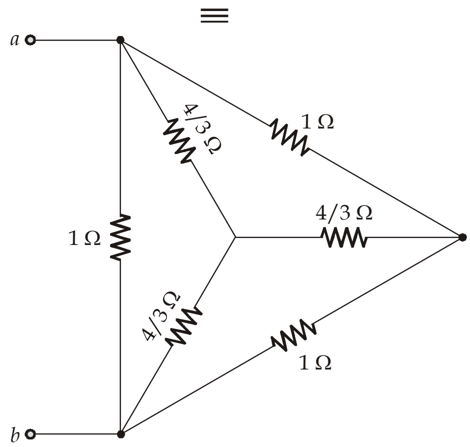
55. (d)

$R_{eq} \Rightarrow$

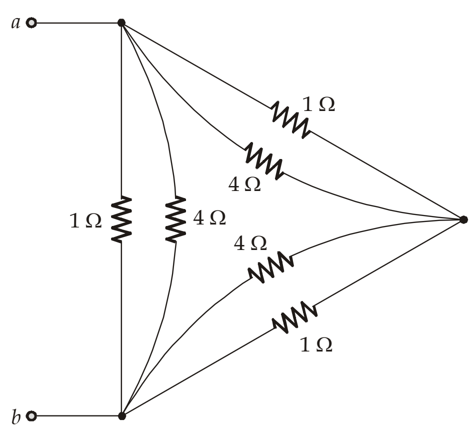


By using delta to star conversion,





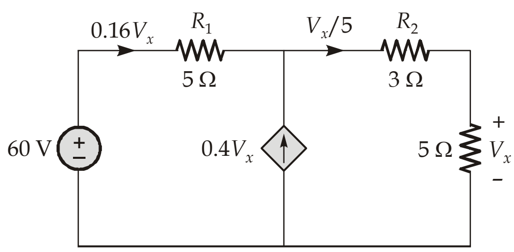
Again by star to delta conversion,



$$R_{ab} = \{(4||1)+(4||1)\}||\{(1||4)\}$$

$$= \left(\frac{4}{5}+\frac{4}{5}\right)\Big\|\frac{4}{5} = \frac{8}{15}\ \Omega$$

56. Sol.



Using KVL in the outer loop,

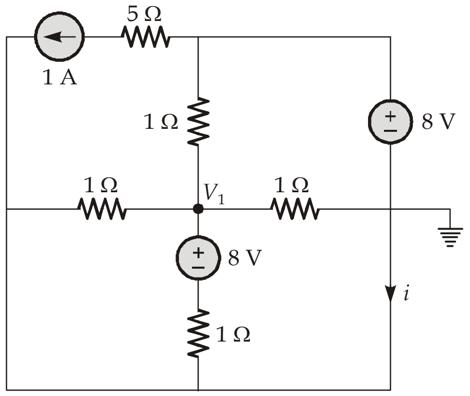
$$60 - 5(0.16V_x) - \frac{V_x}{5}\times 3 - V_x = 0$$

or, $V_x = 25\text{ V}$

$\therefore$ The current flowing through,

$$R_2 = \frac{V_x}{5} = \frac{25}{5} = 5\text{ A}$$

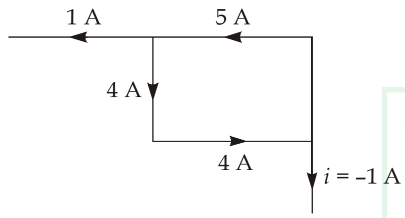
57. Sol.



Using KCL at V_1,

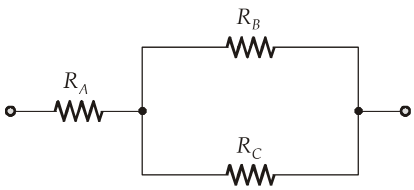
$$\frac{V_1}{1}+\frac{V_1-8}{1}+\frac{V_1-8}{1}+\frac{V_1}{1} = 0 \text{ or } V_1 = 4\text{ V}$$

Considering KVL, we get,



58. Sol.

The connection of resistors is as shown below,



Given resistor values are: 10 Ω, 5 Ω, 2 Ω

The maximum resistance possible is,

$$R_{T(\max)} = 10\,\Omega + (5\,\Omega \,||\, 2\,\Omega)$$

$$= \left(10+\frac{10}{7}\right)\Omega = \frac{80}{7}\,\Omega$$

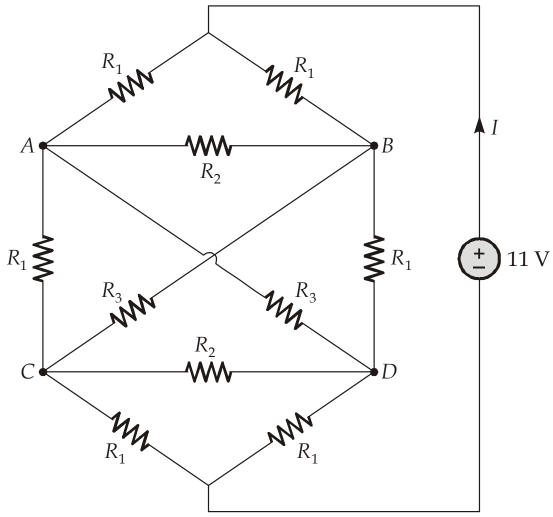
The minimum resistance possible is,

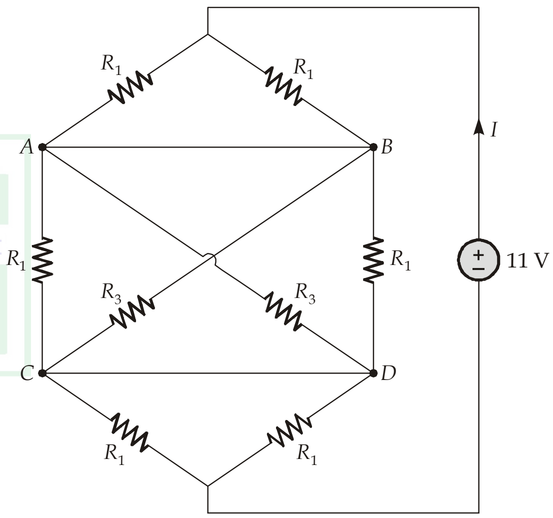
$$R_{T(\min)} = 2\,\Omega + (10\,\Omega \,||\, 5\,\Omega)$$

$$= \left(2+\frac{10}{3}\right)\Omega = \frac{16}{3}\,\Omega$$

$$\frac{R_{T(\max)}}{R_{T(\min)}} = \frac{80/7}{16/3} = \frac{15}{7} = 2.143$$

59. Sol.





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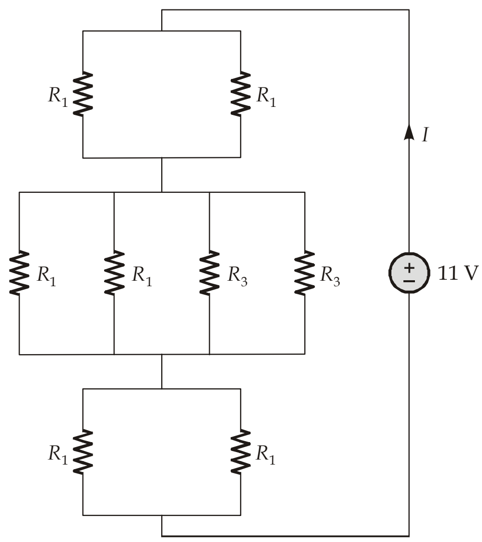


As the network is symmetric,

$$V_A = V_B \text{ and } V_C = V_D$$

So, current through R_2 resistors is zero and as $V_A = V_B$ and $V_C = V_D$, electrically the circuit can be reduced as,

Total resistance,

$$R_T = 2(R_1 || R_1) + (R_1 || R_1 || R_3 || R_3)$$

$$= R_1 + \left(\frac{R_1}{2} \middle\| \frac{R_3}{2}\right)$$

Given that,

$$R_1 = 1\,\Omega \text{ and } R_3 = 3\,\Omega$$

So, $$R_T = 1 + \left(\frac{1}{2} \middle\| \frac{3}{2}\right)\Omega = 1 + \frac{3/2}{4} = \frac{11}{8}\,\Omega$$

$$I = \frac{11\text{ V}}{R_T} = \frac{11}{(11/8)} = 8\text{ A}$$

❑❑❑❑

Answers EE Basics of Network Analysis

1. (d)	2. (c)	3. (c)	4. (b)	5. (5)	6. (31)	7. (2)	8. (c)
9. (b)	10. (d)	11. (b)	12. (d)	13. (b)	14. (b)	15. (c)	16. (c)
17. (d)	18. (c)	19. (b)	20. (a)	21. (d)	22. (c)	23. (a)	24. (a)
25. (b)	26. (a)	27. (d)	28. (a)	29. (b)	30. (b)	31. (d)	32. (b)
33. (a)	34. (c)	35. (c)	36. (b)	37. (330)	38. (2470.44°)	39. (10)	40. (3)
41. (a)	42. (0.5)	43. (0)	44. (d)	45. (2)	46. (0.5)	47. (11.42)	48. (d)
49. (3)	50. (250)	51. (a)	52. (1.4)	53. (1.732)			

Solutions EE Basics of Network Analysis

1. (d)

$$R = 1 + [(1||1+1)||(1||1+1)+1]$$
$$|| \; [(1||(1||1+1)||(1||1+1)+1]$$
$$= \frac{15}{8}\,\Omega$$

$$\Rightarrow \quad I = \frac{V}{R} = \frac{1}{15/8} = \frac{8}{15}\text{ A}$$

2. (c)

As the given bridge is balanced Wheatstone bridge, current flowing through the lamp will remain same irrespective of the state of switch. Hence intensity of lamp will remain same.

3. (c)

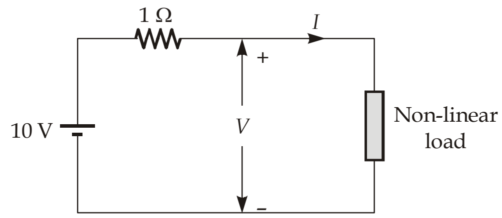
$$P_x = P_{6\text{ V}} - P_{1\,\Omega}$$
$$= 6 \times 1 - 1^2 \times 1 = 5\text{ W}$$

By putting the options, it can be concluded that for $i = 5$ A,

$$P_x = (6 \times 5) - (5^2 \times 1) = 5\text{ W}$$

Option (c) is correct.

5. Sol.



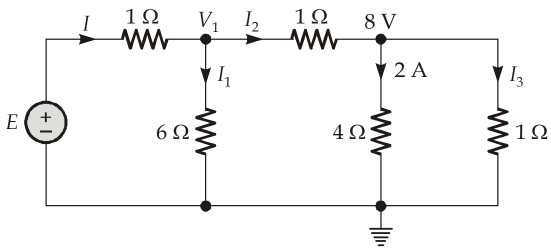
Using KVL,

$$V + I = 10 \quad \text{...(i)}$$

Given, $$7I = V^2 + 2\text{ V} \quad \text{...(ii)}$$

On solving equation (i) and equation (ii) we get, $V = 5$ V, $I = 5$ A

6. Sol.



Voltage across 4 Ω resistor = 4 × 2 = 8 V

Current through 1 Ω resistor,

$$I_3 = \frac{8}{1} = 8\text{ A}$$

$$I_2 = I_3 + 2 = 10\text{ A}$$

$$V_1 = 8 + 1 \times 10$$

$$= 18\text{ V}$$

Current through 6 Ω resistor,

$$I_1 = \frac{18}{6} = 3\text{ A}$$

Current through 1 Ω resistor,

$$I = I_1 + I_2$$

$$= 3 + 10 = 13\text{ A}$$

$$E = V_1 + I \cdot 1$$

$$= 18 + 13 \times 1 = 31\text{ V}$$

7. Sol.

For the given waveforms,

$$v(t) = 2\frac{di(t)}{dt}$$

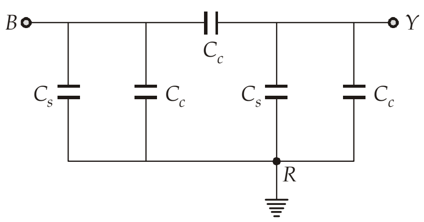
Comparing it with,

$$v(t) = L\frac{di(t)}{dt}$$

we get, $L = 2\text{ H}$

8. (c)

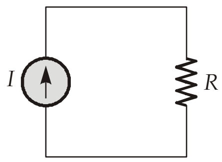
Given circuit can be written as,



$$C_{BY} = \frac{C_s + C_c}{2} + C_c + \frac{C_s + 3C_c}{2}$$

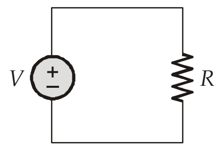
9. (b)

When resistor R is connected to a current source,



$$P = I^2R = 18\text{ W}$$

When resistor R is connected to a voltage source,



$$P = \frac{V^2}{R} = 4.5\text{ W}$$

Given, $V = I$ (in magnitude)

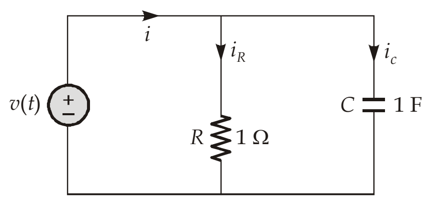
$\Rightarrow$ $I^2R = 18$ ...(i)

$$\frac{I^2}{R} = 4.5 \quad \text{...(ii)}$$

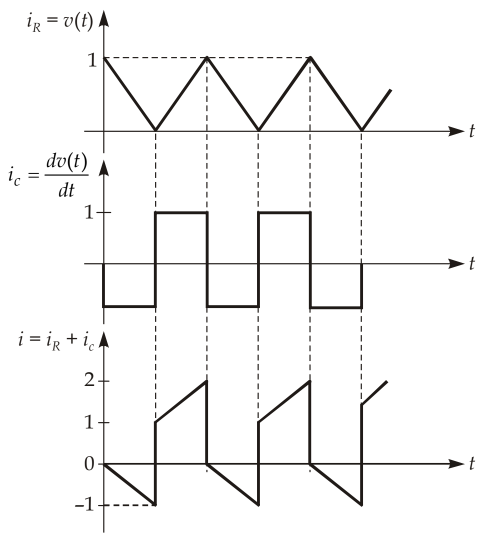
On solving these two equations, we get,

$$I = 3\text{ A};\ R = 2\,\Omega$$

10. (d)

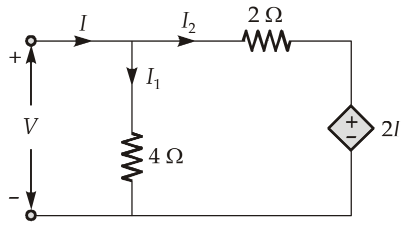


$$i = i_R + i_C$$



$$i = i_R + i_C = \frac{v(t)}{1} + 1 \cdot \frac{dv(t)}{dt}$$

11. (b)



Current through 4 Ω resistor,

$$I_1 = \frac{V}{4}$$

Current through 2 Ω resistor,

$$I_2 = \frac{V-2I}{2}$$

Total current, $I = I_1 + I_2 = \frac{V}{4} + \frac{V-2I}{2}$

$\Rightarrow$ $I = \frac{V}{4} + \frac{V}{2} - I$

$\Rightarrow$ $2I = \frac{3}{4}\text{V}$

$$\text{Load} = \frac{V}{I} = \frac{8}{3}\Omega$$

12. (d)

$\because$ $P \propto \frac{1}{R}$

Therefore resitance of 40 W bulb > resistance of 60 W bulb.

For series connection, current through both the bulbs will be seme $P = I^2R$ (for series connection).

Power consumed by 40 W bulb > power consumed by 60 W bulb.

Hence, the 40 W bulb brighter.

13. (b)

When C is open,

$$R_{AB} = R_A + R_B = 6\ \Omega$$

When B is copen,

$$R_{AC} = R_A + R_C = 9\ \Omega$$

When A is open,

$$R_{BC} = R_B + R_C = 11\ \Omega$$

On solving above equations,

$$R_A = 2\ \Omega,\ R_B = 4\ \Omega$$

and $R_C = 7\ \Omega$

14. (b)

By KCL,

$$I_P + I_Q + I_C + I_L = 0$$
$$2 + 1 + I_C + I_L = 0$$

But, $I_C = C \times \frac{dv}{dt}$

$$= 1 \times \frac{d}{dt}(4\sin 2t) = (8\cos 2t)$$

$\therefore$ $I_L = -(2 + 1 + 8\cos 2t)$

$$= -3 - 8\cos 2t$$

$\therefore$ $V_L = L\left(\frac{di}{dt}\right) = 2 \times 2 \times 8 \sin 2t$

$$= 32\sin 2t$$

Note: KCL is based on the law of conservation of charges.

15. (c)

For 0 < t < 2s current varies linearly with time and given as, $i(t) = 3t$ and for 2s < t < 4s current is constant, $i(t)$ = 6 A.

The energy absorbed by the inductor (Resistance neglected) in the first 2 sec,

$$E_L = \int_0^T Li\frac{di}{dt}dt = E_{L1} + E_{L2}$$

$$E_{L1} = \int_0^T Li\left(\frac{di}{dt}\right)dt$$

$$= \int_0^2 2 \times 3t \times 3\, dt$$

$$= 18\int_0^2 t\, dt = 8 \times \frac{t^2}{2}\Big|_0^2$$

$$= 18 \times \left[\frac{4}{2} - 0\right] = 36\ \text{J}$$

The energy absorbed by the inductor in $(2 \rightarrow 4)$ second,

$$E_{L2} = \int_2^4 Li\left(\frac{di}{dt}\right)dt$$

$$= \int_2^4 2 \cdot 6 \cdot 0\, dt = 0\ \text{J}$$

A pure inductor does not dissipate energy but only stores it. Due to resistance, some energy is dissipated in the resistor. Therefore, total energy absorbed by the inductor is the sum of energy stored in the inductor and the energy dissipated in the resistor.

The energy dissipated by the resistance in 4 sec,

$$E_R = \int_0^T i^2 R\, dt$$

$$= \int_0^T (3t)^2 \times 1\, dt + \int_2^4 6^2 \times 1\, dt$$

$$= \int_0^2 (9t^2)\, dt + 36\int_2^4 1\, dt$$

$$= 9 \times \frac{t^3}{3}\Bigg|_0^2 + 36\, t\Big|_2^4 = 9 \times \left(\frac{8}{3}\right) + 36 \times 2$$

$$= 24 + 72 = 96 \text{ J}$$

The total energy absorbed by the inductor in 4 sec,

$$= 96 \text{ J} + 36 \text{ J} = 132 \text{ J}$$

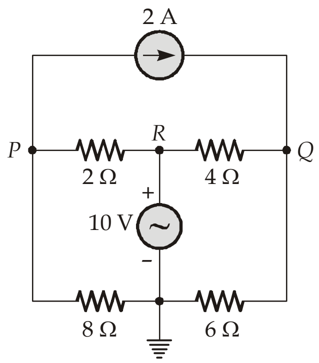
16. (c)

Given, $V_R = 10$ V

By KCL,

$$\frac{V_P - 10}{2} + 2 + \frac{V_P}{8} = 0 \quad \text{...(i)}$$

$$\frac{V_Q - 10}{4} - 2 + \frac{V_Q}{6} = 0 \quad \text{...(ii)}$$



$$4(V_P - 10) + 2 \times 8 + V_P = 0$$

$$4\,V_P - 40 + 16 + V_P = 0$$

$$5\,V_P - 24 = 0$$

$$V_P = 4.8$$

From equation (ii),

$$6(V_Q - 10) - 2 \times 4 \times 6 + 4V_Q = 0$$

$$10\,V_Q - 108 = 0$$

$$\therefore \quad V_Q = 10.8$$

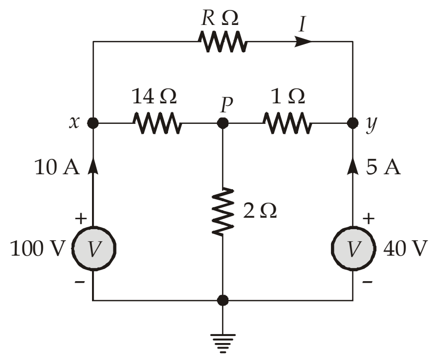
$$\therefore \quad V_P - V_Q = -6 \text{ V}$$

17. (d)

By KCL:

$$\therefore \quad \frac{V_P - 40}{1} + \frac{V_P - 100}{14} + \frac{V_P}{2} = 0$$

$$22\,V_P = 660$$



$$\therefore \quad V_P = 30 \text{ V}$$

Potential difference between node x and y = 60 V.

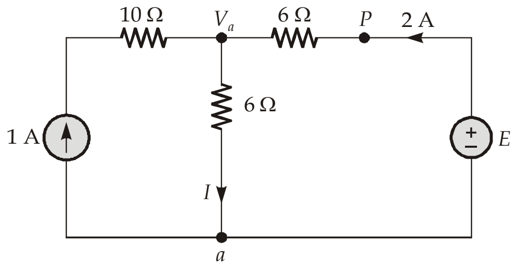
By taking KCL at node y,

$$-I - 5 + \frac{40 - 30}{1} = 0$$

$$\therefore \quad I = 5 \text{ A}$$

$$\therefore \quad I = \frac{60}{5} = 12\ \Omega$$

18. (c)



Method-1:

Using KCL,

$$\frac{V_a - E}{6} + \frac{V_a}{6} - 1 = 0$$

$$\Rightarrow \quad 2V_a - E = 6 \quad \text{...(i)}$$

where, $$\frac{E - V_a}{6} = 2$$

$$\Rightarrow \quad E - V_a = 12 \quad \text{...(ii)}$$

Solving equaton (i) and (ii), we get

$$V_a = 18 \text{ V}$$

and $$E = 30 \text{ V}$$

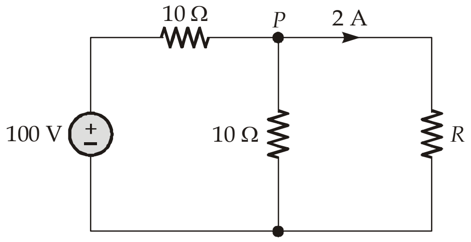
Method-2 :

$$I = 2 + 1 = 3 \text{ A}$$

Apply KVL in second loop,

$$E = 2 \times 6 + 3 \times 6 = 30 \text{ V}$$

19. (b)



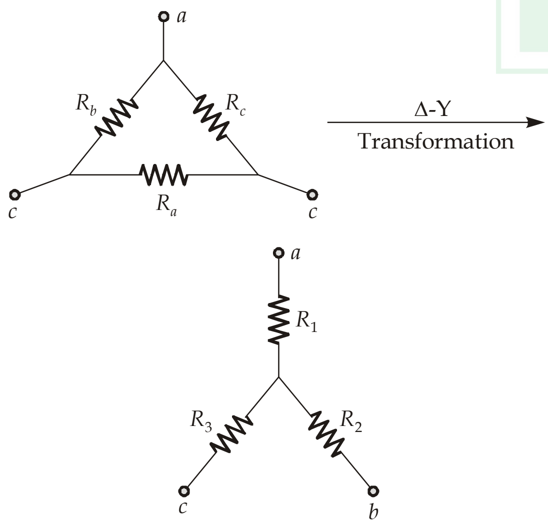
$$\frac{V_P - 100}{10} + \frac{V_P}{10} + 2 = 0$$

$$2V_P - 100 + 20 = 0$$

$$\therefore \quad V_P = \frac{80}{2} = 40 \text{ V}$$

$$\therefore \quad R = \frac{V_P}{2} = \frac{40}{2} = 20\ \Omega$$

20. (a)



Given, $R_a = 20\ \Omega$, $R_b = 10\ \Omega$

and $R_c = 10\ \Omega$

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$= \frac{10 \times 10}{20 + 10 + 10} = 2.5\ \Omega$$

$$R_2 = \frac{R_c R_a}{R_a + R_b + R_c}$$

$$= \frac{10 \times 20}{20 + 10 + 10} = 5\ \Omega$$

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$$

$$= \frac{20 \times 10}{20 + 10 + 10} = 5\ \Omega$$

Remember : If all the branches of Δ-connection has same impedance Z, then the impedance of branch of Y-connection be $Z/3$.

21. (d)

Rms value of dc current = 10 A = I_{dc}

Rms value of sinusoidal current = $\left(\frac{20}{\sqrt{2}}\right)$ A = I_{ac}

Rms value of resultant,

$$I_R = \sqrt{I_{dc}^2 + I_{ac}^2}$$

$$= \sqrt{10^2 + \left(\frac{20}{\sqrt{2}}\right)^2}$$

$$= 17.32 \text{ A}$$

22. (c)

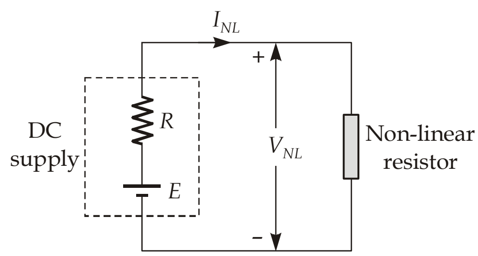
The resultant (R) when viewed from voltage source = $\frac{100}{8} = 12.5$

$$R + 10||10 = 12.5\ \Omega$$

$$\therefore \quad R = 12.5 - 10||10$$

$$= 12.5 - 5 = 7.5\ \Omega$$

23. (a)



$$V_{NL} = I_{NL}^2 \qquad \text{...(i)}$$

$$V_{NL} = E - I_{NL}R$$

where, $E = 3\text{ V}$

and $R = 2\ \Omega$

$$V_{NL} = 3 - 2I_{NL} = I_{NL}^2$$

$$I_{NL}^2 + 2I_{NL} - 3 = 0$$

$$I_{NL} = -3\text{ A or }1\text{ A}$$

–3 A is rejected, because the non-linear resistor is passive and the only active element in the circuit is 3 V dc supply. Which is supplying the power to the resistor.

So, $I_{NL} = 1\text{ A}$

Power dissipated in the non-linear resistor

$$= V_{NL}I_{NL} - I_{NL}^2 I_{NL}$$

$$= I_{NL}^3 = 1^3 = 1\text{ W}$$

24. (a)

$$i = 1\text{ A}$$

Applying KVL,

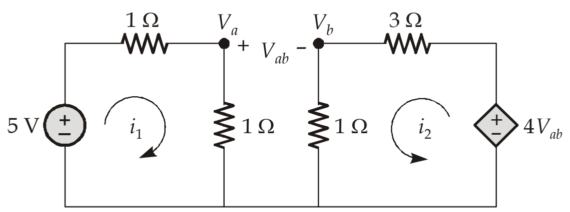
$$V_{ab} - 2i + 5 = 0$$

$$V_{ab} = -5 + 2i$$

$$= -5 + 2 \times 1 = -3\text{ V}$$

Note: KVL is based on the conservation of energy.

25. (b)



By KVL in Loop-1,

$$5 - i_1 - i_1 = 0$$

$$i_1 = \frac{5}{2} = 2.5\text{ A}$$

$\therefore$ $V_a = 2.5\text{ V}$

By KVL in Loop-2,

$$4V_{ab} = 3i_2 + i_2$$

$$i_2 = \frac{4V_{ab}}{4} = V_{ab}$$

$\therefore$ $V_b = 1 \times i_2 = V_{ab}$

$$V_b = V_a - V_b$$

$$V_b = \frac{V_a}{2} = \frac{2.5}{2} = 1.25\text{ V}$$

$$i_2 = V_{ab} = V_b$$

$$i_2 = 1.25\text{ A}$$

26. (a)

Bridge is balanced i.e. node *C* and node *D* are at same parallel. Therefore, no current flows through 2 kΩ resistor.

27. (d)

Let resistance of single incandescent lamp = *R*.

Power consumed by a single lamp,

$$P = 200\text{ W}$$

When connected across voltage,

$$V = 220\text{ V}$$

So, $$P = \frac{V^2}{R} \Rightarrow 200 = \frac{220^2}{R}$$

$\Rightarrow$ $R = 242\ \Omega$

Let, '*n*' number of lamps are connected is series across voltage,

$$V = 200\text{ V}$$

So total resistance of lamps,

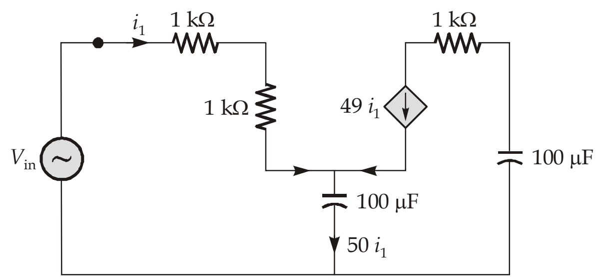
$$R_{eq.} = nR = 242\,n$$

Total power consumed,

$$P = \frac{V^2}{R_{eq.}}$$

$\Rightarrow$ $$100 = \frac{220^2}{242\,n} \Rightarrow n = 2$$

28. (a)



Applying KVL,

$$V_{in} - i_1(1 + 1) - 50\,i_1(-jX_C) = 0$$

$\Rightarrow$ $V_{in} = i_1[2 - j50X_C]$

Input impedance $= \dfrac{V_{in}}{i_1} = 2 - j\,50X_C$

As imaginary part is negative, input impedance has equivalent capacitive reactance $X_{Ceq.}$

$$X_{Ceq.} = 50\,X_C$$

$$\frac{1}{\omega C_{eq.}} = \frac{50}{\omega C} = \frac{50}{\omega \times 100} = \frac{1}{2\omega}$$

$$C_{eq.} = 2\ \mu F$$

29. (b)

Voltage across 2 Ω resistance

$$= V_s = 4\ V$$

Current through 2 Ω resistance

$$= \frac{V_s}{R} = \frac{4}{2} = 2\ A$$

Current source has no effect, when connected across voltage source.

So, to double current though 2 Ω resistance, voltage source is doubled i.e.,

$$V_s = 8\ V$$

30. (b)

A resistor has linear characteristics.

i.e., $V = Ri$

$\Rightarrow$ $V = i$

Load line, $V + i = 100$

$i + i = 100$

Current through resistance,

$$i = \frac{100}{2} = 50\ A$$

31. (d)

In such system, volumetric flow rate C is analogous to current and pressure is analogous to voltage. The hydraulic capacitance due to storage in gravity field is defined as,

$$C = \frac{A}{\rho g}$$

where, A = Area of the tank

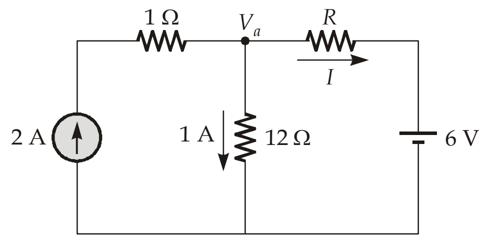
r = Density of the fluid

g = Acceleration due to gravity

The hydraulic capacitance is represented by A and C. Liquid trying to flow out of a container, can meet with resistance in several ways. If the outlet is a pipe, the friction between the liquid and the pipe walls produces resistance to flow. Such resistance is represented by B and D.

32. (b)

Assuming voltage of the node V_a,



$$V_a = 1 \times 12 = 12\ V$$

Applying KCL,

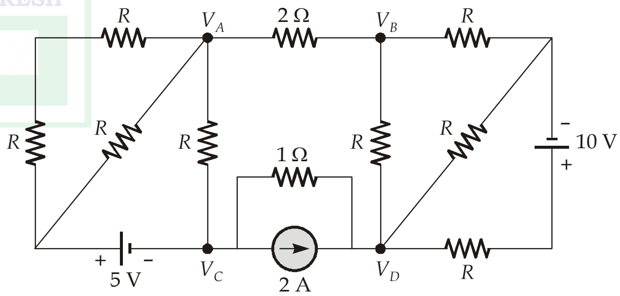
$$-2 + 1 + I = 0$$

$$I = 1\ A$$

$$I = \frac{V_a - 6}{R} = \frac{12-6}{R} = \frac{6}{R}$$

$$\Rightarrow \quad I = \frac{6}{R} \Rightarrow R = 6\ \Omega$$

33. (a)



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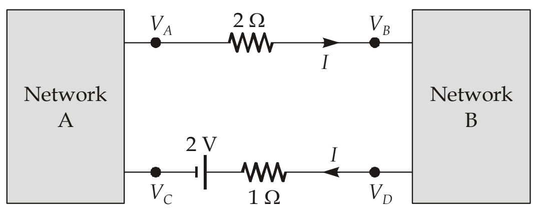


$$V_A - V_B = 2I$$

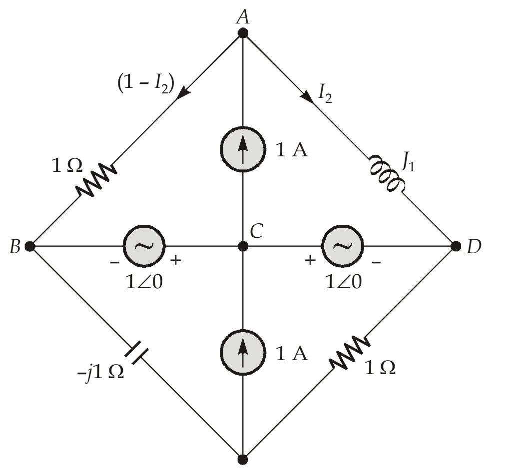
$$\Rightarrow \quad 2I = 6$$

$$\Rightarrow \quad I = 3\ A$$

$$V_C + 2 + 1 \times 1 = V_D$$

$$V_C - V_D = -2 - 3 = -5\ V$$

34. (c)



Apply KCL node at 'A':

So, current flowing through 1 Ω is $(1 - I_2)$

Applying KVL in $ABCD$ loop,

$$1\angle 0 - 1\angle 0 + 1(1 - I_2) - jI_2 = 0$$

$$I_2 = \frac{1}{1+j}$$

35. (c)

$$Q = CV$$

$$Q_1 = C_1V_1$$
$$= 10 \times 10^{-6} \times 10$$
$$= 10\ \mu C$$

$$Q_2 = C_2V_2$$
$$= 5 \times 10^{-6} \times 5$$
$$= 25\ \mu C$$

$$Q_3 = C_3V_3$$
$$= 2 \times 10^{-6} \times 2 = 4\ \mu C$$

Capacitors C_2 and C_3 are in series.

In series charge is same.

So, the maximum charge on C_2 and C_3 will be minimum of (Q_2, Q_3) = min(25 μC, 4 μC) = 4 μC = Q_{23}.

In series the equivalent capacitance of C_2 and C_3 is,

$$C_{23} = \frac{C_2C_3}{C_2+C_3} = \frac{5\times 2}{5+2} = \frac{10}{7}\ \mu F$$

So, the equivalent voltage,

$$V_{23} = \frac{Q_{23}}{C_{23}} = \frac{4\times 10^{-6}}{\frac{10}{7}\times 10^{-6}} = \frac{28}{10} = 2.8\ V$$

In parallel, the voltage is same,

$$V_1 = V_{23} = 2.8\ V$$

Change in capacitor C_1,

$$Q_1 = C_1V_1$$
$$= 10 \times 10^{-6} \times 2.8$$
$$= 28\ \mu C$$

In parallel, the total charge,

$$Q = Q_1 + Q_{23}$$
$$Q = 4 + 28 = 32\ \mu C$$

36. (b)

$$R_A = \frac{R_bR_c}{R_a + R_b + R_c}$$

$$R'_a = kR_a$$

$$R'_b = kR_b$$

$$R'_c = kR_c$$

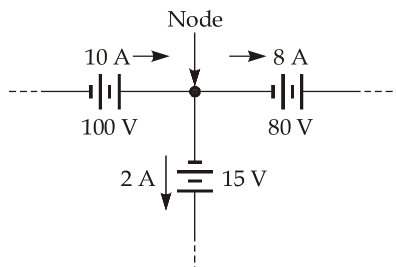
$$R'_A = \frac{kR_b \cdot kR_c}{kR_a + kR_b + kR_c}$$

$$= \frac{k^2R_bR_c}{k(R_a + R_b + R_c)}$$

$$= k \times \frac{R_b\,R_c}{R_a + R_b + R_c} = kR_A$$

37. Sol.

Given, electrical circuit is shown below:



Applying KCL at node, current through 15 V voltage source = 2 A.

∴ Power absorbed by 100 V voltage source

= 10 × 100 = 1000 Watt

Power absorbed by 80 V voltage source

= –(80 × 8) = –640 Watts

and power absorbed by 15 V voltage source

= –(15 × 2) = –30 Watt

∴ Total power absorbed by the three circuit elements = (100 – 640 – 30) Watts = 33 Watts

38. Sol.

Let the resistance of incandescent lamp

$$= R_T = \frac{V^2}{P} = \frac{(240)^2}{40}$$

$$= 1440\ \Omega$$

Given, $R_0 = 120\ \Omega,\ \alpha = 4.5 \times 10^{-3}/°C$

Let, R_T be the resistance of the filament in ON state at temperature T.

Then, $R_T = R_0[1 + \alpha\Delta T]$

or, $[1 + \alpha\Delta T] = \frac{R_T}{R_0} = \frac{1440}{20} = 12$

or, $\alpha\,\Delta\,T = 11$

or, $\Delta T = 2444.44°C$

or, $T = 2444.44° + 26°$

$= 2470.44°C$

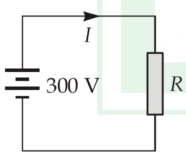
Therefore, ON state temperature of filament

$= 2470.44°C$

39. Sol.

Given, $R = \left(25 + \frac{I}{2}\right)\Omega$

or, $I = (2R - 50)$



Applying KVL in given loop, we have,

$300 = IR$

or $300 = (2R - 50) \times R$

we get, $R = 30\ \Omega$ or $-5\ \Omega$

Since resistance can't be negative. Therefore,

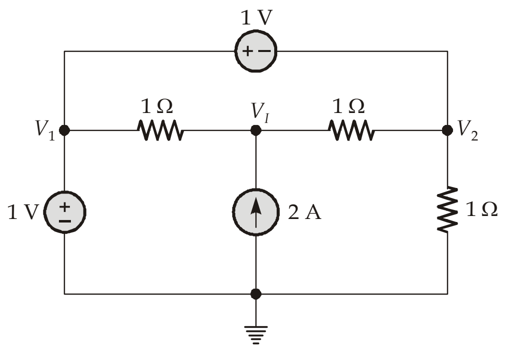
$R = 30\ \Omega$

Hence, $I = (2R - 50)$

$= (2 \times 30 - 50)\ A = 10\ A$

$\therefore$ current, $I = 10\ A$

40. Sol.



Applying nodal analysis at node P, we have,

$$\frac{V_I - V_1}{1} + \frac{V_I - V_2}{1} - 2 = 0$$

or, $2V_I - (V_1 + V_2) = 2$

or, $V_I = \left[\frac{2 + (V_1 + V_2)}{2}\right]$ ...(i)

Also, $V_1 - V_2 = 1$ Volt

and $V_1 = 1$ Volt

$\therefore$ $V_2 = V_1 - 1$

$= 1 - 1 = 0$ Volt

Putting values of V_1 and V_2 in equation (i), we get,

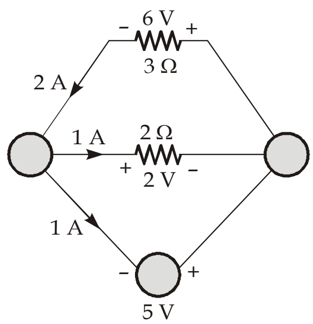
$$V_I = \left[\frac{2 + (1 + 0)}{2}\right] = \frac{3}{2}\text{ Volt}$$

$\therefore$ Power delivered by the current source

$= V_I \cdot I = \frac{3}{2} \times 2$ $[\because I = 2\text{ A(given)}]$

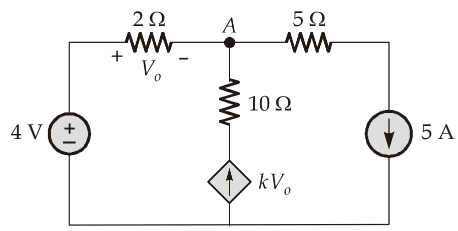
$= 3$ Watts

41. (a)



Power $= 5 \times 1 = 5$ Watt

42. Sol.



$\Rightarrow$ $\frac{V_0^2}{2} = 12.5$

$\Rightarrow$ $V_0^2 = 12.5 \times 2$

$\Rightarrow$ $V_0 = 5$

$I_0 = \frac{5}{2} = 2.5\ A$

KCL at A :

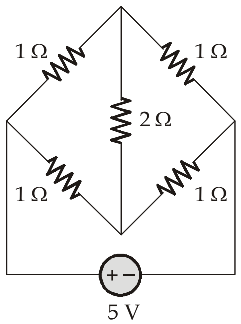
$\Rightarrow \quad -2.5 - k(5) + 5 = 0$

$\Rightarrow \quad k(5) = 2.5$

$\Rightarrow \quad k = \frac{2.5}{5} = \frac{1}{2}$

43. Sol.

Redrawing the circuit,



Bridge is balance, so current flowing through 2 Ω resistor is 0 A.

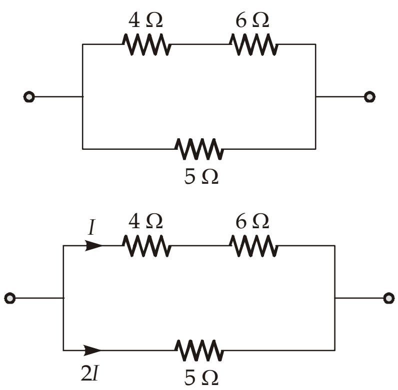
44. (d)

If the equivalent resistance of first figure is R_A then from the second figure, we can see that

$R_B = R_A || 1\,\Omega$.

$$R_B = \frac{R_A}{R_A + 1}$$

45. Sol.

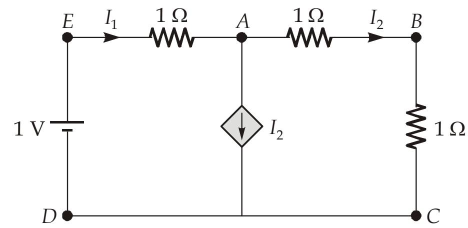


and $\quad (2I)^2 \times 5 = 10$

$\Rightarrow \quad I^2 = \frac{10}{5\times 4} = \frac{2.5}{5} = 0.5$

So, $\quad I^2 \times 4 = 0.5 \times 4 = 2$ cal/sec.

46. Sol.



Applying KCL at node A,

$$-I_1 + I_2 + I_2 = 0$$

$$2I_2 = I_1 \qquad \text{...(i)}$$

and applying KVL in loop *ABCD*,

$$1 - I_1 - I_2 - I_2 = 0$$

$$I_1 + 2I_2 = 1 \qquad \text{...(ii)}$$

From equation (i) and (ii):

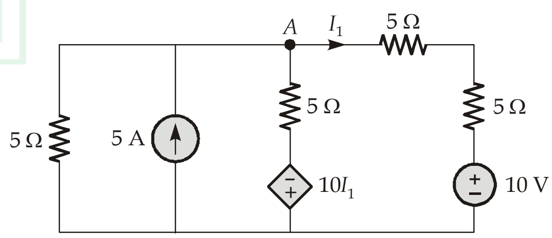
$\Rightarrow \quad 2I_2 + 2I_2 = 1$

$\Rightarrow \quad 4I_2 = 1$

$\Rightarrow \quad I_2 = \frac{1}{4}$ A

and $\quad I_1 = 2\times\frac{1}{4} = \frac{1}{2}$ A

47. Sol.



Applying KCL at node A, we get,

$$\frac{V_A}{5} + \frac{V_A - 10}{10} + \frac{V_A + 10I_1}{5} = 5$$

So, $\quad 2V_A + V_A - 10 + 2V_A + 20I_1 = 5$

$$5V_A + 20I_1 = 60$$

Since, $\quad I_1 = \frac{V_A - 10}{10}$

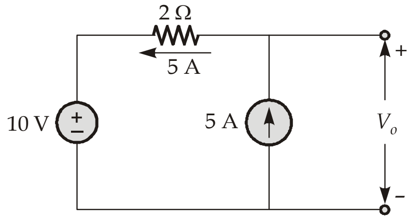
So, $\quad 5V_A + 2V_A - 20 = 60$

$$7V_A = 80$$

$$V_A = \frac{80}{7}$$

$$= 11.42 \text{ Volt}$$

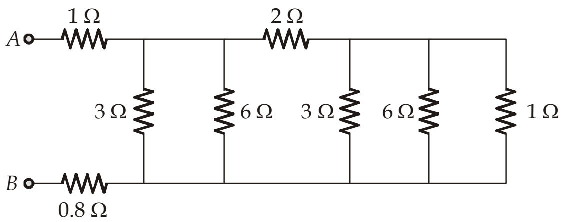
48. (d)



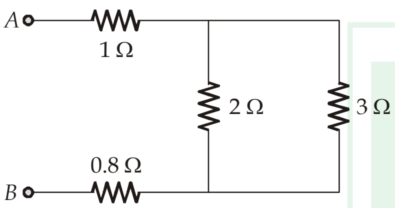
So, $V_{out} = (5 \times 2) + 10 = 20$ V

49. Sol.

Consider the following circuit diagram,



After rearrangement we get,



Now, $R_{AB} = 1 + \frac{6}{5} + 0.8 = 3\,\Omega$

50. Sol.

Using KCL at node, we get,

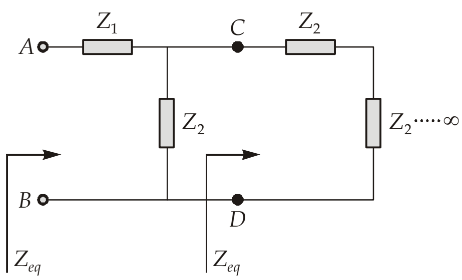
$$I + 0.4I = 14$$

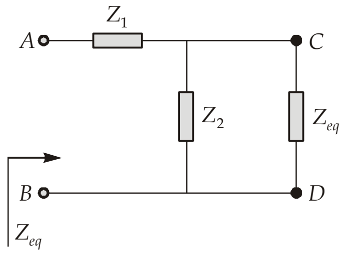
or, $I = 10$ A

Now, power supplied,

$$P = 25 \times 10$$
$$= 250 \text{ W}$$

51. (a)



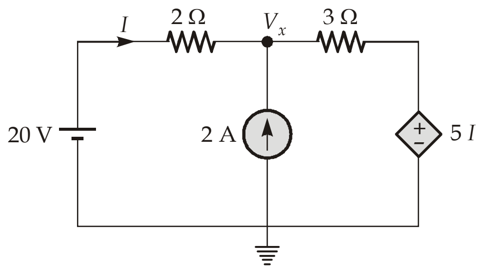


$$Z_1 = j9$$
$$Z_2 = j5 - j1 = j4$$
$$Z_{eq} = Z_1 + \frac{Z_2 Z_{eq}}{Z_2 + Z_{eq}}$$

By solving above equation,

$$Z_{eq} = j12$$

52. Sol.



Applying nodal at node x,

$$-I - 2 + \frac{V_x - 5I}{3} = 0$$
$$-3I - 6 + V_x - 5I = 0$$
$$\Rightarrow \quad 8I = V_x - 6 \quad \text{...(i)}$$

As, $I = \frac{20 - V_x}{2}$

$$\Rightarrow \quad V_x = 20 - 2I \quad \text{...(ii)}$$

Substituting (ii) in (i),

$$8I = 20 - 2I - 6$$
$$\Rightarrow \quad 10I = 14$$
$$I = 1.4 \text{ A}$$

53. Sol.

$$I = 1\angle 10° + 1\angle 70°$$
$$I = 1.732\angle 40°$$

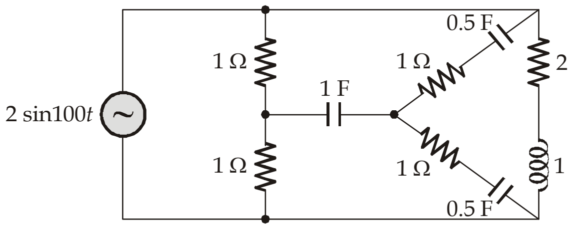
The ready of ammeter is 1.732 A.

❑❑❑❑

2 Sinusoidal Steady State

ELECTRONICS ENGINEERING
(GATE Previous Years Solved Papers)

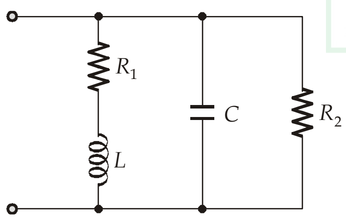
Q.1 The value of current through the 1 Farad capacitor of figure is



(a) zero (b) once
(c) two (d) three

[EC-1987 : 2 Marks]

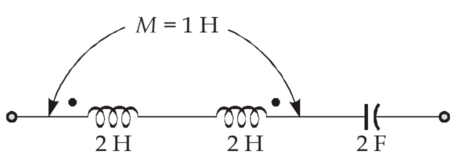
Q.2 The half power bandwidth of the resonant circuit of figure can be increased by



(a) increasing R_1 (b) decreasing R_1
(c) increasing R_2 (b) decreasing R_2

[EC-1989 : 2 Marks]

Q.3 The resonant frequency of the series circuit shown in figure is



(a) $\frac{1}{4\pi\sqrt{3}}$ Hz (b) $\frac{1}{4\pi}$ Hz
(c) $\frac{1}{2\pi\sqrt{10}}$ Hz (d) $\frac{1}{4\pi\sqrt{2}}$ Hz

[EC-1990 : 2 Marks]

Q.4 In a series RLC high Q circuit, the current peaks at a frequency

(a) equal to the resonant frequency.
(b) greater than the resonant frequency.
(c) less than the resonant frequency.
(d) none of the above is true.

[EC-1991 : 2 Marks]

Q.5 For the series RLC circuit of Fig. (1), the partial phasor diagram at a certain frequency is a shown in Fig. (2). The operating frequency of the circuit is

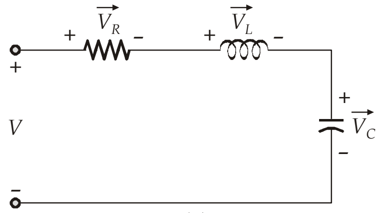


Fig. (1)

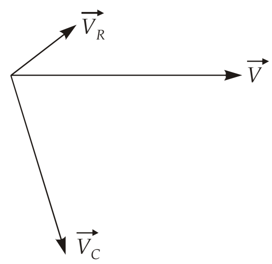
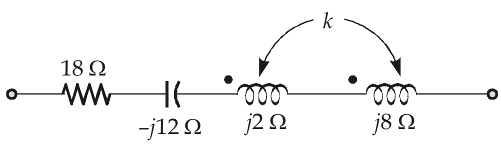


Fig. (2)

(a) equal to the resonance frequency
(b) less than the resonance frequency
(c) greater than the resonance frequency
(d) not zero

[EC-1992 : 2 Marks]

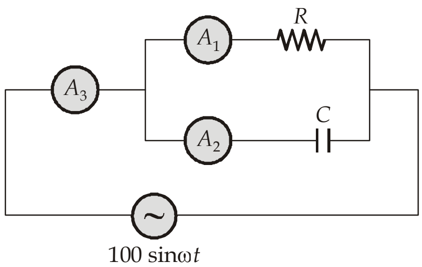
Q.6 In the series circuit shown in figure, for series resonance, the value of the coupling coefficient 'k' will be



(a) 0.25 (b) 0.5
(c) 0.999 (d) 1.0

[EC-1993 : 2 Mark]

Q.7 In figure, A_1, A_2 and A_3 are ideal ammeters. If A_1 reads 5 A, A_2 reads 12 A, then A_3 should read



(a) 7 A (b) 12 A
(c) 13 A (d) 17 A

[EC-1993 : 2 Marks]

Q.8 A series LCR circuit consisting of $R = 10\ \Omega$, $|X_L| = 20\ \Omega$ and $|X_C| = 20\ \Omega$ is connected across an a.c. supply of 200 V rms. The rms voltage across the capacitor is

(a) $200\angle-90°$ V (b) $200\angle+90°$ V
(c) $400\angle+90°$ V (d) $400\angle-90°$ V

[EC-1994 : 1 Mark]

Q.9 A DC voltage source is connected across a series RLC circuit. Under steady-state conditions, the applied DC voltage drops entirely across the

(a) R only
(b) L only
(c) C only
(d) R and L combination

[EC-1995 : 1 Mark]

Q.10 Consider a DC voltage source connected to a series R-C circuit. When the steady-state reaches, the ratio of the energy stored in the capacitor to the total energy supplied by the voltage source, is equal to

(a) 0.362 (b) 0.500
(c) 0.632 (d) 1.000

[EC-1995 : 1 Mark]

Q.11 The current $i(t)$, through a 10 Ω resistor in series with an inductance, is given by

$$i(t) = 3 + 4\sin(100t + 45° + 4\sin(300t + 60°) \text{ Amperes}$$

The rms value of the current and the power dissipated in the circuit are:

(a) $\sqrt{41}$ A, 410 W respectively
(b) $\sqrt{35}$ A, 350 W respectively
(c) 5 A, 250 W respectively
(d) 11 A, 1210 W respectively

[EC-1995 : 1 Mark]

Q.12 A series RLC circuit has a Q of 100 and an impedance of $(100 + j0)\ \Omega$ at its resonant angular frequency of 10^7 radians/sec. The values of R and L are:

R = _______ Ω, L = ________ Henries.

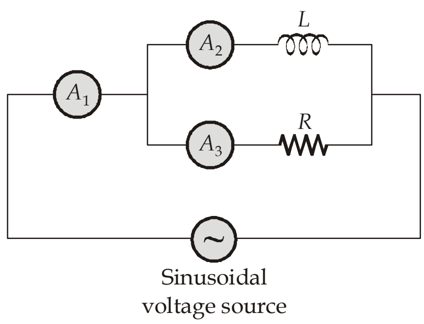
[EC-1995 : 1 Mark]

Q.13 The rms value of a rectangular wave of period T, having a value of $+V$ for a duration, T_1 $(<T)$ and $-V$ for the duration, $T - T_1 = T_2$, equals

(a) V (b) $\frac{T_1 - T_2}{T} V$
(c) $\frac{V}{\sqrt{2}}$ (d) $\frac{T_1}{T_2} V$

[EC-1995 : 1 Mark]

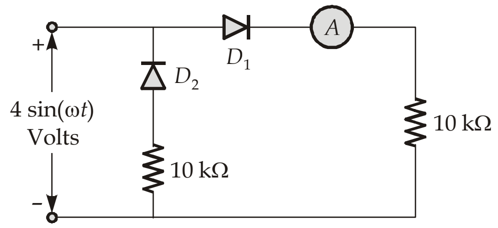
Q.14 In figure A_1, A_2 and A_3 are ideal ammeters. If A_2 and A_3 read 3 A and 4 A respectively, the A_1 should read



(a) 1 A (b) 5 A
(c) 7 A (d) None of the above

[EC-1996 : 1 Mark]

Q.15 In the circuit of figure, assume that the diodes are ideal and the meter is an average indicating ammeter. The ammeter will read

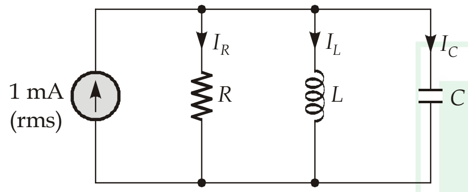


(a) $0.4\sqrt{2}$ mA (b) 0.4 mA

(c) $\frac{0.8}{\pi}$ mA (d) $\frac{0.4}{\pi}$ mA

[EC-1996 : 1 Mark]

Q.16 The parallel RLC circuit shown in figure is in resonance. In this circuit,

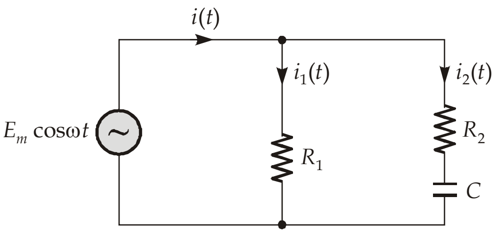


(a) $|I_R| < 1$ mA (b) $|I_R + I_L| > 1$ mA

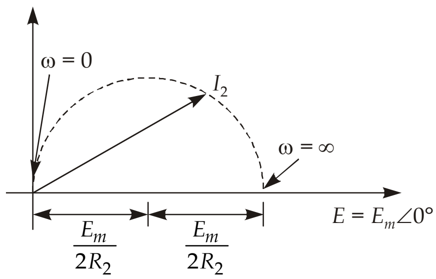
(c) $|I_R + I_C| < 1$ mA (d) $|I_L + I_C| > 1$ mA

[EC-1998 : 1 Mark]

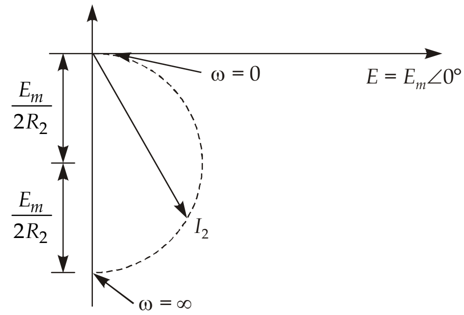
Q.17 When the angular frequency ω in the figure is varied from 0 to ∞, the locus of the current phasor I_2 is given by



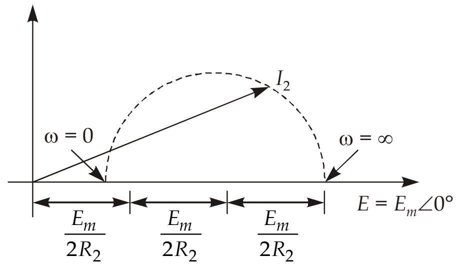
(a)



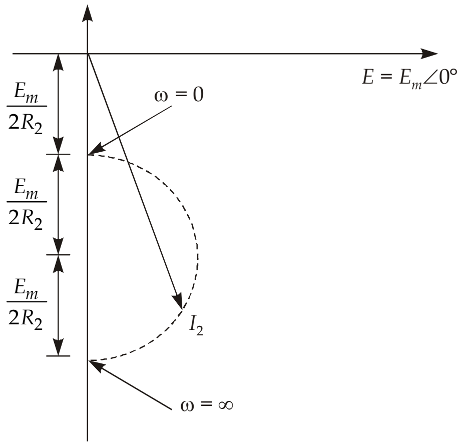
(b)



(c)



(d)



[EC-2001 : 2 Marks]

Q.18 A series RLC circuit has a resonance frequency of 1 kHz and a quality factor $Q = 100$. If each of R, L and C is doubled from its original value, the new Q of the circuit is

(a) 25 (b) 50

(c) 100 (d) 200

[EC-2003 : 1 Mark]

Q.19 An input voltage $v(t) = 10\sqrt{5}\cos(t + 10°) + 10\sqrt{5}\cos(2t + 10°)$ V is applied to a series combination of resistance R = 1 Ω and an inductance L = 1 H. The resulting steady-state current $i(t)$ in ampere is

(a) $10\cos(t + 55°) + 10\cos(2t + 10° + \tan^{-1} 2)$

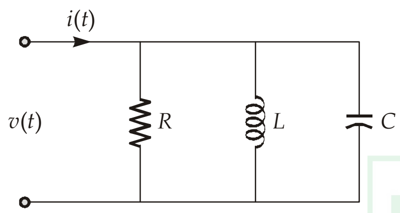
(b) $10\cos(t+55°)+10\sqrt{\frac{3}{2}}\cos(2t+55)$

(c) $10\cos(t - 35°) + 10\cos(2t + 10° - \tan^{-1} 2)$

(d) $10\cos(t-35°)+10\sqrt{\frac{3}{2}}\cos(2t-35°)$

[EC-2003 : 2 Marks]

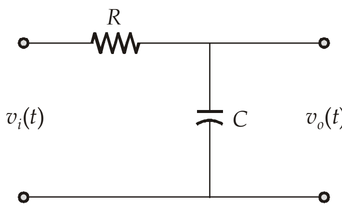
Q.20 The circuit shown in the figure, with $R = \frac{1}{3}\,\Omega$, $L = \frac{1}{4}\,\text{H}, C = 3\,\text{F}$ has input voltage $V(t) = \sin 2t$. The resulting current $i(t)$ is



(a) $5\sin(2t + 53.1°)$ (b) $5\sin(2t - 53.1°)$
(c) $25\sin(2t + 53.1°)$ (d) $25\sin(2t - 53.1°)$

[EC-2004 : 1 Mark]

Q.21 For the circuit shown in the figure, the time constant RC = 1 ms. The input voltage is $v_i(t) = \sqrt{2}\sin 10^3 t$. The output voltage $v_o(t)$ is euqal to



(a) $\sin(10^3t - 45°)$ (b) $\sin(10^3t + 45°)$
(c) $\sin(10^3t - 53°)$ (d) $\sin(10^3t + 53°)$

[EC-2004 : 1 Mark]

Q.22 The transfer function $H(s) = \frac{V_o(s)}{V_i(s)}$ of an RLC circuit is given by

$$H(s) = \frac{10^6}{s^2 + 20s + 10^6}$$

The quality factor (Q-factor) of this circuit is

(a) 25 (b) 50
(c) 10 (d) 5000

[EC-2004 : 2 Marks]

Q.23 Consider the following statements S_1 and S_2:

S_1 : At the resonant frequency the impedance of a series R-L-C circuit is zero.

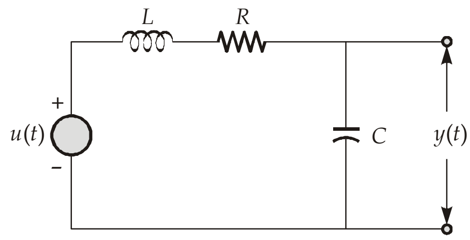
S_2 : In a parallel G-L-C circuit, increasing the conductance G results in increase in its Q-factor.

Which one of the following is correct?

(a) S_1 is false and S_2 is true.
(b) Both S_1 and S_2 are true.
(c) S_1 is true and S_2 is false.
(d) Both S_1 and S_2 are false.

[EC-2004 : 2 Marks]

Q.24 The condition on R, L and C such that the step response $y(t)$ in the figure has no oscillations, is



(a) $R \geq \frac{1}{2}\sqrt{\frac{L}{C}}$ (b) $R \geq \sqrt{\frac{L}{C}}$

(c) $R \geq 2\sqrt{\frac{L}{C}}$ (d) $R = \sqrt{\frac{1}{LC}}$

[EC-2005 : 1 Mark]

Q.25 In a series RLC circuit, $R = 2\,\text{k}\Omega$, $L = 1$ H and $C = \frac{1}{400}\,\mu\text{F}$.

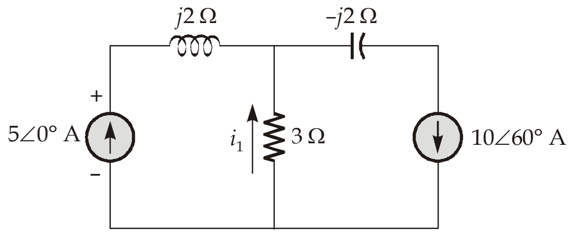
The resonant frequency is

(a) 2×10^4 Hz (b) $\frac{1}{\pi} \times 10^4$ Hz

(c) 10^4 Hz (d) $2\pi \times 10^4$ Hz

[EC-2005 : 1 Mark]

Q.26 For the circuit shown in the figure, the instantaneous current $i_1(t)$ is,

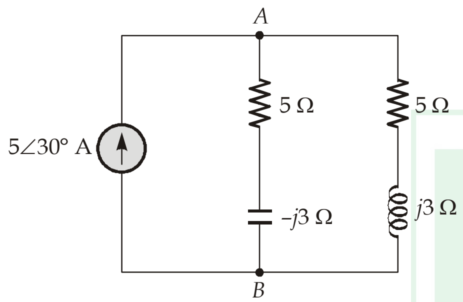


(a) $\frac{10\sqrt{3}}{2}\angle 90°$ A (b) $\frac{10\sqrt{3}}{2}\angle -90°$ A

(c) $5\angle 60°$ A (d) $5\angle -60°$ A

[EC-2005 : 2 Marks]

Q.27 In the AC network shown in the figure, the phasor voltage V_{AB} (in Volts) is

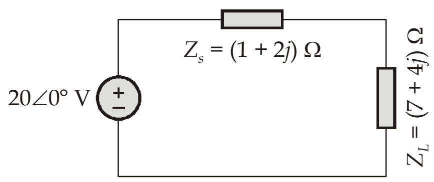


(a) 0 (b) $5\angle 30°$

(c) $12.5\angle 30°$ (d) $17\angle 30°$

[EC-2007 : 2 Marks]

Q.28 An AC source of rms voltage 20 V with internal impedance $Z_s = (1 + 2j)\ \Omega$ feeds a load of impedance $Z_L = (7 + 4j)\ \Omega$ in the figure below. The reactive power consumed by the load is



(a) 8 VAR (b) 16 VAR

(c) 28 VAR (d) 32 VAR

[EC-2009 : 2 Marks]

Q.29 For a parallel RLC circuit, which one of the following statements is not correct?

(a) The bandwidth of the circuit decreases if R is increased.

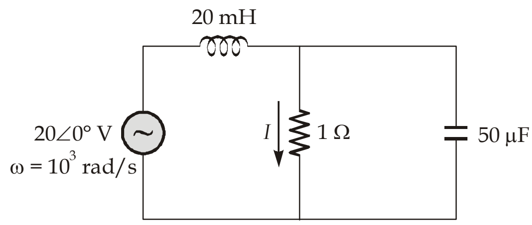
(b) The bandwidth of the circuit remains same if L is increased.

(c) At resonance, input impedance is a real quantity.

(d) At resonance, the magnitude of input impedance attains its minimum value.

[EC-2010 : 1 Mark]

Q.30 The current 'I' in the circuit shown is

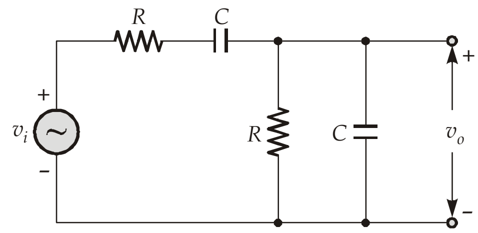


(a) $-j1$ A (b) $j1$ A

(c) 0 A (d) 20 A

[EC-2010 : 2 Marks]

Q.31 The circuit shown below is driven by a sinusoidal input $v_i = V_p \cos(t/RC)$. The steady output v_o is,



(a) $\left(\frac{V_p}{3}\right)\cos\left(\frac{t}{RC}\right)$

(b) $\left(\frac{V_p}{3}\right)\sin\left(\frac{t}{RC}\right)$

(c) $\left(\frac{V_p}{2}\right)\cos\left(\frac{t}{RC}\right)$

(d) $\left(\frac{V_p}{2}\right)\sin\left(\frac{t}{RC}\right)$

[EC-2011 : 1 Mark]

Q.32 Two magnetically uncoupled inductive coils have Q factors q_1 and q_2 at the chosen operating frequency. Their respective resistance are R_1 and R_2. When connected in series, their effective Q factor at the same operating frequency is

(a) $q_1 + q_2$ (b) $\left(\frac{1}{q_1}\right)+\left(\frac{1}{q_2}\right)$

(c) $\frac{(q_1R_1+q_2R_2)}{(R_1+R_2)}$ (d) $\frac{(q_1R_2+q_2R_1)}{(R_1+R_2)}$

[EC-2013 : 2 Marks]

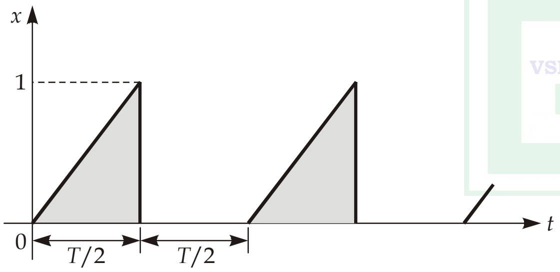
Q.33 A 230 V rms source supplies power to two loads connected in parallel. The first load draws 10 kW at 0.8 leading power factor and the second one draws 10 kVA at 0.8 lagging power factor. The complex power delivered by the source is

(a) $(18 + j1.5)$ kVA (b) $(18 – j1.5)$ kVA

(c) $(20 + j1.5)$ kVA (d) $(20 – j1.5)$ kVA

[EC-2014 : 2 Marks]

Q.34 A periodic variable x is shown in the figure as a function of time. The root-mean-square (rms) value of x is ______ .



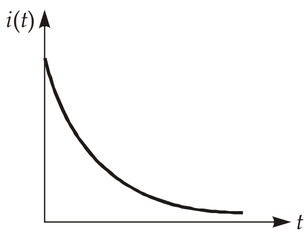
[EC-2014 : 2 Marks]

Q.35 A series RC circuit is connected to DC voltage source at time t = 0. The relation between the source voltage V_s , the resistance R, the capacitance C, and the current $i(t)$ is given below,

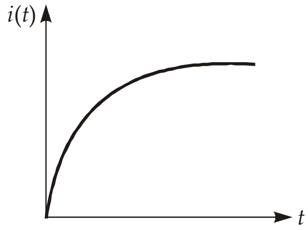
$$V_s = Ri(t)+\frac{1}{C}\int_0^t i(t)\,dt$$

Which one of the following represents the current $i(t)$?

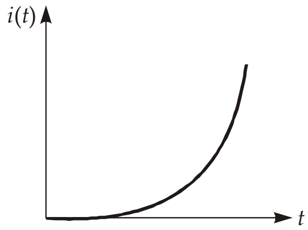
(a)



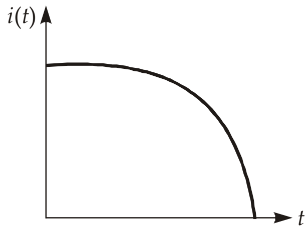
(b)



(c)



(d)

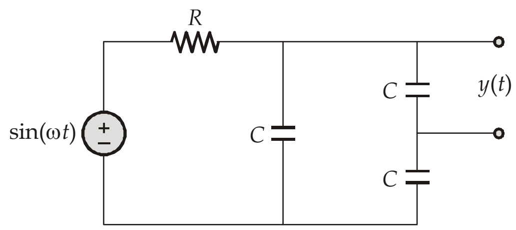


[EC-2014 : 1 Mark]

Q.36 The steady-state output of the circuit shown in the figure is given by

$$y(t) = A(\omega) \sin(\omega t + \phi(\omega))$$

If the amplitude $|A(\omega)| = 0.25$, then the frequency ω is

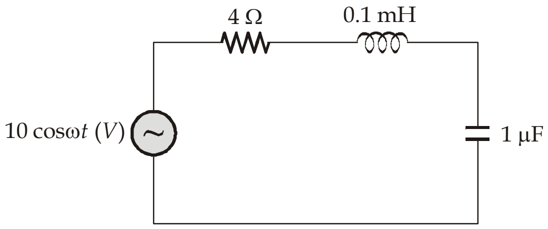


(a) $\frac{1}{\sqrt{3}RC}$ (b) $\frac{2}{\sqrt{3}RC}$

(c) $\frac{1}{RC}$ (d) $\frac{2}{RC}$

[EC-2014 : 2 Marks]

Q.37 In the circuit shown, at resonance, the amplitude of the sinusoidal voltage (in Volts) across the capacitor is ________ .



[EC-2015 : 1 Mark]

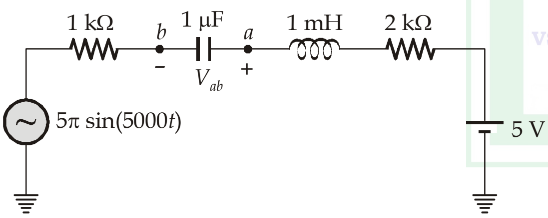
Q.38 The damping ratio of a series RLC circuit can be expressed as

(a) $\frac{R^2C}{2L}$ (b) $\frac{2L}{R^2C}$

(c) $\frac{R}{2}\sqrt{\frac{C}{L}}$ (d) $\frac{2}{R}\sqrt{\frac{L}{C}}$

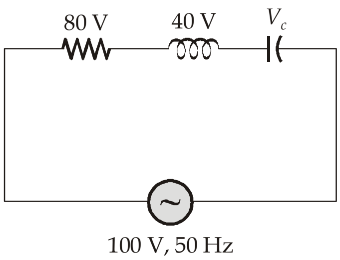
[EC-2015 : 2 Marks]

Q.39 In the circuit shown, the average value of the voltage V_{ab} (in Volts) in steady-state condition is ______ .



[EC-2015 : 1 Mark]

Q.40 The voltage (V_c) across the capacitor (in Volts) in the network shown in ______ .



[EC-2015 : 1 Mark]

Q.41 An LC tank circuit consists of an ideal capacitor C connected in parallel with a coil of inductance L having an internal resistance R. The resonant frequency of the tank circuit is

(a) $\frac{1}{2\pi\sqrt{LC}}$

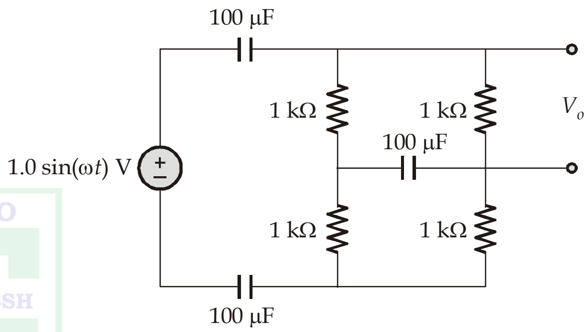
(b) $\frac{1}{2\pi\sqrt{LC}}\sqrt{1-R^2\frac{C}{L}}$

(c) $\frac{1}{2\pi\sqrt{LC}}\sqrt{1-\frac{L}{R^2C}}$

(d) $\frac{1}{2\pi\sqrt{LC}}\left(1-R^2\frac{C}{L}\right)$

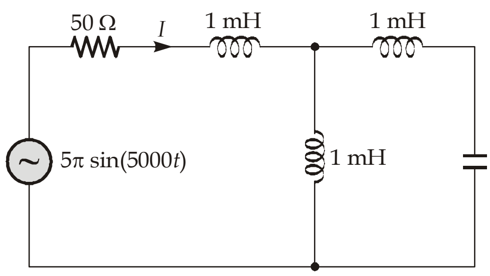
[EC-2015 : 2 Marks]

Q.42 At very high frequencies, the peak output voltage V_o (in Volts) is ______ .



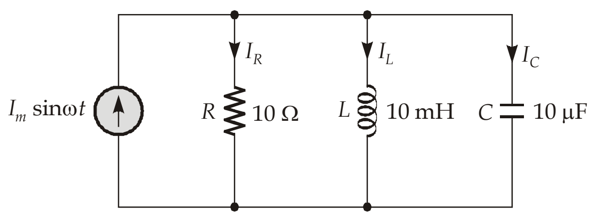
[EC-2015 : 1 Mark]

Q.43 In the circuit shown, the current/flowing through the 50 Ω resistor will be zero if the value of capacitor C (in μF) is ______ .



[EC-2015 : 2 Marks]

Q.44 The figure shows at RLC circuit with a sinusoidal current source.



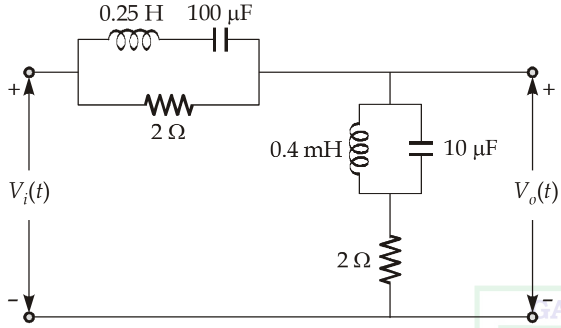
At resonance, the ratio $\frac{|I_L|}{|I_R|}$, i.e., the ratio of the magnitude of the inductor current phasor and the resistor current phasor, is ______ .

[EC-2016 : 1 Mark]

Q.45 In the RLC circuit shown in the figure, the input voltage is given by

$V_i(t) = 2\cos(200t) + 4\sin(500t)$

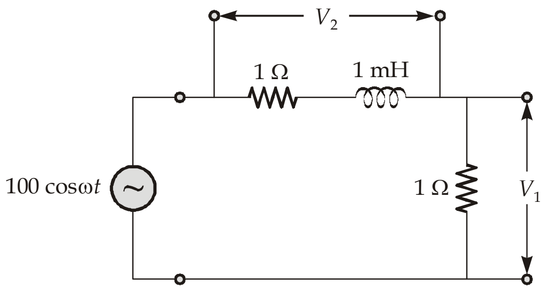
The output voltage $V_o(t)$ is



(a) $\cos(200t) + 2\sin(500t)$
(b) $2\cos(200t) + 4\sin(500t)$
(c) $\sin(200t) + 2\cos(500t)$
(d) $2\sin(200t) + 4\cos(500t)$

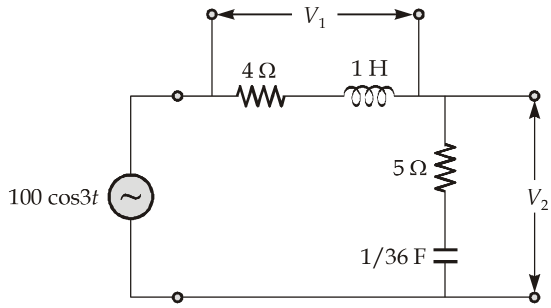
[EC-2016 : 1 Mark]

Q.46 In the circuit shown, the positive angular frequency ω (in radians/second) at which the magnitude of the phase difference between the voltages V_1 and V_2 equals π/4 radians, is ____ .



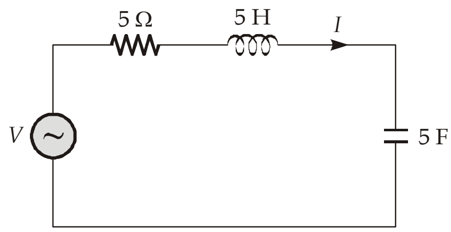
[EC-2017 : 1 Mark]

Q.47 The figure shows an RLC circuit excited by the sinusoidal voltage 100 cos(3t) Volts, where 't' is in seconds. The ratio $\frac{\text{amplitude of } V_2}{\text{amplitude of } V_1}$ is ____ .



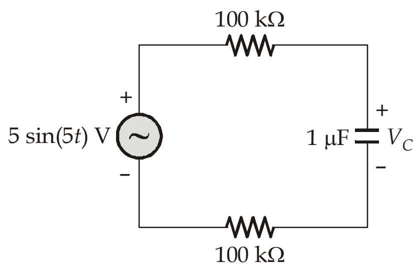
[EC-2017 : 2 Marks]

Q.48 In the circuit shown, V is a sinusoidal voltage source. The current I is in phase with voltage V. The ratio $\frac{\text{amplitude of voltage across the capacitor}}{\text{amplitude of voltage across the resistor}}$ is ______ .



[EC-2017 : 1 Mark]

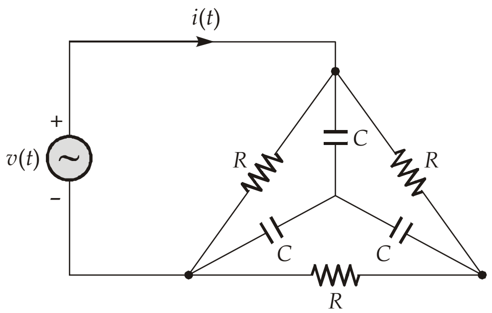
Q.49 For the circuit given in the figure, the voltage V_C (in Volts) across the capacitor is



(a) $1.25\sqrt{2}\sin(5t - 0.25\pi)$
(b) $1.25\sqrt{2}\sin(5t - 0.125\pi)$
(c) $2.5\sqrt{2}\sin(5t - 0.25\pi)$
(d) $2.5\sqrt{2}\sin(5t - 0.125\pi)$

[EC-2018 : 2 Marks]

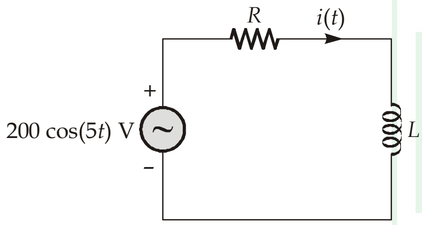
Q.50 In the circuit shown, if $v(t) = 2\sin(1000t)$ Volts. $R = 1$ kΩ and $C = 1$ μF, then the steady-state current $i(t)$, (in mA), is



(a) $3 \sin(1000t) + \cos(1000t)$
(b) $\sin(1000t) + \cos(1000t)$
(c) $\sin(1000t) + 3 \cos(1000t)$
(d) $2 \sin(1000t) + 2 \cos(1000t)$

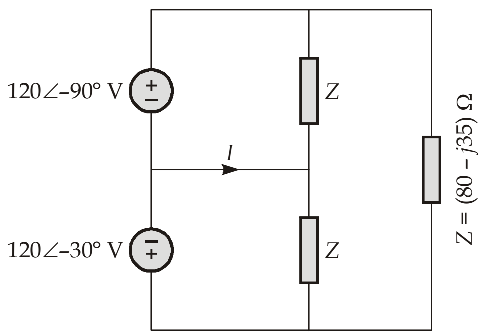
[EC-2019 : 2 Marks]

Q.51 The current in the RL circuit shown below is $i(t) = 10 \cos(5t - \pi/4)$ A. The value of the inductor (Rounded off to two decimal places) is ____ H.



[EC-2020 : 1 Mark]

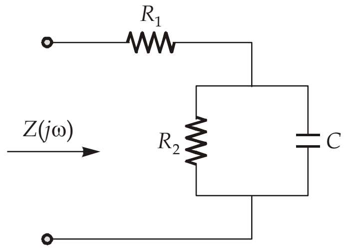
Q.52 The current 'I' in the given network is

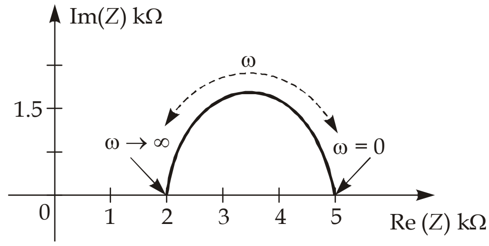


(a) $2.38\angle{-23.63°}$ A (b) 0 A
(c) $2.38\angle{-96.37°}$ A (d) $2.38\angle{143.63°}$ A

[EC-2020 : 2 Marks]

Q.53 For the circuit shown, the locus of the impedance $Z(j\omega)$ is plotted as ω increases from zero to infinity. The values of R_1 and R_2 are:

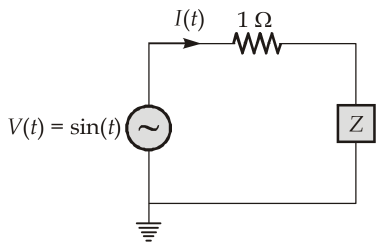


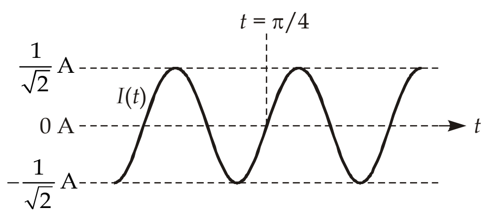


(a) $R_1 = 2$ kΩ, $R_2 = 3$ kΩ
(b) $R_1 = 5$ kΩ, $R_2 = 2$ kΩ
(c) $R_1 = 5$ kΩ, $R_2 = 2.5$ kΩ
(d) $R_1 = 2$ kΩ, $R_2 = 5$ kΩ

[EC-2022]

Q.54 Consider the circuit shown in the figure with input $V(t)$ in volts. The sinusoidal steady-state current $I(t)$ flowing through the circuit is shown graphically (where 't' is in seconds). The circuit element 'Z' can be _______ .



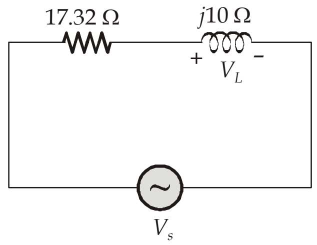


(a) a capacitor of 1 F
(b) an inductor of 1 H
(c) a capacitor of $\sqrt{3}$ F
(d) an inductor of $\sqrt{3}$ F

[EC-2022]

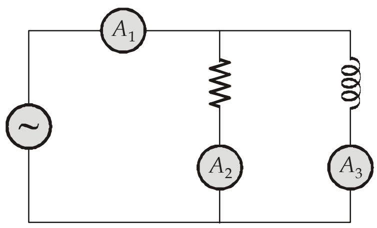
ELECTRICAL ENGINEERING
(GATE Previous Years Solved Papers)

Q.1 In the given circuit, the voltage V_L has a phase angle of ______ with respect to V_s.



[EE-1994 : 2 Marks]

Q.2 In the circuit shown in figure, ammeter A_2 reads 12 A and A_3 reads 9 A. A_1 will read ______ A.



[EE-1995 : 1 Mark]

Q.3 Energy stored in capacitor over a cycle, when excited by an ac source is
(a) the same as that due to a dc source of equivalent magnitude.
(b) half of the due to a dc source of equivalent magnitude.
(c) zero.
(d) none of the above

[EE-1997 : 1 Mark]

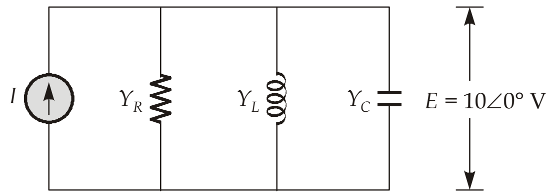
Q.4 The rms value of half wave rectified symmetrical square wave current of 2 A is
(a) $\sqrt{2}$ A (b) 1 A
(c) $\frac{1}{\sqrt{2}}$ A (d) $\sqrt{3}$ A

[EE-1997 : 1 Mark]

Q.5 Current I_1, I_2 and I_3 meet at a junction (node) in a circuit. All currents are marked as entering the node. If $I_1 = -6\sin(\omega t)$ mA and $I_2 = 8\cos(\omega t)$ mA, then I_3 will be
(a) $10\cos(\omega t + 36.87°)$ mA
(b) $14\cos(\omega t + 36.87°)$ mA
(c) $-14\cos(\omega t + 36.87°)$ mA
(d) $-10\cos(\omega t + 36.87°)$ mA

[EE-1999 : 2 Marks]

Q.6 In figure, the admittance values of the elements in Siemens are $Y_R = 0.5 + j0$, $Y_L = 0 - j1.5$, $Y_C = 0 + j0.3$ respectively. The value of 'I' as a phasor when the voltage E across the elements is $10\angle 0°$ V is



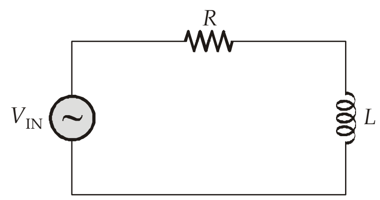
(a) $1.5 + j0.5$ (b) $5 - j18$
(c) $0.5 + j1.8$ (d) $5 - j12$

[EE-2004 : 2 Marks]

Q.7 The rms value of the voltage $u(t) = 3 + 4\cos(3t)$ is
(a) $\sqrt{17}$ V (b) 5 V
(c) 7 V (d) $(3+2\sqrt{2})$ V

[EE-2005 : 1 Mark]

Q.8 The RL circuit of the figure is fed from a constant magnitude, variable frequency sinusoidal voltage source V_{IN}. At 100 Hz, the R and L elements each have a voltage drop u_{rms}. If the frequency of the source is changed to 50 Hz, then new voltage drop across R is



(a) $\sqrt{\frac{5}{8}}\, u_{rms}$ (b) $\sqrt{\frac{2}{3}}\, u_{rms}$
(c) $\sqrt{\frac{8}{5}}\, u_{rms}$ (d) $\sqrt{\frac{3}{2}}\, u_{rms}$

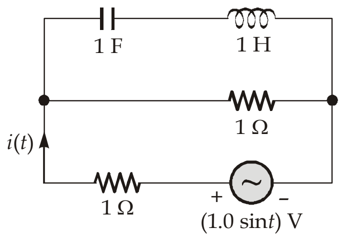
[EE-2005 : 2 Marks]

Q.9 An energy meter connected to an immersion heater (resistive) operating on an AC 230 V, 50 Hz, AC single phase source reads 2.3 units (kWh) in 1 hour. The heater is removed from the supply and now connected to a 400 V peak to peak square wave source of 150 Hz. The power in kW dissipated by the heater will be

(a) 3.478 (b) 1.739
(c) 1.540 (d) 0.870

[EE-2006 : 2 Marks]

Q.10 The rms value of the current $i(t)$ in the circuit shown below is



(a) $\frac{1}{2}$ A (b) $\frac{1}{\sqrt{2}}$ A
(c) 1 A (d) $\sqrt{2}$ A

[EE-2011 : 1 Mark]

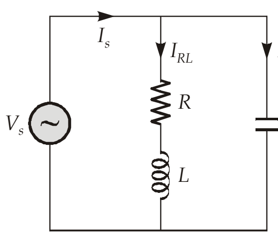
Q.11 The voltage applied to a circuit is $100\sqrt{2}\cos(100\pi t)$ Volts and the circuit draws a current of $10\sqrt{2}\sin(100\pi t + \pi/4)$ amperes. Taking the voltage as the reference phasor, the phasor representation of the current in amperes is

(a) $10\sqrt{2}\angle -\frac{\pi}{4}$ (b) $10\angle -\frac{\pi}{4}$
(c) $10\angle +\frac{\pi}{4}$ (d) $10\sqrt{2}\angle +\frac{\pi}{4}$

[EE-2011 : 1 Mark]

Common Data for Questions (12 and 13):

An RLC circuit with relevant data is given below.



$V_s = 1\angle 0$ V
$I_s = \sqrt{2}\angle \pi/4$ A
$I_{RL} = \sqrt{2}\angle -\pi/4$ A

Q.12 The power dissipated in the resistor R is

(a) 0.5 W (b) 1 W
(c) $\sqrt{2}$ W (d) 2 W

[EE-2011 : 2 Marks]

Q.13 The current I_C in the figure above is

(a) $-j2$ A (b) $-j\frac{1}{\sqrt{2}}$ A
(c) $+j\frac{1}{\sqrt{2}}$ A (d) $+j2$ A

[EE-2011 : 2 Marks]

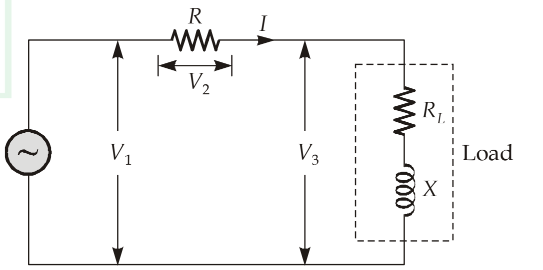
Q.14 The average power delivered to an impedance $(4 - j3)\ \Omega$ by a current $5\cos(100\pi t + 100)$ A is

(a) 44.2 W (b) 50 W
(c) 62.5 W (d) 125 W

[EE-2012 : 1 Mark]

Statement for Linked Answer Questions (15 and 16):

In the circuit shown, the three voltmeter reading are: $V_1 = 220$ V, $V_2 = 122$ V, $V_3 = 136$ V.



Q.15 The power factor of the load is

(a) 0.45 (b) 0.50
(c) 0.55 (d) 0.60

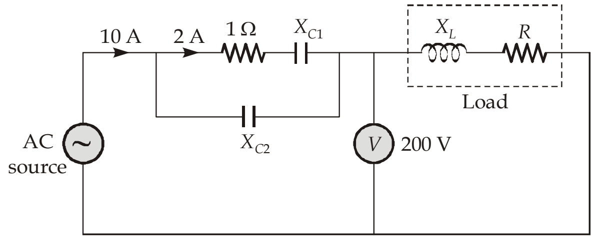
[EE-2012 : 2 Marks]

Q.16 If $R_L = 5\ \Omega$, the approximate power consumption in the load is

(a) 700 W (b) 750 W
(c) 800 W (d) 850 W

[EE-2012 : 2 Marks]

Q.17 The total power dissipated in the circuit, shown in the figure, is 1 kW.



The voltmeter, across the load, reads 200 V. The value of X_L is ______ .

[EE-2014 : 2 Marks]

Q.18 The voltage (V) and current (*I*) across a load are as follows:

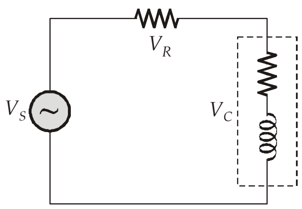
$V(t) = 100 \sin(\omega t)$

$i(t) = 10 \sin(\omega t - 60°) + 2 \sin(3\omega t) + 5 \sin(5\omega t)$

The average power consumed by the load, (in Watt), is _______ .

[EE-2016 : 1 Mark]

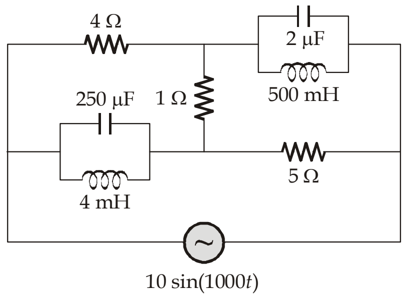
Q.19 A resistance and a coil are connected in series and supplied from a single phase, 100 V, 50 Hz ac source as shown in the figure below. The rms values of plausible voltages across the resistance (V_R) and coil (V_C) respectively, (in Volts) are



(a) 65, 35 (b) 50, 50
(c) 60, 90 (d) 60, 80

[EE-2016 : 1 Mark]

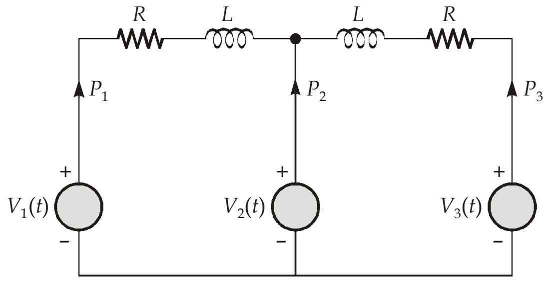
Q.20 In the circuit shown below, the supply voltage is 10 sin(1000*t*) Volts. The peak value of the steady-state current through the 1 Ω resistor, in amperes, is ______ .



[EE-2016 : 2 Marks]

Q.21 In the figure, the voltages are $v_1(t) = 100 \cos(\omega t)$, $v_2(t) = 100 \cos\left(\omega t + \frac{\pi}{18}\right)$ and $v_3(t) = 100 \cos\left(\omega t + \frac{\pi}{36}\right)$.

The circuit is in sinusoidal steady-state, and $R << \omega L$. P_1, P_2 and P_3 are the average power outputs. Which one of the following statements is true?



(a) $P_1 = P_2 = P_3 = 0$

(b) $P_1 < 0, P_2 > 0, P_3 > 0$

(c) $P_1 < 0, P_2 > 0, P_3 < 0$

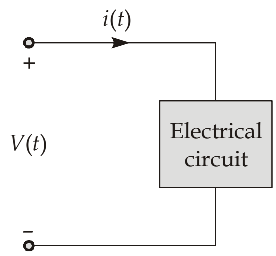
(d) $P_1 > 0, P_2 < 0, P_3 > 0$ **[EE-2018 : 1 Mark]**

Q.22 The voltage across the circuit in the figure and the current through it, are given by the following expressions:

$v(t) = 5 - 10 \cos(\omega t + 60°)$ V

$i(t) = 5 + X \cos(\omega t)$ A

where, $\omega = 100\pi$ radians/s. If the average power delivered to the circuit is zero, then the value of *X*(in Amperes) is _____ (upto 2 decimal places).



[EE-2018 : 2 Mark]

Q.23 A 0.1 μF capacitor charged to 100 V is discharged through a 1 kΩ resistor. The time in rms (round off of 2 decimal) required for the voltage across the capacitor to drop to 1 V is ________.

[EE-2019 : 2 Marks]

❑❑❑❑

Electronics & Electrical Engineering

GATE Previous Years Solved Paper

Answers & Explanations

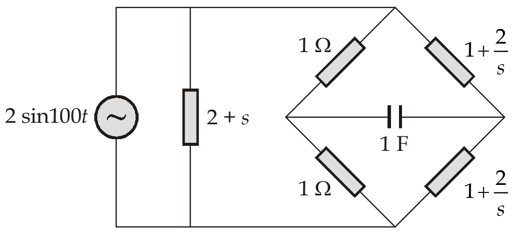
Answers — EC — Sinusoidal Steady State

1. (a)	**2.** (a, d)	**3.** (b)	**4.** (a)	**5.** (b)	**6.** (a)	**7.** (c)	**8.** (d)
9. (c)	**10.** (b)	**11.** (c)	**12.** (1)	**13.** (a)	**14.** (b)	**15.** (d)	**16.** (b)
17. (a)	**18.** (b)	**19.** (c)	**20.** (a)	**21.** (a)	**22.** (d)	**23.** (b)	**24.** (c)
25. (b)	**26.** (a)	**27.** (d)	**28.** (b)	**29.** (d)	**30.** (a)	**31.** (a)	**32.** (c)
33. (b)	**34.** (0.408)	**35.** (a)	**36.** (b)	**37.** (17.68)	**38.** (c)	**39.** (5)	**40.** (100)
41. (b)	**42.** (0.5)	**43.** (20)	**44.** (0.316)	**45.** (b)	**46.** (1)	**47.** (2.6)	**48.** (0.2)
49. (c)	**50.** (a)	**51.** (2.828)	**52.** (d)	**53.** (a)	**54.** (b)		

Solutions — EC — Sinusoidal Steady State

1. (a)

The given circuit is a bridge,



Product of opposite arms are equal,

$$1\left(1+\frac{2}{s}\right) = 1\left(1+\frac{2}{s}\right)$$

So, the current through the diagonal element (1 F capacitor) is zero.

2. (a, d)

Selectivity $\propto Q$

$$Q = \frac{f_r}{\text{B.W.}}; \qquad Q \propto \frac{1}{\text{B.W.}}$$

$$\text{B.W.} \propto \frac{1}{Q}; \qquad \text{B.W.} \propto \frac{1}{\text{selectivity}}$$

If, $R_1 \to 0$

and $R_2 \to \infty$

then the circuit will have only L and C elements and has high selectivity.

So, the half power bandwidth can be increased by reducing the selectivity.

So, by increasing the series resistance R_1 and decreasing the parallel resistance R_2, the half power bandwidth can be increased.

3. (b)

$$L_{eq} = L_1 + L_2 - 2M$$

$$L_{eq} = 2 + 2 - 2(1) = 2 \text{ H}$$

At resonance,

$$X_L = X_C$$

$$\omega L_{eq} = \frac{1}{\omega C}$$

$$\omega^2 = \frac{1}{L_{eq}C}$$

$$\omega = \frac{1}{\sqrt{2\times 2}} = \frac{1}{2} \text{ rad/sec.}$$

$$2\pi f = \frac{1}{2}$$

$$f = \frac{1}{4\pi} \text{ Hz}$$

4. (a)

At resonance frequency,

$$Z_{min} = R$$

$$I_{max} = \frac{V}{Z_{min}}$$

5. (b)

Given network is the series R-L-C circuit in resistor R, voltage V_R and current I_R is in phase and in series circuit current is same in all the elements,

$$I = I_R$$

So, the current is leading the voltage in the circuit.

So, the given circuit will behave as capacitive circuit,

$$V_C > V_L$$
$$IX_C > IX_L$$
$$X_C > X_L$$
$$\frac{1}{\omega C} > \omega L$$
$$\omega^2 < \frac{1}{LC}$$
$$\omega^2 < \omega_r^2$$
$$\omega < \omega_r$$

6. (a)

At resonance,

$$X_L - X_C = 0$$
$$|X_L| = |X_C|$$
$$|X_L| = |j12|$$
$$X_L = j12$$
$$X_L = X_{L_1} + X_{L_2} + 2k\sqrt{X_{L_1}\cdot X_{L_2}}$$
$$X_L = j2 + j8 + 2k\sqrt{j2\,j8} = j12$$
$$2\,k\,j4 = j2$$
$$k = 0.25$$

7. (c)

$$A_3^2 = A_1^2 + A_2^2$$
$$A_3^2 = (5)^2 + (12)^2$$
$$A_3^2 = 169$$
$$A_3 = 13 \text{ Ampere}$$

8. (d)

$$\because \quad X_L = X_C$$

So, the circuit is at resonance,

$$I = \frac{V}{R} = \frac{200}{10} = 20 \text{ Ampere}$$

Voltage across the capacitor,

$$V_c = I(-jX_c) = 20(-j20) = -j400$$
$$V_c = 400\angle -90° \text{ V}$$

9. (c)

For DC supply:

Inductor behave as short-circuit capacitor behave as open-circuit.

So, under steady-state conditions, the applied dc voltage drops entirely across the capacitor (C) only.

10. (b)

$$W_s = CV_s^2$$
$$W_c = \frac{1}{2}CV_s^2$$
$$\frac{W_c}{W_s} = 0.5$$

11. (c)

$$I_{rms} = \sqrt{3^2 + \left(\frac{4}{\sqrt{2}}\right)^2 + \left(\frac{4}{\sqrt{2}}\right)^2} = 5 \text{ A}$$

Power is dissipated only in the 10 Ω resistor,

$$P = I_{rms}^2 R = (5)^2 \times 10$$
$$= 250 \text{ W}$$

12. Sol.

$$Z = R + j(X_L - X_C)$$
$$= 100 + j0$$

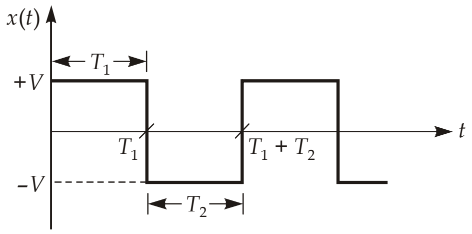
Compare the real part,

$$R = 100\ \Omega$$

$$Q = \frac{\omega L}{R}$$

$$L = \frac{QR}{\omega} = \frac{100 \times 100}{10^7} = 1\text{ mH}$$

13. (a)



Rms value of $x(t)$

$$= \sqrt{\frac{1}{T}\int_0^T x^2(t)\,dt} = \sqrt{\frac{1}{T_1+T_2}\left[\int_0^{T_1}(V)^2\,dt + \int_{T_1}^{T_1+T_2}(-V)^2\,dt\right]}$$

$$= \sqrt{\frac{1}{T_1+T_2}[V^2T_1 + V^2T_2]} = \sqrt{V^2} = V$$

14. (b)

$$A_1^2 = A_2^2 + A_3^2 = 3^2 + 4^2$$
$$A_1 = 5\text{ Ampere}$$

15. (d)

Diode D_1 will conduct for the positive half cycle of the input.

The ammeter will read the average value,

$$I_{avg.} = \frac{V_m}{\pi} \times \frac{1}{R} = \frac{4}{\pi} \times \frac{1}{10 \times 10^3}$$

$$I_{avg.} = \frac{0.4}{\pi}\text{ mA}$$

16. (b)

At resonance,

$$I = I_R = 1\text{ mA}$$

$$|I_R + I_L| = \sqrt{I_R^2 + I_L^2} = \sqrt{1^2 + I_L^2} > 1\text{ mA}$$

$$|I_R + I_L| > 1\text{ mA}$$

17. (a)

$$i_2(t) = \frac{E_m \cos\omega t}{R_2 + \frac{1}{j\omega C}} = E_m\angle 0 \frac{j\omega C}{1 + j\omega C R_2}$$

$$\angle i_2(t) = \frac{E_m\angle 0\ \omega C\angle 90°}{\sqrt{1+\omega^2C^2R^2}\ \angle\tan^{-1}\omega C R_2}$$

$$i_2(t) = \frac{E_m \omega C}{\sqrt{1+\omega^2C^2R^2}}\angle 90° - \tan^{-1}\omega CR$$

At $\omega = 0,\ i_2(t) = 0,\ \omega = \infty,\ i_2(t) = \frac{E_m}{R_2}$

Option (a) satisfies both conditions.

18. (b)

$$Q = \frac{f_0}{\text{B.W.}}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$\text{B.W.} = \frac{R}{L}$$

(Characteristic equation $= s^2 + \frac{Rs}{L} + \frac{1}{LC}$)

or, $$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

when R, L, C are doubled,

$$Q' = \frac{1}{2}Q = 50$$

19. (c)

$$i(t) = \frac{v(t)}{R + j\omega L} = \frac{10\sqrt{2}\cos(t+10°)}{1+1j} + \frac{10\sqrt{5}\cos(2t+10°)}{1+2j}$$

$$i(t) = \frac{10\sqrt{2}\cos(t+10°)}{\sqrt{2}\angle 45°} + \frac{10\sqrt{5}\cos(2t+10°)}{\sqrt{5}\angle\tan^{-1}2}$$

$$\therefore\ i(t) = 10\cos(t - 35°) + 10\cos(2t + 10 - \tan^{-1}2)$$

20. (a)

$$i(t) = V(t)\cdot Y$$

$$Y = V(t)\left[\frac{1}{R_1} + \frac{1}{j\omega L} + j\omega C\right]$$

$$= \sin 2t\left[3 + \frac{4}{2j} + j \times 2 \times 3\right]$$

$= \sin 2t[3 - 2j + 6j] = \sin 2t[3 + 4j]$

$= 5\sin 2t\angle\tan^{-1}\frac{4}{3} = 5\sin(2t + 53.1°)$

21. (a)

$$v_o(t) = \frac{\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}} v_i(t) = \frac{1}{1 + j\omega CR}\sqrt{2}\sin 10^3 t$$

$$= \frac{1}{1 + j\times 10^3 \times 10^{-3}}\sqrt{2}\sin 10^3 t$$

$$v_o(t) = \sin(10^3 t - 45°)$$

22. (b)

Characteristic equation = $s^2 + 20s + 10^6$

$$Q = \frac{\omega_o}{\text{B.W.}},\ \omega_o = \sqrt{10^6}$$

$$Q = \frac{10^3}{20} = \frac{1000}{20} = 50$$

23. (d)

S_1 : Impedance of series RLC circuit at resonant frequency is minimum,

$$Z = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

$$\omega L - \frac{1}{\omega C} = 0$$

$Z = R$ (Purely resistive)

S_2 :
$$Q = R\sqrt{\frac{C}{L}}$$

$$G = \frac{1}{R} \Rightarrow Q = \frac{1}{G}\sqrt{\frac{C}{L}}$$

$G\uparrow$ then $Q\downarrow$ if C and L are same.

24. (c)

Transfer function

$$= \frac{\frac{1}{sC}}{R + sL + \frac{1}{sC}} = \frac{1}{s^2 LC + sCR + 1}$$

$$\frac{Y(s)}{U(s)} = \frac{\frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

$$2\xi\omega_n = \frac{R}{L}$$

$$\omega_n = \frac{1}{\sqrt{LC}}$$

$$\xi = \frac{R}{2L}\sqrt{LC} = \frac{R}{2}\sqrt{\frac{C}{L}}$$

For no oscillations, $\xi \geq 1$

$$\frac{R}{2}\sqrt{\frac{C}{L}} \geq 1; \qquad R \geq 2\sqrt{\frac{L}{C}}$$

25. (b)

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{1 \times \frac{1}{400} \times 10^{-6}}}$$

$$= \frac{10^3 \times 20}{2\pi} = \frac{10^4}{\pi}\ \text{Hz}$$

26. (a)

When $5\angle 0°$ is acting along,

$i_1(t) = -5\angle 0°$

(as $10\angle 60°$ is kept open)

When $10\angle 60°$ is acting along,

$i_1(t) = 10\angle 60°$

(as $5\angle 0°$ is kept open)

$i_1(t) = 10\angle 60° - 5\angle 0°$

$= 5 + 8.66j - 5$

$i_1(t) = 8.66j$

$i_1(t) = 5\sqrt{3}\angle 90°$

$= \frac{10}{2}\sqrt{3}\angle 90°$

27. (d)

V_{AB} = Current × Impedance

$= 5\angle 30° \times (5 - 3j) || (5 + 3j)$

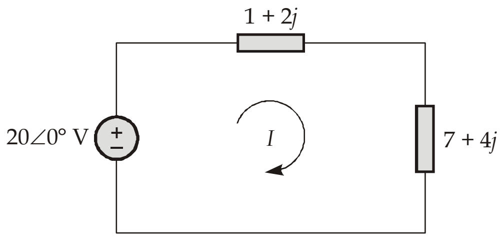
$$= 5\angle 30° \times \frac{(5 - 3j)\times(5 + 3j)}{5 - 3j + 5 + 3j}$$

$$= 5\angle 30° \times \frac{25 + 9}{10}$$

$= 5\angle 30° \times 3.4$

$= 17\angle 30°$

28. (b)



$$I = \frac{20}{8+6j} = \frac{10}{4+3j} = 2\angle -36.87°$$

Reactive power,

$$Q = I^2 X_L = 4 \times 4 = 16 \text{ VAR}$$

29. (d)

Characteristic equation for a parallel RLC circuit is

$$s^2 + \frac{1}{RC}s + \frac{1}{LC} = 0$$

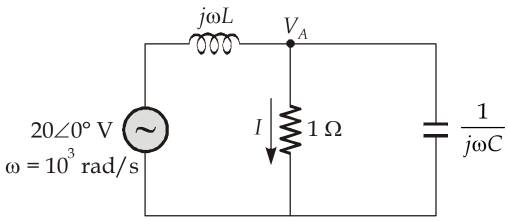
where, Bandwidth $= \dfrac{1}{RC}$

(i) It is clear that the bandwidth of a parallel RLC circuit is independent of L and decreases if R is increased.

(ii) At resonance, imaginary part of input impedance is zero. Hence, at resonance input impedance is a real quantity.

(iii) In parallel RLC circuit, the admittance is minimum at resonance. Hence magnitude of input impedance attains its maximum value at resonance.

30. (a)



($L = 20$ mH, $C = 50$ μH)

Nodal analysis at node A,

$$\frac{V_A - 20}{j\omega L} + \frac{V_A}{1} + \frac{V_A}{\frac{1}{j\omega C}} = 0$$

$$V_A\left[\frac{1}{j10^3 \times 20 \times 10^{-3}} + 1 + j10^3 \times 50 \times 10^{-6}\right] = \frac{20}{j10^3 \times 20 \times 10^{-3}}$$

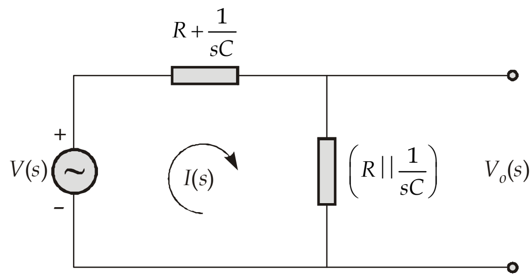
$$V_A\left[\frac{-j}{20} + 1 + \frac{j}{20}\right] = -j1$$

$$V_A = -j1 \text{ V}$$

$$I = \frac{V_A}{1} = -j1 \text{ A}$$

31. (a)

Redrawing the circuit s-domain,



$$V_i(s) = \left(R + \frac{1}{sC}\right)I(s) + \frac{R \cdot \frac{1}{sC}}{R + \frac{1}{sC}} I(s)$$

$$V_i(s) = \frac{1+sCR}{sC} I(s) + \frac{R}{1+sCR} I(s) \quad \text{...(i)}$$

$\because \quad v_i = V_p \cos(t/RC)$

So here, $\omega = \dfrac{1}{RC}$

Now,

$$V_i(s) = \frac{(1+j\omega CR)}{j\omega C} I(s) + \frac{R}{(1+j\omega CR)} I(s)$$

Put, $\quad \omega = \dfrac{1}{RC}$

So, $$V_i(s) = \left[\frac{(1+j)R}{j} + \frac{R}{1+j}\right] I(s)$$

$$\frac{V_i(s)}{I(s)} = \frac{3R}{(1+j)}$$

$$I(s) = \frac{V_i(s)}{3R} \times (1+j)$$

Now, $$V_o(s) = \left(R || \frac{1}{sC}\right) I(s)$$

$$\Rightarrow \quad V_o(s) = \frac{R\cdot\frac{1}{sC}}{R+\frac{1}{sC}} I(s)$$

$$\Rightarrow \quad V_o(s) = \frac{R}{1+sCR}\cdot\frac{V_i(s)}{3R}(1+j)$$

$$\Rightarrow \quad V_o(s) = \frac{R}{1+j}\cdot\frac{V_i(s)}{3R}(1+j)$$

$$\Rightarrow \quad V_o(s) = \frac{V_i(s)}{3}$$

In time domain,

$$V_o(t) = \frac{1}{3}V_i(t)$$

$$\Rightarrow \quad V_o(t) = \frac{V_p}{3}\cos\left(\frac{t}{RC}\right)$$

32. (c)

$$q_1 = \frac{\omega L_1}{R_1} \text{ and } q_2 = \frac{\omega L_2}{R_2}$$

$$\omega L_1 = q_1 R_1 \text{ and } \omega L_2 = q_2 R_2$$

Coils are connected in series,

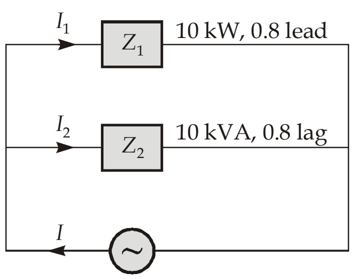
So, $\quad q \cdot R = \omega L_1 + \omega L_2 = q_1 R_1 + q_2 R_2$

$$q = \frac{q_1 R_1 + q_2 R_2}{R}$$

$$R = R_1 + R_2$$

$$q = \frac{q_1 R_1 + q_2 R_2}{R_1 + R_2}$$

33. (b)



Real power (kW),

$$P = VI\cos\phi \quad \text{...(i)}$$

$$\therefore \quad P_1 = V \times I_1 \cos\phi$$

Thus, $\quad I_1 = \dfrac{10\times 10^3}{230\times 0.8} = 54.34\angle 36.86 \quad$ ...(ii)

Total power (kVA),

$$P = V \cdot I_2$$

$$\therefore \quad I_2 = 43.47\angle{-36.86} \quad \text{...(iii)}$$

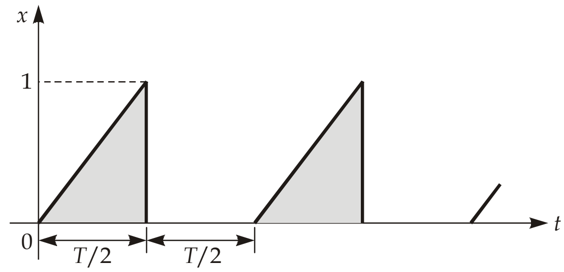
Therefore, $\vec{I} = \vec{I}_1 + \vec{I}_2 = 78.25 + j6.25 \quad$ ...(iv)

So, the complex power delivered by source,

$$S = VI^* = 230(78.25 - j6.25)$$

or, $\quad S = (18 - j1.5)$ kVA

34. Sol.



$$\text{Rms value} = \sqrt{\frac{1}{T}\int_0^T x^2(t)\,dt}$$

where, $\quad T$ = time period

For the given signal,

$$\text{Rms value} = \sqrt{\frac{1}{T}\int_0^{T/2}\left(\frac{2}{T}t\right)^2 dt + \int_{T/2}^{T}(0)^2\,dt}$$

$$= \sqrt{\frac{1}{T}\int_0^{T/2}\frac{4}{T^2}t^2 dt} = \sqrt{\frac{1}{4}\times\frac{4}{T^2}\times\left(\frac{t^3}{3}\right)_0^{T/2}}$$

$$= \sqrt{\frac{4}{T^3}\left(\frac{T^3}{24}\right)} = \sqrt{\frac{1}{6}} = 0.408$$

35. (a)

Given that, $\quad V_s = Ri(t) + \dfrac{1}{C}\displaystyle\int_0^t i(t)\,dt \quad$ ...(i)

Using Laplace transform,

$$V(s) = RI(s) + \frac{1}{Cs}I(s) \quad \text{...(ii)}$$

or, $\quad I(s) = \dfrac{V(s)}{\left(R+\dfrac{1}{Cs}\right)} \quad$ ...(iii)

For, $\quad V(s) = \dfrac{1}{s}$

From equation (iii) and (iv),

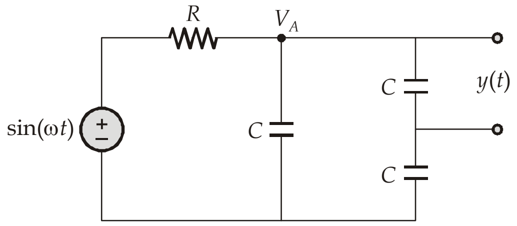
$$I(s) = \frac{C}{(RCs+1)} = \frac{1}{R\left(s+\frac{1}{RC}\right)} \quad ...(v)$$

Using inverse Laplace transform in equation (v), we get,

$$i(t) = \frac{1}{R}e^{-t/RC}$$

Thus, option (a) is correct.

36. (b)



Applying KCL at node A, we get

$$= \frac{V_A - \sin\omega t}{R} + \frac{V_A}{\frac{1}{j\omega C}} + \frac{V_A}{\frac{2}{j\omega C}} = 0 \quad ...(i)$$

$$= V_A\left[\frac{1}{R} + j\omega C + \frac{j\omega C}{2}\right] = \frac{\sin\omega t = 1\angle 0°}{R}$$

$$= V_A = \frac{2}{2+3RC\cdot j\omega} \quad ...(ii)$$

Also, $$Y = \frac{V_A}{2} = \frac{1}{2+3j\omega RC} \quad ...(iii)$$

$$\because \quad |A(\omega)| = \frac{1}{4}$$

$$\therefore \quad \frac{1}{4} = \frac{1}{\sqrt{4+9\omega^2(RC)^2}}$$

or, $$\omega = \frac{2}{\sqrt{3}RC}$$

37. Sol.

At resonance,

$$I = \frac{10/\sqrt{2}}{4}$$

$$\omega = \frac{1}{\sqrt{0.1\times10^{-3}\times10^{-6}}} = 10^5 \text{ rad/sec}$$

$$X_C = \frac{1}{\omega C} = \frac{1}{10^5\times1\times10^{-6}} = 10\ \Omega$$

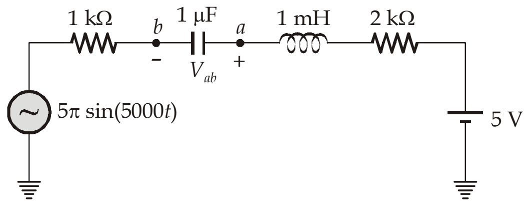
$$V_C = IX_C = 10\times\frac{10/\sqrt{2}}{4} = \frac{25}{\sqrt{2}} = 17.68\text{ V}$$

38. (c)

$$\xi = \frac{1}{2Q};\ Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

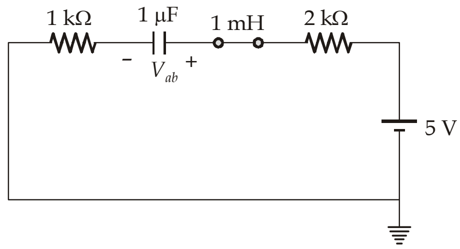
$$\therefore \text{ Damping ratio } = \xi = \frac{R}{2}\sqrt{\frac{C}{L}}$$

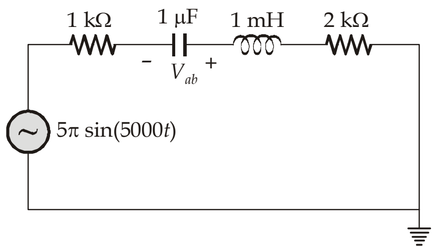
39. Sol.



Applying superposition:

V_{ab} =5 V (open circuited in steady-state)

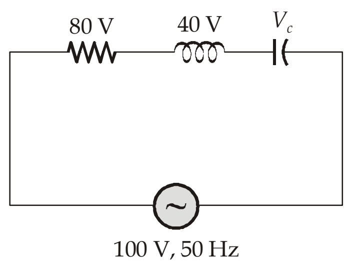




V_{ab} will be sinusoid with average value zero.

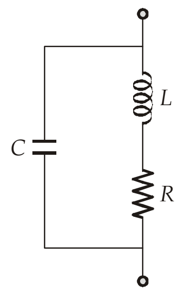
$\Rightarrow$ Average, V_{ab} = 5 V

40. Sol.



$$(80)^2 + (40 - V_C)^2 = 100^2$$
$$(40 - V_C)^2 = 100^2 - 80^2 = 3600$$
$$|40 - V_C| = 60$$
$$V_C = 100 \text{ V}$$

41.



$$Z_{eq} = \frac{\frac{1}{j\omega C} \times (j\omega L + R)}{\frac{1}{j\omega C} \times j\omega L + R}$$

$$Z_{eq} = \frac{\left(\frac{R}{j\omega C} + \frac{L}{C}\right)}{R + j\left(\omega L - \frac{1}{\omega C}\right)} \times \frac{R - j\left(\omega L - \frac{1}{\omega C}\right)}{R - j\left(\omega L - \frac{1}{\omega C}\right)}$$

Equating imaginary part to zero,

$$\text{Img} = -\frac{R^2}{\omega C} - \frac{L}{C}\left(\omega L - \frac{1}{\omega C}\right) = 0$$

$$\frac{R^2}{\omega C} + \frac{L}{C}\left(\omega L - \frac{1}{\omega C}\right) = 0$$

$$\frac{CR^2 + \omega^2 L^2 C - L}{\omega C^2} = 0$$

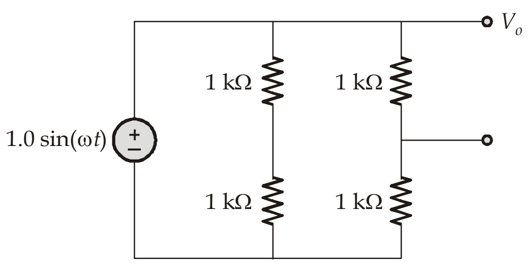
$$\omega^2 = \frac{1}{\sqrt{LC}}\sqrt{1 - \frac{R^2 C}{L}}$$

$$f = \frac{1}{2\pi\sqrt{LC}}\sqrt{1 - \frac{R^2 C}{L}}$$

42. Sol.

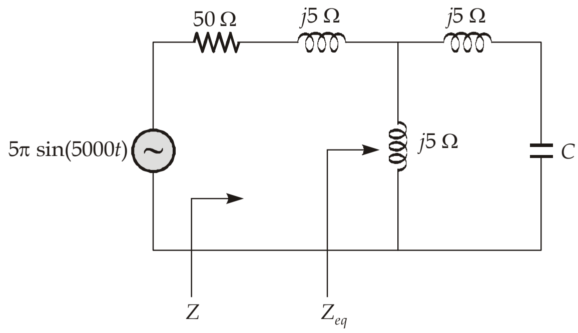
Circuit contains balanced Wheatstone bridge. Also at high frequencies capacitor can be considered as short-circuits.

Redrawing the circuit,



$$V_o = 1 \sin\omega t \times 1 \text{ k}\Omega$$
$$= 0.5 \sin\omega t$$
$$\text{Peak output} = 0.5 \text{ V}$$

43. Sol.



$$Z_{eq} = \frac{j5\,\Omega \times \left(\frac{1}{j\omega C} + j5\right)}{j5\,\Omega + j5\,\Omega + \frac{1}{j\omega C}}$$

$$I = 0 \text{ if } Z \text{ is } \infty$$
$$Z = Z_{eq} + 50 + j5$$

For Z to be ∞,

$$Z_{eq} = \infty$$

$$\Rightarrow \quad j5 + j5 + \frac{1}{j\omega C} = 0$$

$$10 = \frac{1}{5000 \times C}$$

$$C = \frac{1}{5 \times 10^3 \times 10} = 20\ \mu\text{F}$$

44. Sol.

At resonance (for parallel RLC circuit),

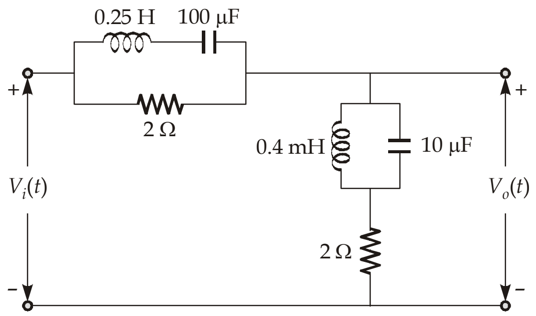
$$I_R = I$$
$$I_L = QI\angle -90°$$
$$I_C = QI\angle -90°$$

For parallel RLC circuit,

$$\frac{|I_L|}{|I_R|} = \frac{IQ}{I} = Q = R\sqrt{\frac{C}{L}}$$

$$= 10\sqrt{\frac{10 \times 10^{-6}}{10 \times 10^{-3}}} = 0.316$$

45. (b)



where, $V_i(t) = 2\cos(200t) + 4\sin(500t)$

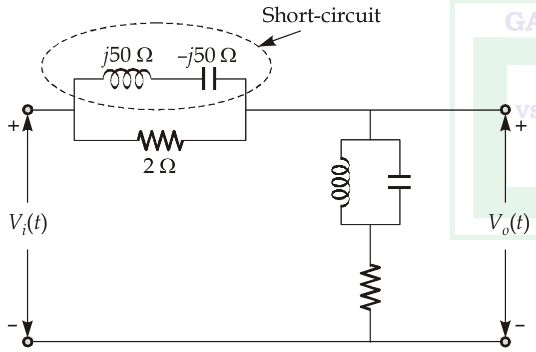
As different frequencies are operating, using superposition theorem, we get for

$$\omega = 200 \text{ rad/sec}$$

$$X_L = \omega L = (200)(0.25) = 50\ \Omega$$

$$X_C = \frac{1}{\omega C} = \frac{1}{200 \times 100 \times 10^{-6}}$$

$$= 50\ \Omega$$

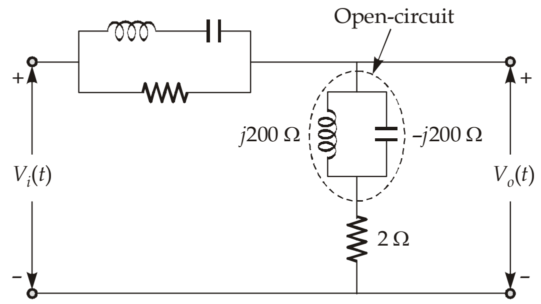


$\because$ $V_o(t) = V_i(t)$

For, $\omega = 500$ rad/sec.

$$X_L = 0.4 \times 500 = 200\ \Omega$$

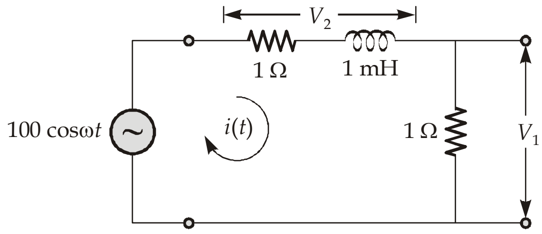
$$X_C = \frac{1}{10 \times 10^{-6} \times 500} = 200\ \Omega$$



$$V_o(t) = V_i(t)$$

Therefore, $V_o(t) = 2\cos(200t) + 4\sin(500t)$

46. Sol.



Let, $i(t) = I_m \angle \theta_i$ and $Z_2 = 1 + j\omega$

$$= \sqrt{1+\omega^2}\,\angle\theta_2$$

$$\theta_2 = \tan^{-1}\left(\frac{\omega}{1}\right)$$

$$V_1 = i(t)\,(1\ \Omega) = I_m \angle\theta_i$$

$$V_2 = i(t)\,Z_2$$

$$= I_m\sqrt{1+\omega^2}\,\angle\theta_2 + \theta_i$$

From the given data,

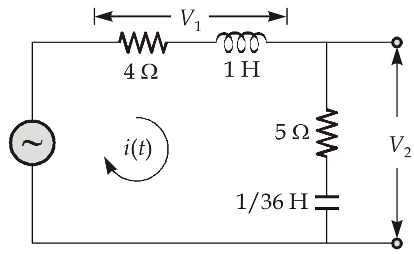
$$(\theta_i + \theta_2) - (\theta_i) = \frac{\pi}{4}$$

$$\theta_2 = \frac{\pi}{4}$$

$$\tan^{-1}\left(\frac{\omega}{1}\right) = \frac{\pi}{4}$$

$$\omega = 1 \text{ rad/sec}$$

47. Sol.



$$\omega = 3 \text{ rad/sec},$$

$$Z_1 = (4 + j3)\ \Omega$$

and $Z_2 = (5 - j12)\ \Omega$

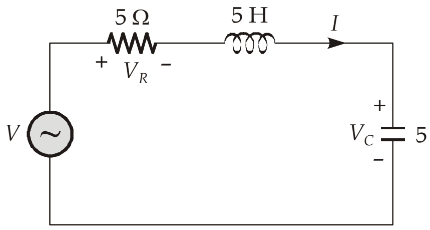
$$|V_2| =$$

$$|i||Z_2| = |i|\sqrt{5^2 + 12^2} = 13|i|$$

$$|V_1| = |i||Z_1| = |i|\sqrt{4^2 + 3^2} = 5|i|$$

$$\frac{|V_2|}{|V_1|} = \frac{13|i|}{5|i|} = \frac{13}{5} = 2.6$$

48. Sol.



Given that, V and I have same phase. So, the circuit is resonance.

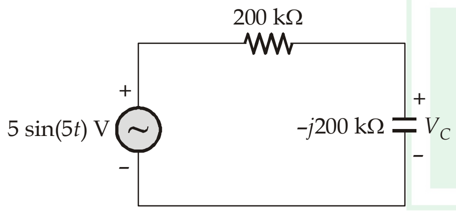
At resonance, $V_C = QV_R$

So, $\frac{\text{Amplitude of } V_C}{\text{Amplitude of } V_R} = Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

$= \frac{1}{5}\sqrt{\frac{5}{5}} = 0.2$

49. (c)

$\frac{1}{\omega C} = \frac{1}{5 \times 10^{-6}} = 200\ \text{k}\Omega$



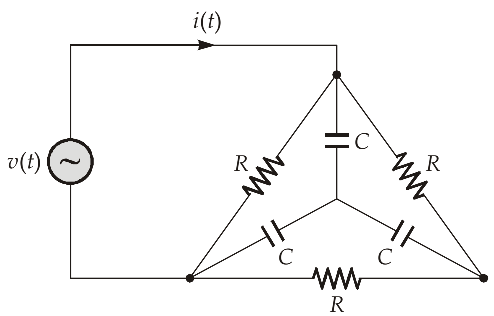
$V_C = \frac{5\angle 0°}{200 - j200} \times (-j200)$ V

$= \frac{5\angle 0° \times 1\angle -90°}{\sqrt{2}\angle -45°}$

$= \frac{5}{\sqrt{2}}\angle -45°\ \text{V} = 2.5\sqrt{2}\sin\left(5t - \frac{\pi}{4}\right)$ V

$= 2.5\sqrt{2}\sin(5t - 0.25\pi)$ V

50. (a)



Here, $X_C = \frac{1}{\omega C} = \frac{1}{10^3 \times 10^{-6}} = \frac{1}{10^{-3}}$

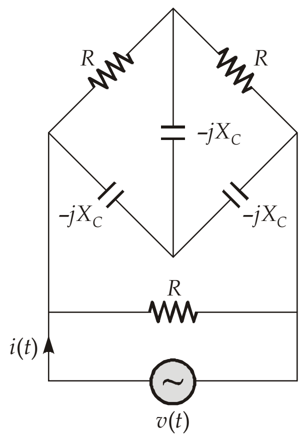
$X_C = 10^3\ \Omega$

$R = 10^3\ \Omega$ (Given)

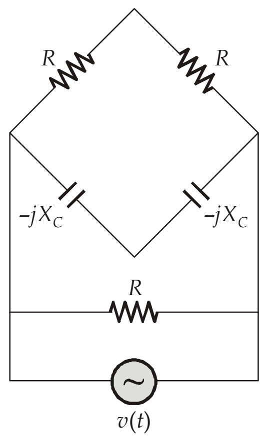
$v(t) = 2 \sin 1000t$ V

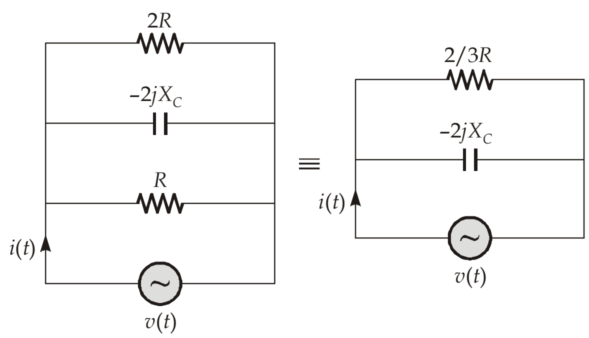
$= 2\angle 0°$ V

Redrawing the given network, we get,



As the bridge is balanced, it can be redrawn as,





$\therefore \quad Y_{eq} = Y_1 + Y_2$

$$= \frac{3}{2R} + \frac{1}{-2jX_C}$$

$$= \frac{3}{2}\times 10^{-3} + j\frac{1}{2}\times 10^{-3}$$

$$\therefore \quad i(t) = v(t) \times Y_{eq} = 2\angle 0^\circ \left[\frac{3}{2} + j\frac{1}{2}\right] \text{mA}$$

$$= (3 + j1)\text{ mA}$$

$$= 3\sin(1000t) + \cos(1000t)\text{ mA}$$

51. Sol.

$$Z = \frac{V}{I} = \frac{200\angle 0^\circ}{10\angle -45^\circ} = 20\angle 45^\circ$$

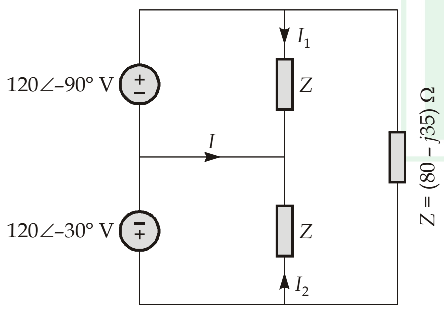
$$Z = 10\sqrt{2} + j10\sqrt{2}$$

$$X_L = 10\sqrt{2}$$

$$\omega L = 10\sqrt{2}$$

$$L = \frac{10\sqrt{2}}{5} = 2.828\text{ H}$$

52. (d)



$$I = -[I_1 + I_2]$$

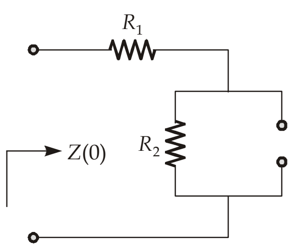
$$I = -\left[\frac{120\angle -90^\circ}{80 - j35} + \frac{120\angle -30^\circ}{80 - j35}\right]$$

$$I = 2.38\angle 143.7^\circ$$

53. (a)

At $\omega = 0$ rad/sec,

$$X_C = \frac{1}{\omega C} = \infty$$



Impedance, $Z(0) = R_1 + R_2$

With the help of graph at $\omega = 0$,

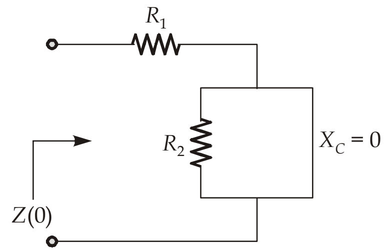
$$Z(0) = 5\text{ k}\Omega$$

$$R_1 + R_2 = 5\text{ k}\Omega$$

At $\omega = \infty$ rad/sec,

$$X_C = \frac{1}{\omega C}$$

$$X_C = 0$$



Impedance, $Z(\infty) = R_1 = 2\text{ k}\Omega$

$$R_1 + R_2 = 5\text{ k}\Omega$$

$$R_2 = 3\text{ k}\Omega$$

54. (b)

As the current $i(t)$ is lagging, element Z is inductor,

$$I = \frac{V}{Z_0};\ I = \frac{\sin t}{Z_0}$$

Maximum value of current,

$$i(t) = \frac{1}{\sqrt{2}}$$

$$\therefore \quad |Z_0| = \sqrt{2}$$

$$Z_0 = R + jX_L = 1 + j\omega L$$

$$\sqrt{1 + \omega^2 L^2} = \sqrt{2}$$

$$1 + \omega^2 L^2 = 2$$

Given, $\omega = 1$ rad/sec.

$$L^2 = 1$$

$$L = 1\text{ H}$$

□□□□

Answers — EE — Sinusoidal Steady State

1. (60)	**2.** (15)	**3.** (c)	**4.** (a)	**5.** (d)	**6.** (d)	**7.** (a)	**8.** (c)
9. (b)	**10.** (b)	**11.** (b)	**12.** (b)	**13.** (d)	**14.** (b)	**15.** (a)	**16.** (b)
17. (17.332)	**18.** (250)	**19.** (*)	**20.** (1)	**21.** (c)	**22.** (10)	**23.** (0.46)	

Solutions — EE — Sinusoidal Steady State

1. Sol.

$$V_L = V_s \times \frac{j10}{17.32 + j10}$$

(Using voltage division rule)

$$= V_s \times 0.5\angle 60° \text{ Volts}$$

Hence, V_L has phase angle of 60° with respect to V_s.

2. Sol.

∵ Currents in resistor and inductor well be in quadrature for same voltage across them.

$$\therefore \quad I_{A1} = \sqrt{I_{A2}^2 + I_{A8}^2} = \sqrt{12^2 + 9^2} = 15 \text{ A}$$

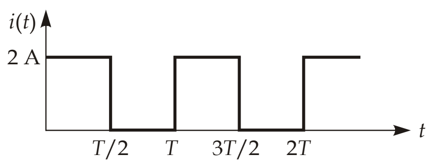
3. (c)

When excited by an ac source, capacitor stores the energy in one half cycle and delivers that energy in another half cycle. Hence total energy stored in a capacitor over a complete cycle, when excited by an ac source is zero.

4. (a)

To find: Rms value of $i(t)$

We have,



$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(t)\, dt}$$

$$= \sqrt{\frac{1}{T} \times 4 \times \frac{T}{2}} = \sqrt{2} \text{ A}$$

5. (d)

$$I_1 + I_2 + I_3 = 0$$

$$I_3 = -I_1 - I_2$$

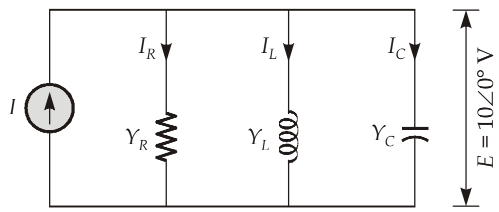
$$= -[-6 \sin(\omega t)] - 8 \cos\omega t$$

$$= 10\left[\frac{6}{10}\sin \omega t - \frac{8}{10}\cos \omega t\right]$$

$$= -10[\cos(36.87°) \cos\omega t - \sin(36.87°) \sin\omega t]$$

$$= -10 \cos(\omega t + 36.87°) \text{ mA}$$

6. (d)



$$I_R = Y_R E = (0.5 + j0) \times 10\angle 0° = 5 \text{ A}$$

$$I_Y = Y_L E = (0.5 - j1.5) \times 10\angle 0° = -j15 \text{ A}$$

$$I_C = Y_C E = (0 + j0.3) \times 10\angle 0° = j3 \text{ A}$$

$$I = I_R + I_Y + I_C = 5 + (-j15) + j3 = 5 - j12 \text{ A}$$

7. (a)

Rms value of dc voltage = $V_{dc}^{(\text{rms})} = 3$ V

Rms value of ac voltage = $V_{ac}^{(\text{rms})}$

$$= \left(\frac{4}{\sqrt{2}}\right) \text{V}$$

∴ Rms value of the voltage

$$= \sqrt{3^2 + \left(\frac{4}{\sqrt{2}}\right)^2} = \sqrt{9+8} = \sqrt{17} \text{ V}$$

8. (c)

At, $f = 100$ Hz

$$|V_R| = |V_L|$$

As R and L are series connected, current through R and L is same.

So, $IR = IX_L = I\omega L$

$\Rightarrow$ $R = X_L = \omega L$

$$I = \frac{V_{in}}{\sqrt{R^2 + X_L^2}} = \frac{V_{in}}{\sqrt{R^2 + R^2}} = \frac{V_{in}}{\sqrt{2}R}$$

$$V_R = u_{rms} = IR$$

$$V_R = \left(\frac{V_{in}}{\sqrt{2}R}\right) \times R = \frac{V_{in}}{\sqrt{2}}$$

$$\Rightarrow \quad V_{in} = \sqrt{2}\, u_{rms} \quad \text{...(i)}$$

At, $f = 50$ Hz,

$X_L \propto f$

$$X_L' = X_L \times \frac{50}{100} = \frac{X_L}{2} = \frac{R}{2}$$

So, $$I' = \frac{V_{in}}{\sqrt{R^2 + (X_L')}}$$

$$= \frac{V_{in}}{\sqrt{R^2 + \left(\frac{R}{2}\right)^2}} = \frac{2V_{in}}{\sqrt{5}R}$$

$$V_R' = I'R = \left(\frac{2V_{in}}{\sqrt{5}R}\right) R = \frac{2}{\sqrt{5}} V_{in}$$

From equation (i),

$$V_R' = \frac{2}{\sqrt{5}} \times (\sqrt{2}\, u_{rms})$$

$$= \frac{2\sqrt{2}}{\sqrt{5}} u_{rms} = \sqrt{\frac{8}{5}}\, u_{rms}$$

9. (b)

Assuming resistance of the heater = R

(i) When heater connected to 230 V, 50 Hz source, energy consumed by the heater = 2.3 units of 2.3 kWh in 1 hour.

Power consumed by the heater

$$= \frac{\text{energy}}{\text{time period}} = \frac{2.3 \text{ kWh}}{1 \text{ hour}}$$

$$P_1 = 2.3 \text{ kW}$$

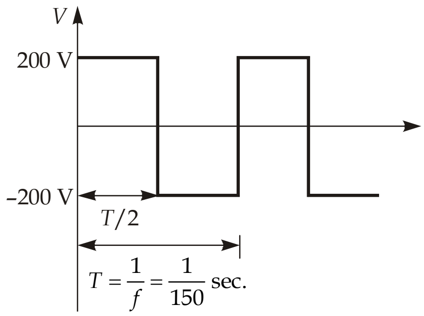
Rms value of the input voltage

$$= V_{rms} = 230 \text{ V}$$

$$P_1 = \frac{V_{rms}^2}{R}$$

$$\Rightarrow 230 \times 10^3 = \frac{230^2}{R} \Rightarrow R = 23\ \Omega$$

(ii) When heater connected to 400 V (peak to peak) square wave source of 150 Hz.



V_{rms} value of the input voltage,

$$V_{rms} = \left[\frac{1}{T}\int_0^T V^2 dt\right]^{1/2}$$

$$= \left[\frac{1}{T}\left\{\int_0^{T/2} 200^2\, dt + \int_{T/2}^{T} (-200)^2\, dt\right\}\right]^{1/2}$$

$$V_{rms} = 200 \text{ V}$$

$$P_2 = \frac{V_{rms}^2}{R} = \frac{200^2}{23} \times 10^{-3} = 1.739 \text{ kW}$$

10. (b)

$$V_s = 1 \sin t \equiv V_m \sin \omega t$$

$$V_m = 1 \text{ V and } \omega = 1 \text{ rad/sec.}$$

Impedance of the branch containing inductor and capacitor,

$$Z = j(X_L - X_C)$$

$$= j\left(\omega L - \frac{1}{\omega C}\right)$$

$$= j\left(1 \times 1 - \frac{1}{1 \times 1}\right) = 0$$

So, this branch is short-circuit and the whole current flow through it,

$$i(t) = \frac{1.0 \sin t}{1} = 1.0 \sin t$$

Rms value of the current = $\frac{1}{\sqrt{2}}$ A

11. **(b)**

$$V(t) = 100\sqrt{2}\cos(100\pi t)$$

Voltage represented in phasor form,

$$V_{ph} = V_{rms}\angle\phi$$

$$V_{ph} = \frac{100\sqrt{2}}{\sqrt{2}}\angle 0°$$

$$i(t) = 10\sqrt{2}\sin\left(100\pi t + \frac{\pi}{4}\right)$$

$$i(t) = 10\sqrt{2}\cos\left(100\pi t + \frac{\pi}{4} - \frac{\pi}{2}\right)$$

$$I_{ph} = \frac{10\sqrt{2}}{\sqrt{2}}\angle\left(\frac{\pi}{4} - \frac{\pi}{2}\right) = 10\angle\left(-\frac{\pi}{4}\right) \text{ A}$$

12. **(b)**

Power supplied by the source = $V_s I_s \cos\phi$

where, ϕ = angle between V_s and $I_s = \frac{\pi}{4}$

Inductor and capacitor do not consume power. Therefore, power dissipated in R = Power supplied by the source

$$P_R = V_s I_s \cos\phi$$

$$= 1 \times \sqrt{2} \times \cos\frac{\pi}{4}$$

$$= \sqrt{2} \times \frac{1}{\sqrt{2}} = 1 \text{ W}$$

13. **(d)**

Using KCL,

$$-I_s + I_{RL} + I_C = 0$$

$$\Rightarrow \quad I_C = I_s - I_{RL}$$

$$= \sqrt{2}\angle\frac{\pi}{4} - \sqrt{2}\angle -\frac{\pi}{4}$$

$$= 2\angle 90° = +j2 \text{ A}$$

14. **(b)**

$$i = 5\cos(100\pi t + 100° \text{ A})$$

$$= 5\angle 100° \text{ A}$$

$$Z = (4 - j3)\ \Omega$$

$$= 5\angle -36.87°\ \Omega$$

$$v = iZ = 25\angle 63.13° \text{ V}$$

The average power is,

$$P = \frac{1}{2}V_m I_m \cos\phi$$

$$= \frac{1}{2} \times 25 \times 5 \times \cos(36.87°)$$

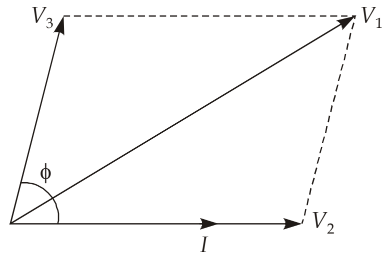
$$= \frac{1}{2} \times 25 \times 5 \times \frac{4}{5} = 50 \text{ W}$$

Alternate method:

$$P = |I_{rms}|^2 R$$

$$P = \left(\frac{5}{\sqrt{2}}\right)^2 \times 4 = 50$$

15. **(a)**



$$V_1^2 = V_2^2 + V_3^2 + 2V_2V_3\cos\phi$$

$$(220)^2 = (122)^2 + (136)^2 + 2 \times 122 \times 136 \times \cos\phi$$

$$\Rightarrow \quad \cos\phi = 0.45$$

16. **(b)**

Given, $\quad R_L = 5\ \Omega$

$$\therefore \quad \cos\phi = \frac{R_L}{|Z|}$$

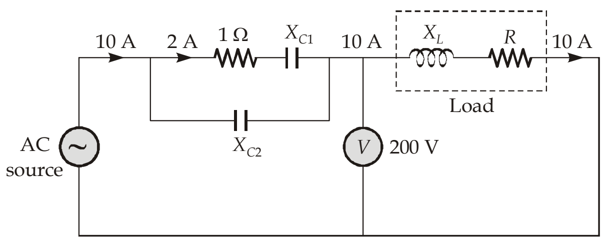
$$\Rightarrow \quad |Z| = \frac{5}{0.45} = 11.11$$

Power consumed by load,

$$P_L = \left(\frac{V_3}{|Z|}\right)^2 R_L$$

$$= \left(\frac{136}{11.11}\right)^2 \times 5 = 749.1 \simeq 750 \text{ W}$$

17. **Sol.**



Given, total power dissipated in the circuit

= 1 kW = 1000 Watt

$\therefore \quad 2^2 \times 1 + 10^2 \times R = 100$

or, $\quad R = \dfrac{998}{100} = 9.98\ \Omega$

Also, voltage drop across R,

$$V_R = IR = 10 \times 9.98$$
$$= 99.8 \text{ Volt}$$

Voltage drop across load,

$$V = 200 \text{ Volt} = \sqrt{V_R^2 + V_{XL}^2}$$

$\therefore$ Voltage drop across inductor,

$$V_{XL} = \sqrt{V^2 - V_R^2}$$
$$= \sqrt{(200)^2 - (99.8)^2}$$
$$= 173.32 \text{ Volt}$$

Now, $\quad V_{XL} = IX_L \text{ or } \dfrac{V_{XL}}{I}$

$$= \frac{173.32}{10} = 17.332\ \Omega$$

$\therefore \quad X_L = 17.332\ \Omega$

18. Sol.

The average power consumed by the load =

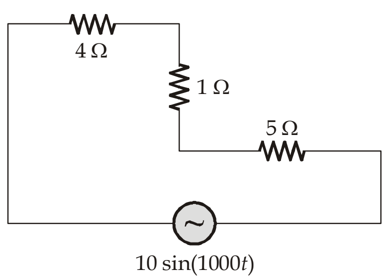
$$P = V_1 I_1 \cos\phi_1$$
$$= \frac{100}{\sqrt{2}} \cdot \frac{10}{\sqrt{2}} \cos 60^\circ = 250 \text{ W}$$

19. (*)

All answer are wrong, answer given by IISc is (c).

20. Sol.

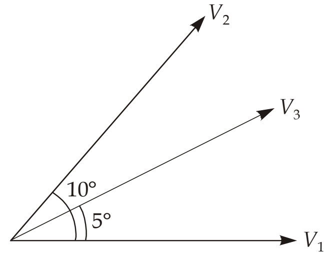
If we observe the parallel LC combination we get that at $\omega = 1000$ rad/sec the parallel LC is at resonance thus it is open-circuited. The circuit given in question can be redrawn as,



So, $\quad I = \dfrac{10 \sin 1000t}{10} = \sin 100t$

So peak value is 1 Amp.

21. (c)



$$V_2 : \frac{\pi}{18} = \frac{180^\circ}{18} = 10^\circ$$
$$V_3 : \frac{\pi}{36} = \frac{180^\circ}{36} = 5^\circ$$

V_2 leads V_1 and V_3.

So, V_2 is a source, V_1 and V_3 are absorbing.

Hence, $\quad P_2 > 0,\ P_1, P_3 < 0$

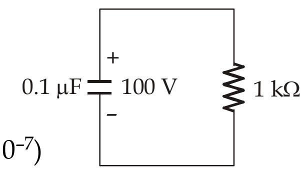
22. Sol.

Given that,

$$v(t) = 5 - 10 \cos(\omega t + 60^\circ)$$
$$i(t) = 5 + X \cos(\omega t - 0^\circ)$$
$$P_{req} = 0$$
$$0 = 5 \times 5 + \frac{1}{2}[(-10)(X)\cos(60^\circ)]$$
$$-25 = \frac{1}{2}[(-10)(X)\cos(60^\circ)]$$
$$X = 10$$

23. Sol.

$$v_c(t) = V_o e^{-t/\tau}$$
$$V_o = 100 \text{ V}$$
$$\tau = RC$$
$$= (10^3)(10^{-7})$$
$$= 10^{-4} \text{ sec}$$



$\therefore \quad v_c(t) = 100 e^{-10^4 t}$ V

Let the time required by the voltage across the capacitor to drop to 1 V is t_1.

$\therefore \quad v_c(t_1) = 100 e^{-10^4 t_1},\ v_c(t_1) = 1 \text{ V}$

$\Rightarrow \quad 1 = 100 e^{-10^4 t_1}$

$$e^{-10^4 t_1} = 0.01$$
$$t_1 = 0.46 \text{ msec}$$

□□□□

3 Network Theorems

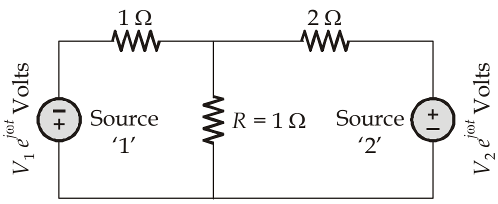
ELECTRONICS ENGINEERING
(GATE Previous Years Solved Papers)

Q.1 If an impedance Z_L is connected across voltage source V with source impedance Z_s, then for maximum power transfer the load impedance must be equal to

(a) source impedance Z_s
(b) complex conjugate of Z_s
(c) real part of Z_s
(d) imaginary part of Z_s

[EC-1988 : 2 Marks]

Q.2 In the circuit of figure, the power dissipated in the resistor R is a 1 W when only source '1' is present and '2' is replaced by a short. The power dissipated in the same resistor R is 4 W when only source '2' is present and '1' is replaced by a short. When both the sources '1' and '2' are present, the power dissipated in R will be



(a) 1 W (b) 3 W
(c) 4 W (d) 5 W

[EC-1989 : 2 Marks]

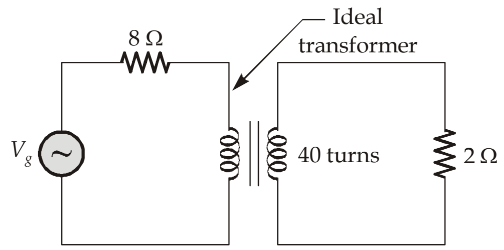
Q.3 A load, $Z_L = R_L + jX_L$ is to be matched, using an ideal transformer, to a generator of internal impedance, $Z_s = R_s + jX_s$. The turns ratio of the transformer required is

(a) $\sqrt{|Z_L / Z_s|}$ (b) $\sqrt{|R_L / R_s|}$

(c) $\sqrt{|R_L / Z_s|}$ (d) $\sqrt{|R_L / Z_s|}$

[EC-1989 : 2 Marks]

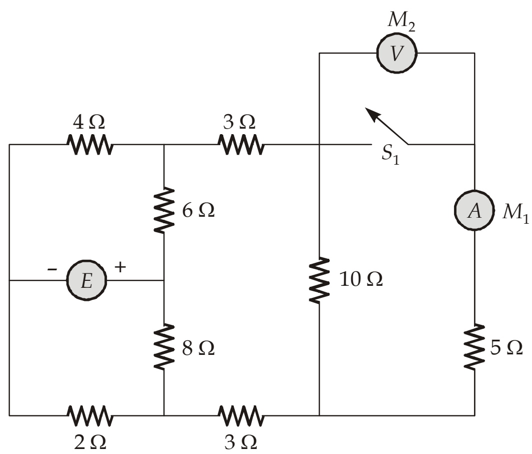
Q.4 If the secondary winding of the ideal transformer shown in the circuit of figure has 40 turns, the number of turns in the primary winding for maximum power transfer to the 2 Ω resistor will be



(a) 20 (b) 40
(c) 80 (d) 160

[EC-1993 : 1 Mark]

Q.5 In the circuit of figure , when switch S_1 is closed, the ideal ammeter M_1 reads 5 A. What will the ideal voltmeter M_2 read when S_1 is kept open? (The value of E is not specified).

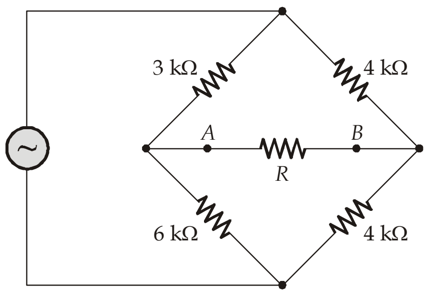


[EC-1993 : 2 Marks]

Q.6 A generator of internal impedance, Z_G delivers maximum power to a load impedance, Z_L only if Z_L = _______ .

[EC-1994 : 1 Mark]

Q.7 The value of the resistance, R connected across the terminals, A and B (ref. figure), which will absorb the maximum power, is



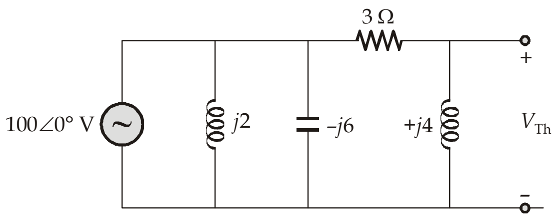
(a) 4.00 kΩ (b) 4.11 kΩ
(c) 8.00 kΩ (d) 9.00 kΩ

[EC-1995 : 1 Mark]

Q.8 Superposition theorem is not applicable to networks containing
(a) non-linear elements
(b) dependent voltage sources
(c) dependent current sources
(d) transformers

[EC-1998 : 1 Mark]

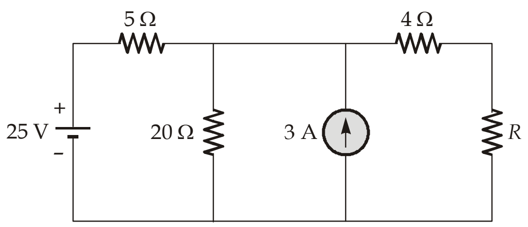
Q.9 The Thevenin equivalent voltage V_{Th} appearing between the terminals A and B of the network shown in the figure is given by



(a) $j16(3 - j4)$ (b) $j16(3 + j4)$
(c) $16(3 + j4)$ (d) $16(3 - j4)$

[EC-1999 : 2 Marks]

Q.10 The value of R (in Ω) required for maximum power transfer in the network shown in the figure is



(a) 2 (b) 4
(c) 8 (d) 16

[EC-1999 : 2 Marks]

Q.11 Use the data of the Fig. (a). The current 'i' in the circuit of the Fig. (b).

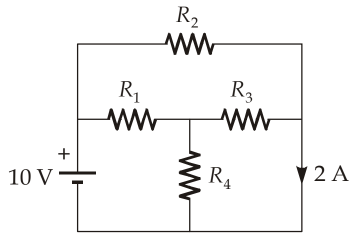


Fig. (a)

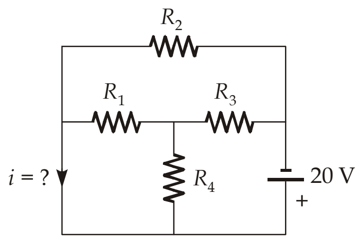
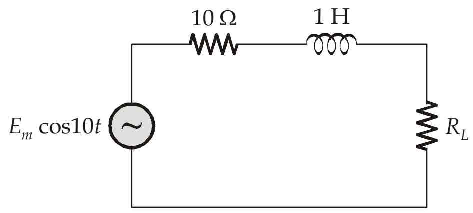


Fig. (b)

(a) –2 A (b) 2 A
(c) –4 A (d) +4 A

[EC-2000 : 2 Marks]

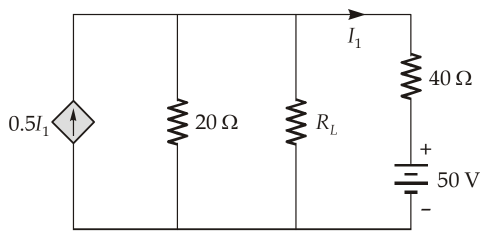
Q.12 In the figure, the value of the load resistor R which maximizes the power delivered to it is



(a) 14.14 Ω (b) 10 Ω
(c) 200 Ω (d) 28.28 Ω

[EC-2001 : 2 Marks]

Q.13 In the network of the figure, the maximum power is delivered to R_L if its value is



(a) 16 Ω (b) $\frac{40}{3}$ Ω

(c) 60 Ω (d) 20 Ω

[EC-2002 : 2 Marks]

Q.14 A source of angular frequency 1 rad/sec has a source impedance consisting of 1 Ω resistance in series with 1 H inductance. The load that will obtain the maximum power transfer is

(a) 1 Ω resistance.

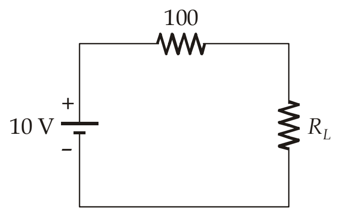
(b) 1 Ω resistance in parallel with 1 H inductance.

(c) 1 Ω resistance in series with 1 F capacitor.

(d) 1 Ω resistance in parallel with 1 F capacitor.

[EC-2003 : 1 Mark]

Q.15 The maximum power that can be transferred to the load resistor R_L from the voltage source in the figure is

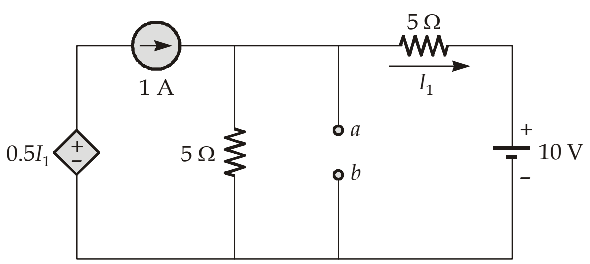


(a) 1 W (b) 10 W

(c) 0.25 W (d) 0.5 W

[EC-2005 : 1 Mark]

Q.16 For the circuit shown in the figure, Thevenin's voltage and Thevenin's equivalent resistance at terminals *a-b* is



(a) 5 V and 2 Ω (b) 7.5 V and 2.5 Ω

(c) 4 V and 2 Ω (d) 3 V and 2.5 Ω

[EC-2005 : 2 Marks]

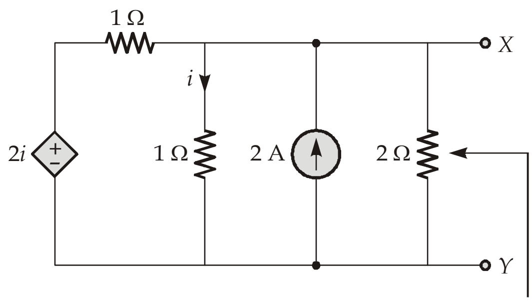
Q.17 An independent voltage source in series with an impedance $Z_s = R_s + jX_s$ delivers a maximum average power to a load impedance Z_L when

(a) $Z_L = R_s + jX_s$ (b) $Z_L = R_s$

(c) $Z_L = jX_s$ (d) $Z_L = R_s - jX_s$

[EC-2007 : 1 Mark]

Q.18 For the circuit shown in the figure, the Thevenin voltage and resistance looking into *X-Y* are

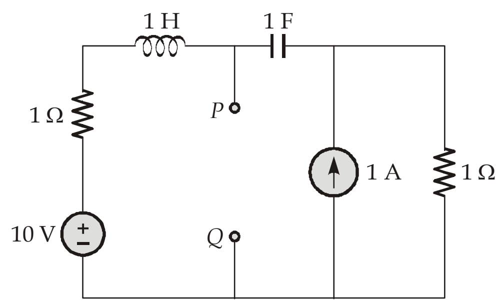


(a) $\frac{4}{3}$ V, 2 Ω (b) 4 V, $\frac{2}{3}$ Ω

(c) $\frac{4}{3}$ V, $\frac{2}{3}$ Ω (d) 4 V, 2 Ω

[EC-2007 : 2 Marks]

Q.19 The Thevenin equivalent impedance Z_{Th} between the nodes *P* and *Q* in the following circuit is

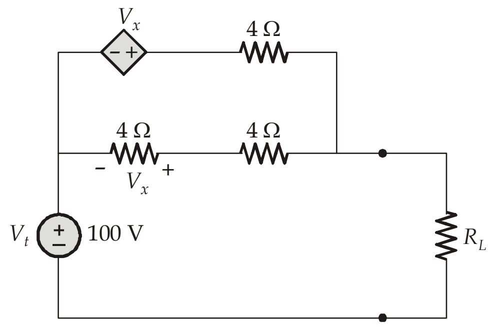


(a) 1 (b) $1+s+\frac{1}{s}$

(c) $2+s+\frac{1}{s}$ (d) $\frac{s^2+s+1}{s^2+2s+1}$

[EC-2008 : 2 Marks]

Q.20 In the circuit shown, what value of R_L maximizes the power delivered to R_L?

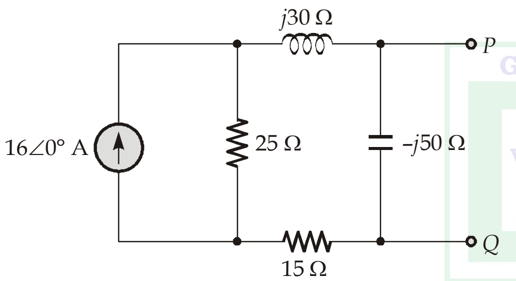


(a) 2.4 Ω (b) $\frac{8}{3}$ Ω

(c) 4 Ω (d) 6 Ω

[EC-2009 : 2 Marks]

Q.21 In the circuit shown below, the Norton equivalent current in amperes with respect to the terminals P and Q is

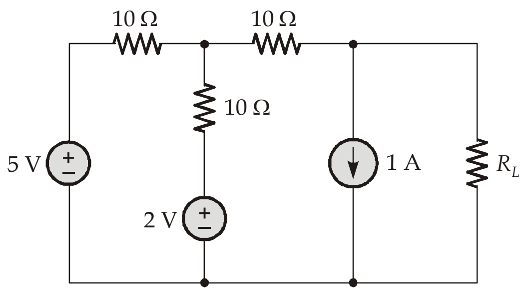


(a) $6.4 - j4.8$ (b) $6.56 - j7.87$

(c) $10 + j0$ (d) $16 + j0$

[EC-2011 : 1 Mark]

Q.22 In the circuit shown below, the value of R_L such that the power transferred to R_L is maximum is

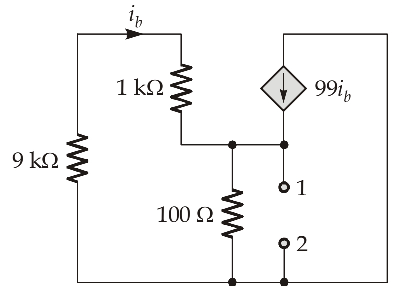


(a) 5 Ω (b) 10 Ω

(c) 15 Ω (d) 20 Ω

[EC-2011 : 1 Mark]

Q.23 The impedance looking into nodes 1 and 2 in the given circuit is

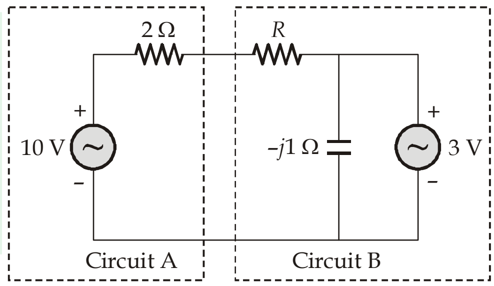


(a) 50 Ω (b) 100 Ω

(c) 5 kΩ (d) 10.1 kΩ

[EC-2012 : 1 Mark]

Q.24 Assuming both the voltage sources are in phase, the value of R for which maximum power is transferred from circuit A to circuit B is,



(a) 0.8 Ω (b) 1.4 Ω

(c) 2 Ω (d) 2.8 Ω

[EC-2012 : 2 Marks]

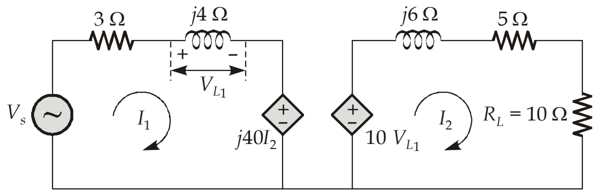
Q.25 A source $v_s(t) = V\cos 100\pi t$ has an internal impedance of $(4 + j3)$ Ω. If a purely resistive load connected to this source has to extract the maximum power out of the source, its value (in Ω) should be

(a) 3 (b) 4

(c) 5 (d) 7

[EC-2013 : 1 Mark]

Q.26 In the circuit shown below, if the source voltage $V_s = 100\angle 53.13$ V, then the Thevenin's equivalent voltage (in Volts) as seen by the load resistance R_L is



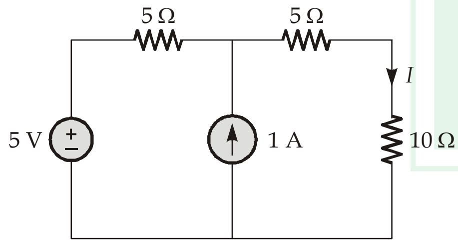
(a) $100\angle 90°$ (b) $800\angle 0°$
(c) $800\angle 90°$ (d) $100\angle 60°$

[EC-2013 : 2 Marks]

Q.27 Norton's theorem states that a complex network connected to a load can be replaced with an equivalent impedance
(a) in series with a current source
(b) in parallel with a voltage source
(c) in series with a voltage source
(d) in parallel with a current source

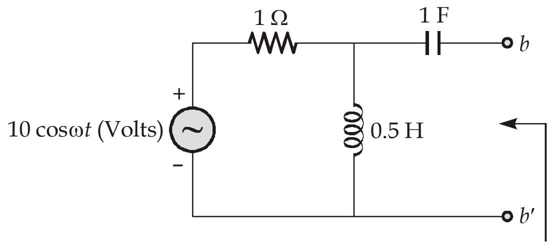
[EC-2014 : 1 Mark]

Q.28 In the figure shown, the value of the current I (in Amperes) is _____ .



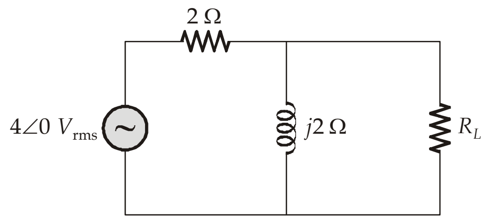
[EC-2014 : 1 Mark]

Q.29 In the circuit shown in the figure, the angular frequency ω (in rad/sec), at which the Norton equivalent impedance as seen from terminals b-b' is purely resistive, is ________ .



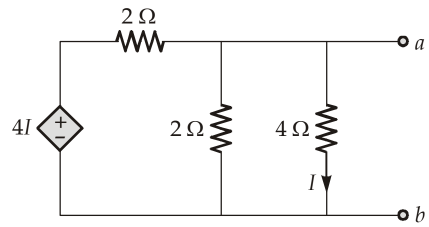
[EC-2014 : 2 Marks]

Q.30 In the given circuit, the maximum power (in Watts) that can be transferred to the load R_L is _____ .



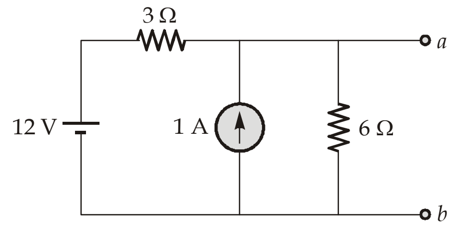
[EC-2015 : 2 Marks]

Q.31 In the circuit shown, the Norton equivalent resistance (in Ω) across terminals a-b is ____ .



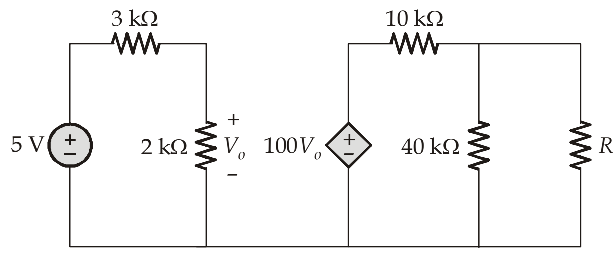
[EC-2015 : 2 Marks]

Q.32 For the current shown in the figure, the Thevenin equivalent voltage (in Volts) across terminals a-b is _____ .



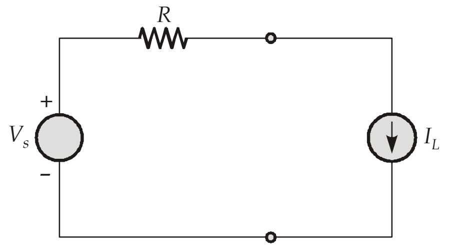
[EC-2015 : 1 Mark]

Q.33 In the circuit shown in the figure, the maximum power (in Watt) delivered to the resistor R is _______ .



[EC-2016 : 2 Marks]

Q.34 In the circuit shown below, V_s is constant voltage source and I_L is a constant current load. The value of I_L that maximizes the power absorbed by the constant current load is

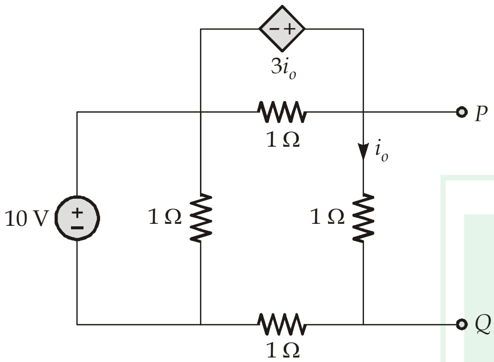


(a) $\frac{V_s}{4R}$ (b) $\frac{V_s}{2R}$

(c) $\frac{V_s}{R}$ (d) ∞

[EC-2016 : 1 Mark]

Q.35 Consider the circuit shown in the figure.

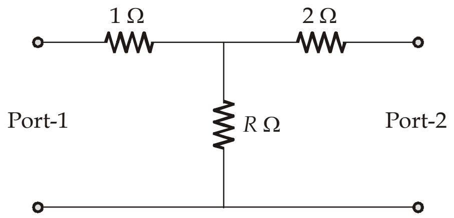


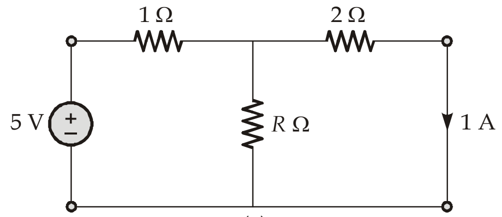
The Thevenin equivalent resistance (in Ω) across P-Q is ______ .

[EC-2017 : 2 Marks]

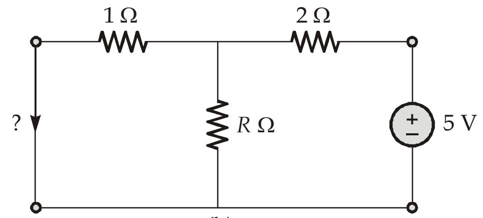
Q.36 Consider the two-port resistive network shown in the figure. When an excitation of 5 V is applied across port-1 and port-2 is shorted, the current through the short-circuit at port-2 is measured to be 1 A [see (a) in the figure].

Now, if an excitation of 5 V is applied across port-2, and port-1 is shorted [see (b) in the figure], what is the through the short-circuit at port-1?





(a)



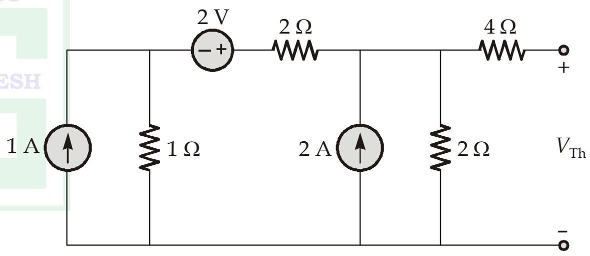
(b)

(a) 0.5 A (b) 2.5 A

(c) 1 A (d) 2 A

[EC-2019 : 1 Mark]

Q.37 In the circuit shown below, the Thevenin voltage V_{Th} is



(a) 2.8 V (b) 3.6 V

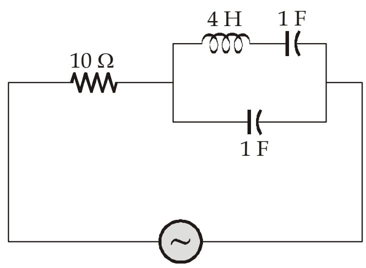
(c) 2.4 V (d) 4.5 V

[EC-2020 : 1 Mark]

ELECTRICAL ENGINEERING
(GATE Previous Years Solved Papers)

SECTION-A

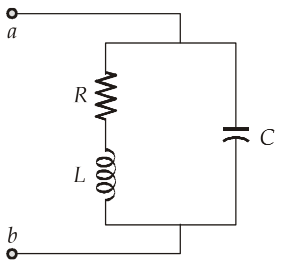
Q.1 The following circuit shown in figure resonates at



(a) all frequencies (b) 0.5 rad/sec
(c) 5 rad/sec (d) 1 rad/sec

[EE-1993 : 1 Mark]

Q.2 At resonance, the given parallel circuit constituted by an iron-cored coil and a capacitor behaves like



(a) an open-circuit
(b) a short-circuit
(c) a pure resistor of value R
(d) a pure resistor of value much higher than R

[EE-1994 : 1 Mark]

Q.3 A series RLC circuit has the following parameter values: $R = 10\ \Omega$, $L = 0.01$ H, $C = 100$ mF. The Q-factor of the circuit at resonance is ______ .

[EE-1995 : 1 Mark]

Q.4 A coil (which can be modeled as a series RL circuit) has been designed for high Q-performance at a rated voltage and a specified frequency. If the frequency of operation is doubled and the coil is operated at the same rated voltage then the Q-factor and the active power P consumed by the coil will be affected as follows:

(a) P is doubled, Q is halved.
(b) P is halved, Q is doubled.
(c) P remains constant, Q is doubled.
(d) P decreased 4 times, Q is doubled.

[EE-1996 : 2 Marks]

Q.5 A sinusoidal source of voltage V and frequency f is connected to a series circuit of variable resistance R and a fixed reactance X. The locus of the tip of the current phasor I as R is, varied from 0 to ∞ is

(a) a semicircle with a diameter of V/X.
(b) a straight line with a slope of R/X.
(c) an ellipse with V/R as major axis.
(d) a circle of radius R/X and origin at $(0, V/2)$.

[EE-1998 : 1 Mark]

Q.6 A circuit with a resistor, inductor and capacitor in series is resonant at f_0 Hz. If all the component values are now doubled, the new resonant frequency is

(a) $2f_0$ (b) still f_0
(c) $\frac{f_0}{4}$ (d) $\frac{f_0}{2}$

[EE-1998 : 1 Mark]

Q.7 A fixed capacitor of reactance $-j0.02\ \Omega$ is connected in parallel across a series combination of a fixed inductor of reactance $j0.01\ \Omega$ and a variable resistance R. As R is varied from zero to infinity, the locus diagram of the admittance of this RLC circuit will be

(a) a semi-circle of diameter $j100$ and center at zero.
(b) a semi-circle of diameter $j50$ and center at zero.
(c) a straight line inclined at an angle.
(d) a straight line parallel to the x-axis.

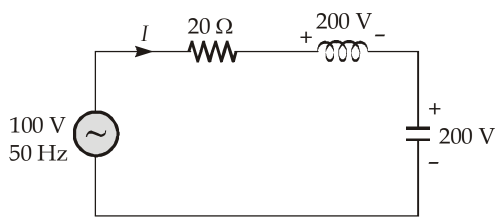
[EE-1999 : 2 Marks]

Q.8 A series RLC circuit when excited by a 10 V sinusoidal voltage source of variable frequency, exhibits resonance at 100 Hz and has a 3 dB bandwidth of 5 Hz. The voltage across the inductor L at resonance is

(a) 10 V (b) $10\sqrt{2}$ V
(c) $\frac{10}{\sqrt{2}\ \text{V}}$ (d) 200 V

[EE-1999 : 1 Mark]

Q.9 The current in the circuit shown in figure is



(a) 5 A (b) 10 A
(c) 15 A (d) 25 A

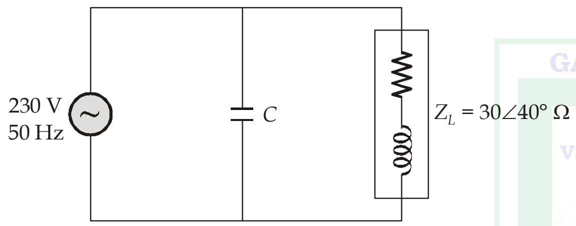
[EE-1999 : 1 Mark]

Q.10 In a series RLC circuit at resonance, the magnitude of the voltage developed across the capacitor

(a) is always zero.
(b) can never be greater than the input voltage.
(c) can be greater than the input voltage, however it is 90° out of phase with the input voltage.
(d) can be greater than the input voltage, and is in phase with the input voltage.

[EE-2000 : 1 Mark]

Q.11 In the circuit shown in figure, what value of C will cause a unity power factor at the ac source.



(a) 68.1 μF (b) 165 μF
(c) 0.681 μF (d) 6.81 μF

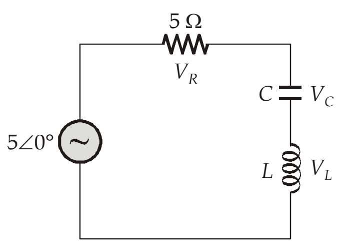
[EE-2002 : 2 Marks]

Q.12 A series RLC circuit has $R = 50\ \Omega$, $L = 100\ \mu H$ and $C = 1\ \mu F$. The lower half power frequency of the circuit is

(a) 30.55 kHz (b) 3.055 kHz
(c) 51.92 kHz (d) 1.92 kHz

[EE-2002 : 2 Marks]

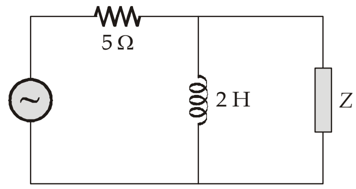
Q.13 In the circuit of figure, the magnitudes of V_L and V_C are twice that of V_R. Given that, $f = 50$ Hz, the inductance of the coil is



(a) 2.14 mH (b) 5.30 mH
(c) 31.8 mH (d) 1.32 mH

[EE-2003 : 2 Marks]

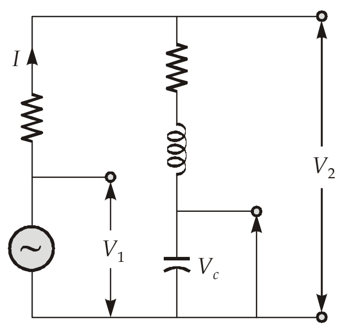
Q.14 The value of Z in figure which is most appropriate to cause parallel resonance at 500 Hz is



(a) 125.00 mH (b) 304.20 μF
(c) 2.0 μF (d) 0.05 μF

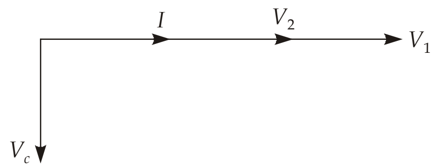
[EE-2004 : 1 Mark]

Q.15 The circuit shown in the figure is energized by a sinusoidal voltage source V_1 at a frequency which causes resonance with a current of I.

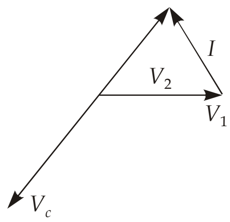


The phasor diagram which is applicable to this circuit is

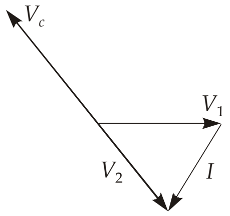
(a)



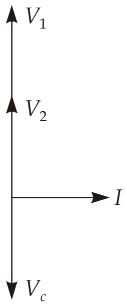
(b)



(c)

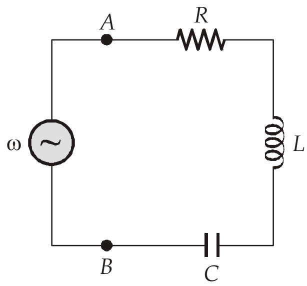


(d)

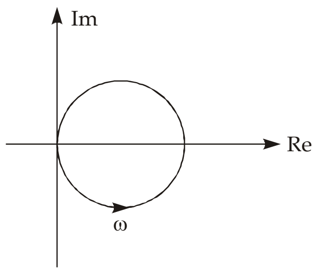


[EE-2006 : 2 Marks]

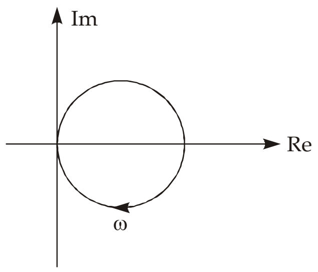
Q.16 The RLC series circuit shown is supplied from a variable frequency voltage source. The admittance locus of the RLC network at terminals AB for increasing frequency ω is



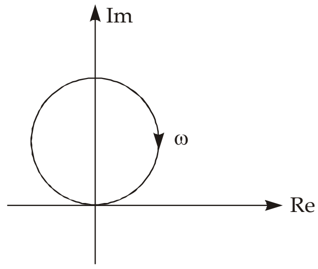
(a)



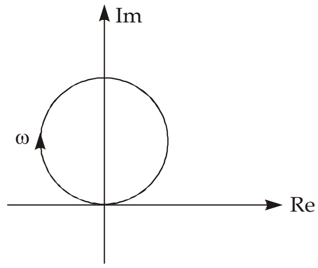
(b)



(c)

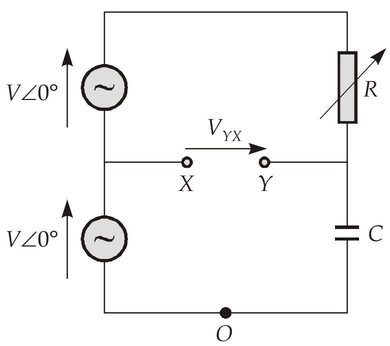


(d)

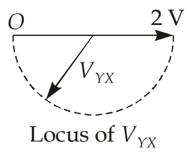


[EE-2007 : 2 Marks]

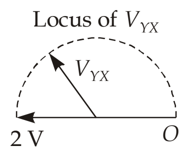
Q.17 In the figure given below all phasors are with reference to the potential at point 'O'. The locus of voltage phasor V_{YX} as R is varied from zero to infinity is shown by



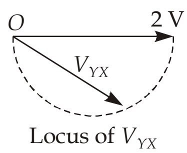
(a)



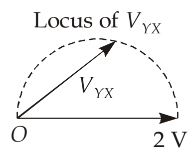
(b)



(c)

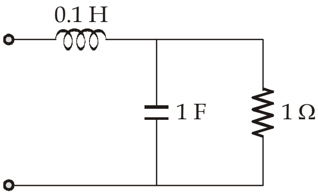


(d)



[EE-2007 : 2 Marks]

Q.18 The resonant frequency for the given circuit will be



(a) 1 rad/sec (b) 2 rad/sec
(c) 3 rad/sec (d) 4 rad/sec

[EE-2008 : 2 Marks]

Q.19 Two magnetically uncoupled inductive coils have Q-factors q_1 and q_2 at the chosen operating frequency. Their respectively resistances are R_1 and R_2. When connected in series, their effective Q-factor at the same operating frequency is

(a) $q_1 + q_2$ (b) $\left(\frac{1}{q_1}\right)+\left(\frac{1}{q_2}\right)$

(c) $\left(\frac{q_1R_1+q_2R_2}{R_1+R_2}\right)$ (d) $\left(\frac{q_1R_2+q_2R_1}{R_1+R_2}\right)$

[EE-2013 : 2 Marks]

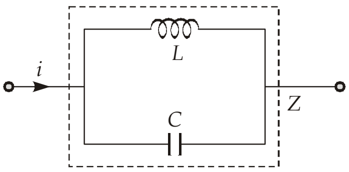
Q.20 A series RLC circuit is observed at two frequencies. At ω_1 = 1 k-rad/s, we note that source voltage $V_1 = 100\angle 0°$ V results in a current $I_1 = 0.03\angle 31°$ A.

At ω_2 = 2 k-rad/s the source voltage $V_2 = 100\angle 0°$ V results i a current $I_2 = 2\angle 0°$ A. The closest values for R, L, C out of the following options are:

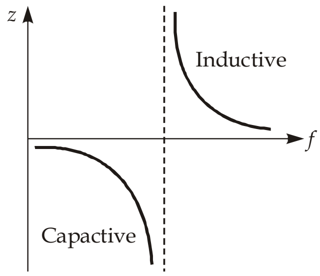
(a) $R = 50\ \Omega, L = 25$ mH, $C = 10\ \mu$F
(b) $R = 50\ \Omega, L = 10$ mH, $C = 25\ \mu$F
(c) $R = 50\ \Omega, L = 50$ mH, $C = 5\ \mu$F
(d) $R = 50\ \Omega, L = 5$ mH, $C = 50\ \mu$F

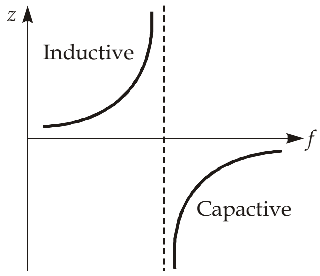
[EE-2014 : 2 Marks]

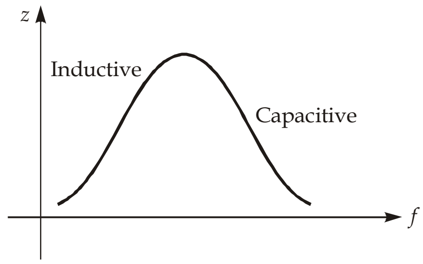
Q.21 An inductor is connected in parallel with a capacitor as shown in the figure.

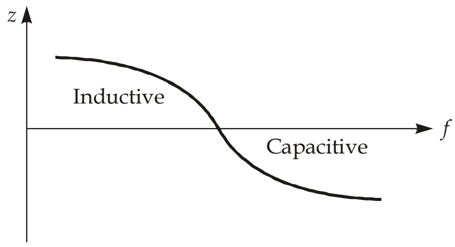


As the frequency of current i is increased, the impedance (z) of the network varies as,

(a)


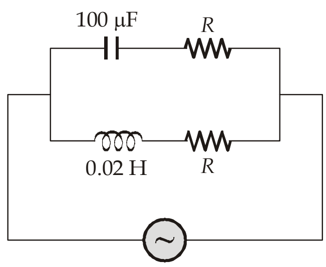
(b)


(c)


(d)


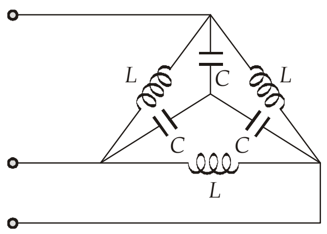
[EE-2015 : 1 Mark]

Q.22 The circuit below is excited by a sinusoidal source. The value of R in Ω, for which the admittance of the circuit becomes a pure conductance at all frequencies is _______ .



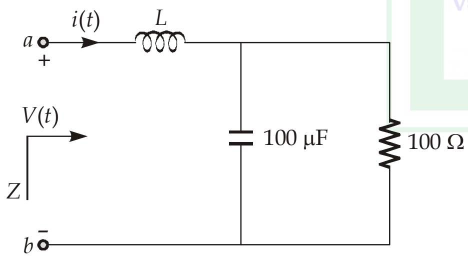
[EE-2016 : 2 Marks]

Q.23 In the balanced 3-phase, 50 Hz circuit shown below, the value of inductance (L) is 10 mH. The value of the capacitance (C) for which all the line currents are zero, in milli-farads, is ________ .



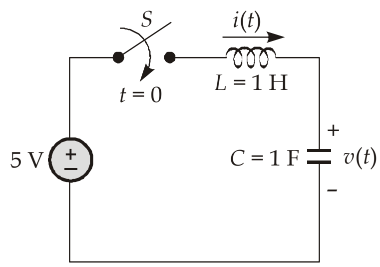
[EE-2016 : 2 Marks]

Q.24 The voltage $v(t)$ across the terminals a and b shown in the figure, is a sinusoidal voltage having a frequency $\omega = 100$ rad/sec. When the inductor current $i(t)$ is in phase with the voltage $v(t)$, the magnitude of the impedance Z (in Ω) seen between the terminals a and b is ______ (upto 2 decimal places).

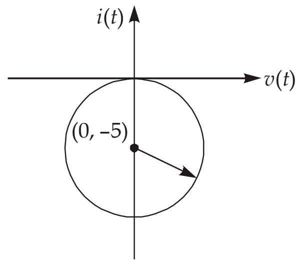


[EE-2018 : 2 Marks]

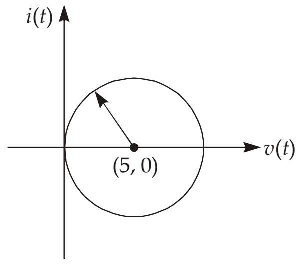
Q.25 A dc voltage source is connected to a series L-C circuit by turning on the switch S at time $t = 0$ as shown in the figure. Assume $i(0) = 0$, $v(0) = 0$. Which one of the following circular loci represents the plot of $i(t)$ versus $v(t)$?



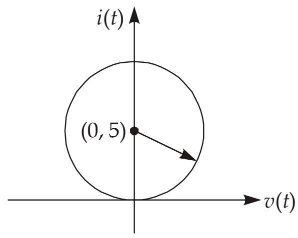
(a)



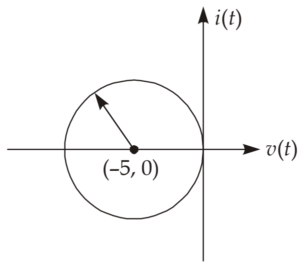
(b)



(c)



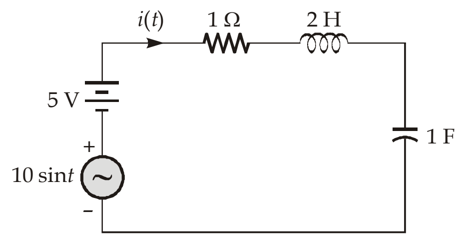
(d)



[EE-2018 : 2 Marks]

SECTION-B

Q.1 In the following circuit, $i(t)$ under steady-state is



(a) zero (b) 5

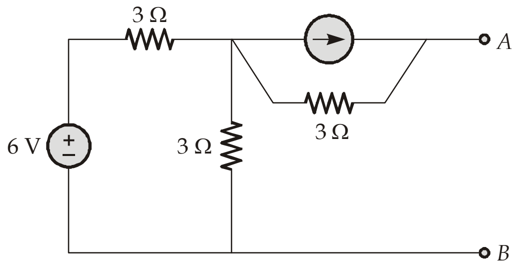
(c) 7.07 sin$t$ (d) 7.07 sin(t – 45°)

[EE-1993 : 1 Mark]

Q.2 Superposition principle is not applicable to a network containing time-varying resistors. (True/False)

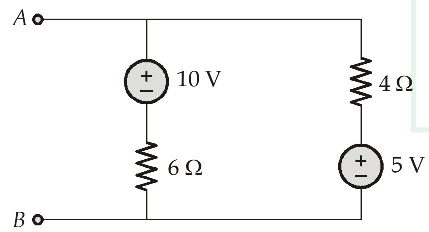
[EE-1994 : 1 Mark]

Q.3 For the circuit shown in figure. The Norton equivalent source current values is ________ . A and its resistance is ______ Ω.



[EE-1997 : 2 Marks]

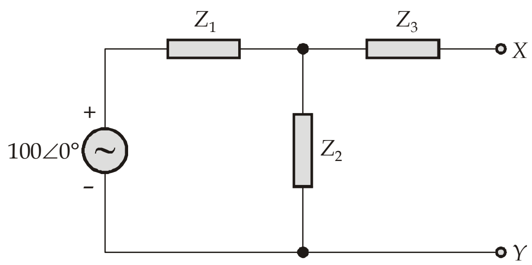
Q.4 Viewed from the terminals A and B, the following circuit shown in figure can be reduced to an equivalent circuit of a single voltage source in series with a single resistor with the following parameters.



(a) 10 Volt source in series with 10 Ω resistor.
(b) 7 Volt source in series with 2.4 Ω resistor.
(c) 15 Volt source in series with 2.4 Ω resistor.
(d) 1 Volt source in series with 10 Ω resistor.

[EE-1998 : 2 Marks]

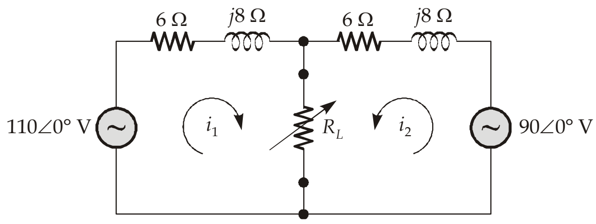
Q.5 In the figure, $Z_1 = 10\angle{-60°}$, $Z_2 = 10\angle 60°$, $Z_3 = 50\angle 53.13°$. Thevenin impedance seen from X-Y is



(a) $56.66\angle 45°$ (b) $60\angle 30°$
(c) $70\angle 30°$ (d) $34.4\angle 65°$

[EE-2003 : 1 Mark]

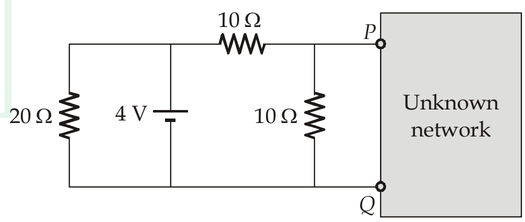
Q.6 Two a.c. sources feed a common variable resistive loads as shown in figure. Under the maximum power transfer condition, the power absorbed by the load resistance R_L is



(a) 2200 W (b) 1250 W
(c) 1000 W (d) 625 W

[EE-2003 : 2 Marks]

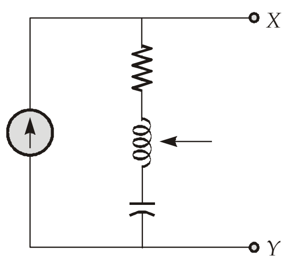
Q.7 In the given figure, the Thevenin's equivalent pair (voltage, impedance), as seen at the terminals P-Q, is given by



(a) (2 V, 5 Ω) (b) (2 V, 7.5 Ω)
(c) (4 V, 5 Ω) (d) (4 V, 7.5 Ω)

[EE-2005 : 2 Marks]

Q.8 In the figure the current source is $1\angle 0$ A, $R = 1\ \Omega$, the impedance are $Z_C = -j\ \Omega$ and $Z_L = 2j\ \Omega$. The Thevenin equivalent looking into the cicuit across XY is,



(a) $5\sqrt{2}\angle 0°$ V, $(1+2j)\ \Omega$

(b) $2\angle 45°$ V, $(1-2j)\ \Omega$

(c) $2\angle 45°$ V, $(1+j)\ \Omega$

(d) $\sqrt{2}\angle 45°$ V, $(1+j)\ \Omega$ **[EE-2006 : 1 Mark]**

Q.9 The Thevenin's equivalent of a circuit operating at ω = 5 rad/sec has $V_{OC} = 3.71\angle -15.9°$ V and $Z_0 = 2.38 - j0.667\ \Omega$. At this frequency, the minimal realization of the Thevenin's impedance will have a

(a) resistor and a capacitor and an inductor.

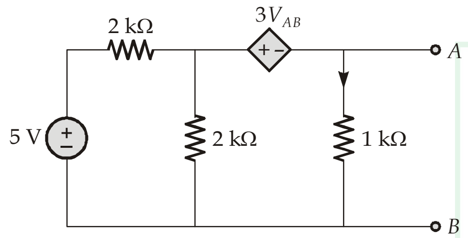
(b) resistor and a capacitor.

(c) resistor and an inductor.

(d) capacitor and an inductor.

[EE-2008 : 1 Mark]

Statement for Linked Answer Questions (10 and 11):



Q.10 For the circuit given above, the Thevenin's resistance across the terminals A and B is

(a) 0.5 kΩ (b) 0.2 kΩ

(c) 1 kΩ (d) 0.11 kΩ

[EE-2009 : 2 Marks]

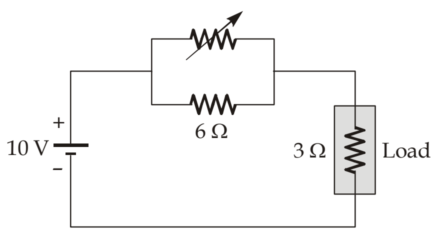
Q.11 For the circuit given above, the Thevenin's voltage across the terminal A and B is

(a) 1.25 V (b) 0.25 V

(c) 1 V (d) 0.5 V

[EE-2009 : 2 Marks]

Q.12 In the circuit given below, the value of 'R' required for the transfer of maximum power to the load having a resistance of 3 Ω is

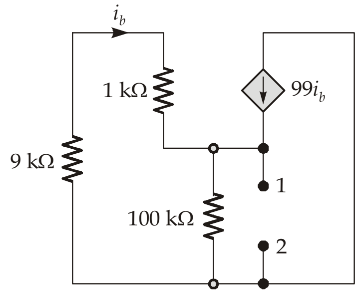


(a) Zero (b) 3 Ω

(c) 6 Ω (d) Infinity

[EE-2011 : 1 Mark]

Q.13 The impedance looking into nodes 1 and 2 in the given circuit is

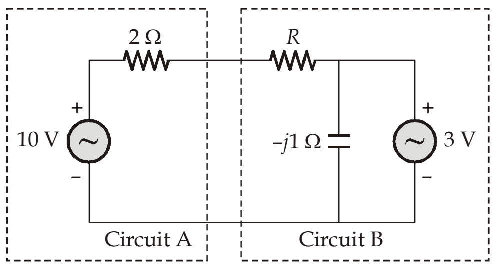


(a) 50 Ω (b) 100 Ω

(c) 5 kΩ (d) 10.1 kΩ

[EE-2012 : 1 Mark]

Q.14 Assuming both the voltage sources are in phase, the value of R for which maximum power is transferred from circuit A to circuit B is



(a) 0.8 Ω (b) 1.4 Ω

(c) 2 Ω (d) 2.8 Ω

[EE-2012 : 2 Marks]

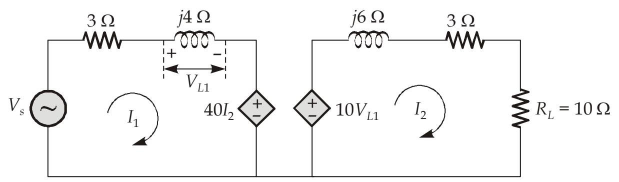
Q.15 A source $v_s(t) = V\cos 100\pi t$ has an internal impedance of $(4 + j3)\ \Omega$. If a purely resistive load connected to this source has to extract the maximum power out of the source, its value (in Ω) should be

(a) 3 (b) 4

(c) 5 (d) 7

[EE-2013 : 1 Mark]

Q.16 In the circuit shown below, if the source voltage $V_s = 100\angle 53.13°$ V, then the Thevenin's equivalent voltage (in Volts) as seen by the load resistance R_L is

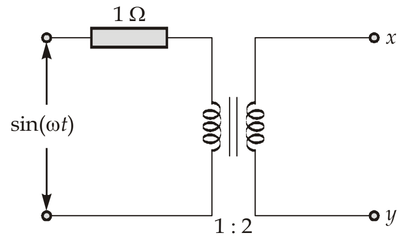


(a) 100∠90° V (b) 800∠0° V

(c) 800∠90° V (b) 100∠60° V

[EE-2013 : 2 Marks]

Q.17 Assuming an ideal transformer, the Thevenin's equivalent voltage and impedance as seen from the terminals x and y for the circuit in figure are



(a) 2 sin(ωt), 4 Ω (b) 1 sin(ωt), 1 Ω

(c) 1 sin(ωt), 2 Ω (d) 2 sin(ωt), 0.5 Ω

[EE-2014 : 1 Mark]

Q.18 A non-ideal voltage source V_s has an internal impedance of Z_s. If a purely resistive load is to be chosen that maximizes the power transferred to the load, its values must be

(a) 0

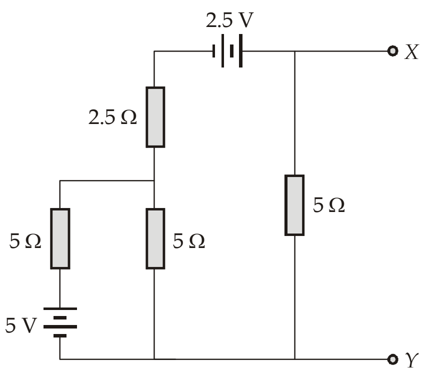
(b) real part of Z_s

(c) magnitude of Z_s

(d) complex conjugate of Z_s

[EE-2014 : 1 Mark]

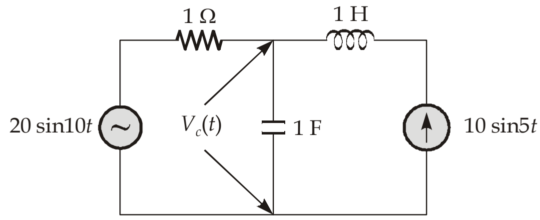
Q.19 The Norton's equivalent source in amperes as seen into the terminals X and Y is ______ .



[EE-2014 : 2 Marks]

Q.20 The voltage across the capacitor, as shown in the figure, is expressed as:

$$V_c(t) = A_1 \sin(\omega_1 t - \theta_1) + A_2 \sin(\omega_2 t - \theta_2)$$



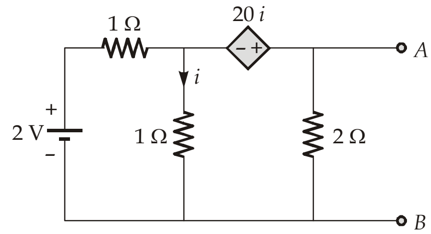
The values of A_1 and A_2 respectively, are

(a) 2.0 and 1.98 (b) 2.0 and 4.20

(c) 2.5 and 3.50 (d) 5.0 and 6.40

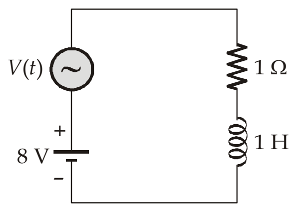
[EE-2014 : 2 Marks]

Q.21 For the given circuit, the Thevenin equivalent is to be determined. The Thevenin voltage, V_{Th} (in Volt), seen from terminal AB is ______ .



[EE-2015 : 1 Mark]

Q.22 The circuit shown in the figure has two sources connected in series. The instantaneous voltage of the AC source (in Volt) is given by $V(t)$ = 12 sin$t$. If the circuit is in steady-state. Then the rms value of the current (in Ampere) flowing in the circuit is ______ .



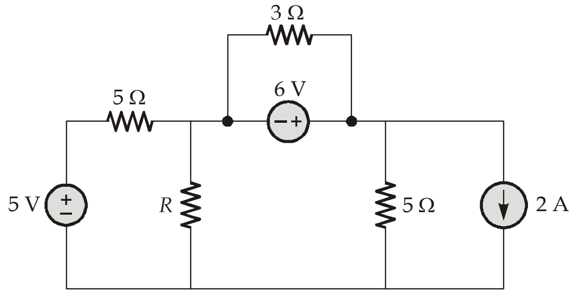
[EE-2015 : 2 Marks]

Q.23 In a linear two-port network, when 10 V is applied to port-1, a current of 4 A flows through port-2 when it is short circuited. When 5 V is applied to port-1, a current of 1.25 A flows through a 1 Ω resistance connected across port-2.

When 3 V is applied to port-1, the current (in Ampere) through a 2 Ω resistance connected across port-2 is ______ .

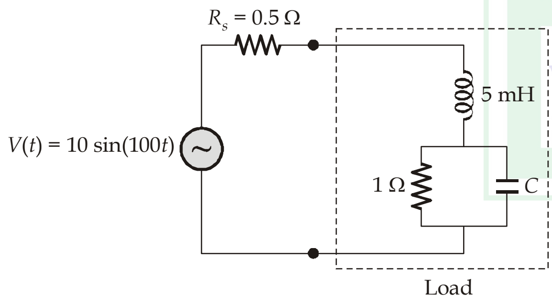
[EE-2015 : 2 Marks]

Q.24 In the circuit shown below, the maximum power transferred to the resistor R is ______ W.



[EE-2017 : 2 Marks]

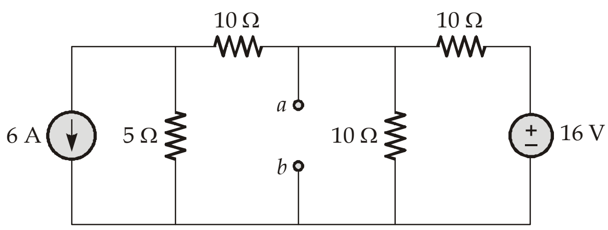
Q.25 In the circuit shown below, the value of capacitor C required for maximum power to be transferred to the load is



(a) 1 nF (b) 1 μF
(c) 1 mF (d) 10 mF

[EE-2017 : 2 Marks]

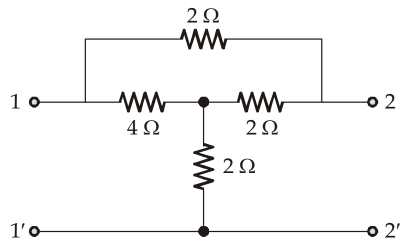
Q.26 For the network given in figure below, the Thevenin's voltage V_{ab} is



(a) –1.5 V (b) –0.5 V
(c) 0.5 V (d) 1.5 V

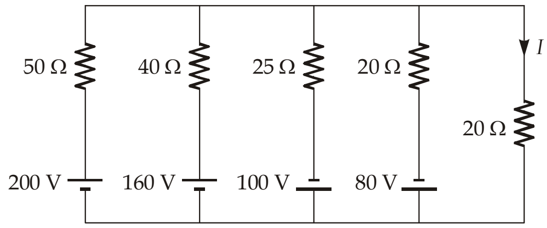
[EE-2017 : 2 Marks]

Q.27 For the given two-port network, the value of transfer impedance Z_{21} (in Ω) is ______ .



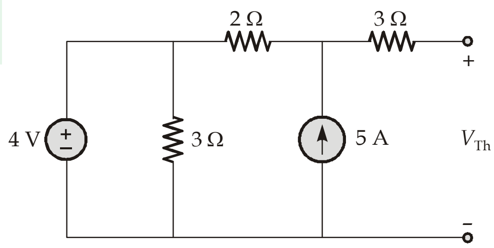
[EE-2017 : 1 Mark]

Q.28 The current I flowing in the circuit shown below (in Ampere), is ______ .



[EE-2019 : 2 Marks]

Q.29 The Thevenin equivalent voltage, V_{Th} (in Volt) (Rounded of to 2 decimal places) of the network shown below, is ______ .



[EE-2020 : 1 Mark]

Q.30 A benchtop dc power supply acts as an ideal 4 A current source as long as its terminal voltage is below 10 V. Beyond this point, it begins to behave as an ideal 10 V voltage source for all load currents going down to 0 A. When connected to an ideal rheostat, find the load resistance value at which maximum power is transferred, and the corresponding load voltage and current.

(a) 2.5 Ω, 4 A, 10 V (b) 2.5 Ω, 4 A, 5 V
(c) Open, 4 A, 0 V (d) Short, ∞ A, 10 V

[EE-2020 : 2 Marks]

❑❑❑❑

Electronics & Electrical Engineering

GATE Previous Years Solved Paper

Answers & Explanations

Answers — EC — Network Theorem

1. (b)	**2.** (a)	**3.** (a)	**4.** (c)	**5.** (5)	**6.** (Sol.)	**7.** (a)	**8.** (a)
9. (a)	**10.** (c)	**11.** (c)	**12.** (a)	**13.** (a)	**14.** (c)	**15.** (c)	**16.** (b)
17. (d)	**18.** (d)	**19.** (a)	**20.** (c)	**21.** (a)	**22.** (c)	**23.** (a)	**24.** (a)
25. (c)	**26.** (c)	**27.** (d)	**28.** (0.5)	**29.** (2)	**30.** (1.649)	**31.** (1.33)	**32.** (10)
33. (0.8)	**34.** (b)	**35.** (–1)	**36.** (c)	**37.** (b)			

Solutions — EC — Network Theorem

1. (b)

According to maximum power transfer theorem,

$$Z_L = Z_S^*$$

2. (a)

$$P_1 = 1\text{ W}; \quad P_2 = 4\text{ W}$$

Since the polarity of both the sources are different,

$$P = (\sqrt{P_1} - \sqrt{P_2})^2$$

$$P = (\sqrt{1} - \sqrt{4})^2 = (1-2)^2$$

$$P = 1\text{ W}$$

3. (a)

$$\frac{Z_L}{Z_S} = \left(\frac{n_2}{n_1}\right)^2$$

$$\frac{n_2}{n_1} = \sqrt{\left|\frac{Z_L}{Z_S}\right|}$$

4. (c)

$$\left(\frac{n_2}{n_1}\right)^2 = \frac{|Z_L|}{|Z_S|}$$

$$\left(\frac{n_2}{n_1}\right)^2 = \frac{2}{8} = \frac{1}{4}$$

$$\frac{n_2}{n_1} = \frac{1}{2}$$

$$n_1 = 2n_2$$

$$= 2 \times 40 = 80$$

5. Sol.

Across switch S_1,

$$I_{SC} = 5\text{ A}$$

$$R_{Th} = [(4||6 + 2||8) + 3 + 3]||10 + 5$$

$$R_{Th} = (2.4 + 1.6 + 3 + 3)||10 + 5$$

$$= 10||10 + 5 = 5 + 5$$

$$R_{Th} = 10\ \Omega$$

$$V_{OC} = V_{AB} = I_{SC} R_{Th} = 5 \times 10 = 50\text{ V}$$

6. Sol.

$$Z_L = Z_G^*$$

$$Z_G = R_G + jX_G$$

$$Z_L = R_G - jX_G$$

7. (a)

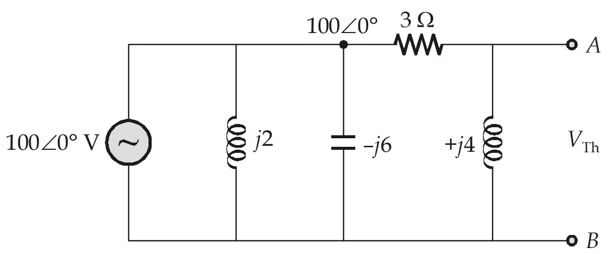
Maximum power will be absorbed by R when $R = R_{Th}$.

$$R_{AB} = R_{Th} = (3||6) + (4||4)$$
$$R_{Th} = R = 2 + 2 = 4\ k\Omega$$

8. (a)

Superposition theorem is applicable for linear network.

9. (a)

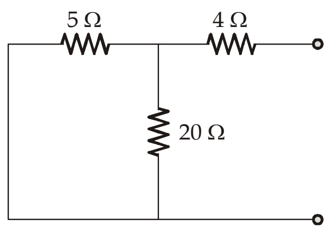


$$V = 100\angle 0°$$

$$\therefore \quad V_{Th} = 100\angle 0° \cdot \frac{4j}{3+4j}$$
$$= \frac{100 \times 4j(3-4j)}{25}$$
$$V_{Th} = 16j(3 - 4j)$$

10. (c)

For MPT, R should be equal to R_{eq} of the circuit seen from the terminal after removing R. Deactivating voltage and current sources.



$$R = (5||20) + 4 = 4 + 4$$
$$= 8\ \Omega$$

11. (c)

This is a reciprocal and linear network. According to reciprocity theorem which states "Two loops A and B of a network N and if an ideal voltage source E in loop E produces a current I in loop B, then interchanging positions an identical source in loop B produces the same current in loop A". Since network is linear, principle of homogeneity holds and so when volt source is doubled, current also doubles with opposite direction.

12. (a)

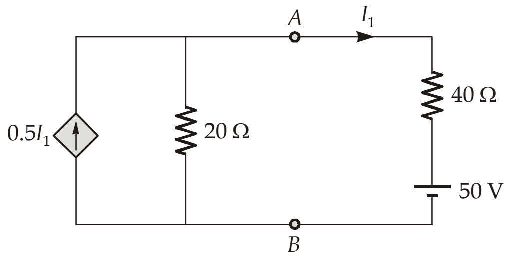
$$X_S = \omega L = 10\ \Omega$$
$$Z_S = 10 + j10$$

R for max power transfer $= |Z_s| = 10\sqrt{2}$

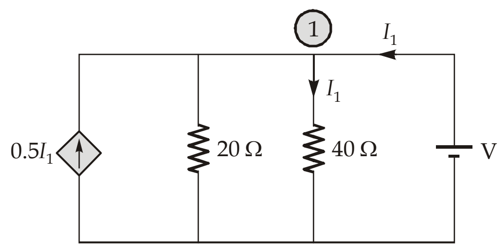
$$= |10 + 10j| = 10\sqrt{2}\angle 45°$$
$$= 14.14\ \Omega$$

13. (a)

For maximum power delivered to R_L, open circuit R_L,



R_{Th} across AB,



KCL at node 1,

$$0.5I_1 + I = \frac{V}{20} + \frac{V}{40}$$

$$\Rightarrow \quad 0.5 \cdot \frac{V}{40} + I = \frac{V}{20} + \frac{V}{40}$$

$$I = V\left(\frac{1}{20} + \frac{1}{40} - \frac{1}{80}\right)$$

$$\Rightarrow \quad \frac{V}{I} = R_{Th} = 16$$

$$\therefore \quad R_L = R_{Th} = 16$$

14. (c)

$$Z_L = R_s - jX_s$$
$$\therefore \quad Z_L = 1 - 1j$$

15. (c)

For maximum power transfer,

$$R_L = R_s = 100\ \Omega$$
$$\therefore \quad P = \frac{V^2}{R} = \frac{5\times 5}{100} = 0.25\ \text{W}$$

(V across $R_L = 5$ V)

16. (b)

For V_{Th}:

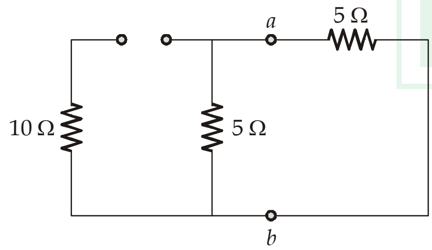
$$\frac{V_{ab}}{5} + \frac{V_{ab}-10}{5} = 1$$

(when current source is in series with voltage source effect of current source is taken),

$$2V_{ab} = 15 \Rightarrow V_{ab} = 7.5$$
$$\frac{0.5I_1}{I_1} = \frac{5}{R} \Rightarrow R = 10\ \Omega$$

(Impedance connected to $0.5I_1$ current source)

For R_{Th}, make independent sources dead,



$$R_{Th} = 5||5 = 2.5\ \Omega$$

17. (d)

$$Z_L = R_s - jX_s$$

For maximum power transfer,

$$Z_L = Z_s^*$$
$$Z_L = R_s - jX_s$$

18. (d)

For V_{Th}, applying KCL at node X,

$$2 = \frac{V_{Th}}{2} + \frac{V_{Th}}{1} + \frac{V_{Th}-2i}{1}$$

where, $\quad i = \dfrac{V_{Th}}{1}$

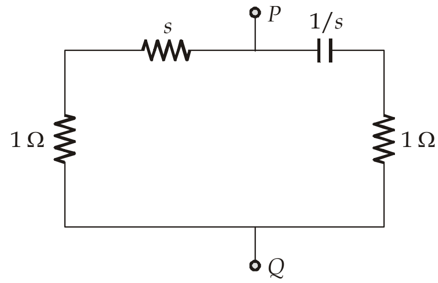
So, $\quad 2 = V_{Th}\left(\frac{1}{2}+\frac{1}{1}+\frac{1}{1}-\frac{2}{1}\right)$

$$V_{Th} = 4\ \text{Volt}$$

From the figure $I_{sc} = 2$ Ampere

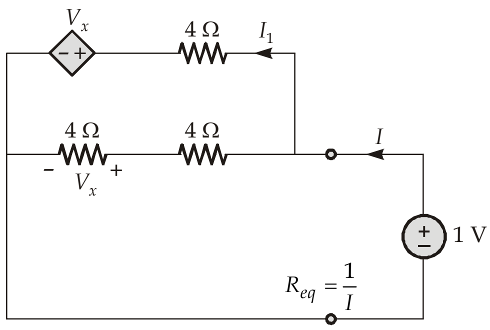
So, $\quad R_{Th} = \dfrac{V_{Th}}{I_{sc}} = \dfrac{4}{2} = 2\ \Omega$

19. (a)



$$Z_{Th} = (s+1)||\left(1+\frac{1}{s}\right) = \frac{(s+1)\left(1+\frac{1}{s}\right)}{(s+1)+1+\frac{1}{s}}$$
$$= \frac{(s+1)^2/s}{(s+1)\,(s+1)/s} = 1$$

20. (c)



For P_{max}: $\quad R_L = R_{eq}$

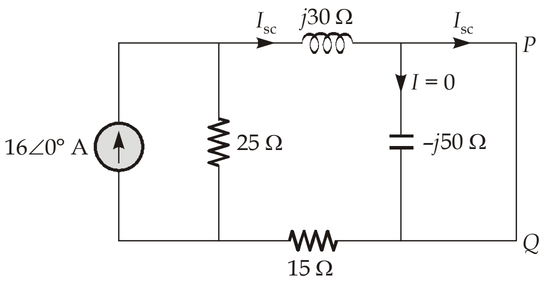
KVL, $\quad 1 = 4I_1 + V_x \quad$ ...(i)

$\quad V_x = 4(I - I_1) \quad$ ...(ii)

Simplifying, $\quad R_{eq} = \dfrac{1}{I} = 4\ \Omega$

21. (a)

For Norton equivalent current short circuiting the terminal PQ.



Short-circuit current,

$$I_{SC} = \frac{25}{15+j30+25}\times 16\angle 0^\circ$$

$$= \frac{25}{40+j30}\times 16\angle 0^\circ = \frac{(25\times 16)\angle 0^\circ}{50\angle 36.86}$$

$$= 8\angle -36.86^\circ$$

Hence Norton current is,

$$I_N = I_{SC} = 8\angle -36.86^\circ$$

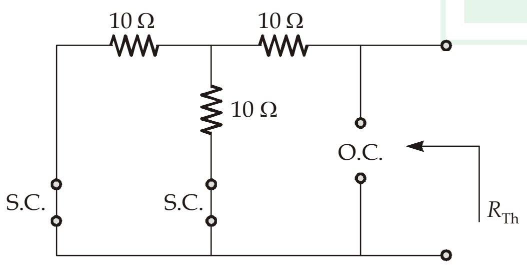
$$I_N = (6.4 - j4.8)\text{ A}$$

22. (c)

For maximum power transfer,

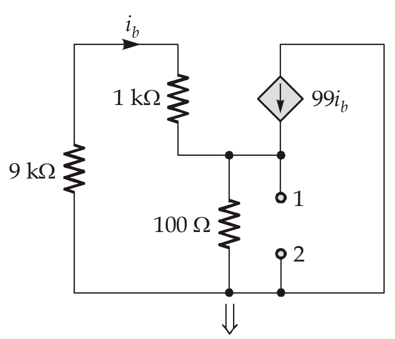
$$R_L = R_{Th}$$

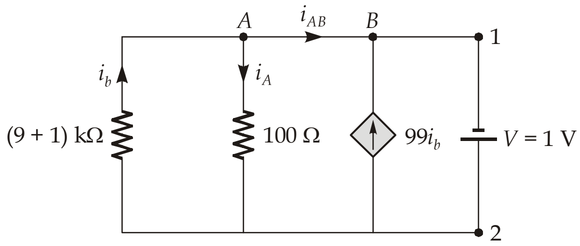
To calculate R_{Th} deactivate all the energy sources.



$$R_{Th} = 10 + 10\,||\,10 = 15\ \Omega$$

23. (a)





To find Thevenin impedance across node 1 and 2. Connect a 1 V source and find the current through voltage source.

Then, $Z_{Th} = \frac{1}{I}$

By applying KCL at node B and A,

$$i_{AB} + 99i_b = I$$

$$i_b = i_A + i_{AB}$$

$$\Rightarrow \quad i_b - i_A + 99i_b = I$$

$$\Rightarrow \quad 100i_b - i_A = I \quad \text{...(i)}$$

By applying KVL in outer loop,

$$10\times 10^3\, i_b = 1$$

$$i_b = 10^{-4}\text{ A}$$

and $10\times 10^3\, i_b = -100\, i_A$

$$\Rightarrow \quad i_A = -100\, i_b$$

From equation (i),

$$100i_b + 100i_b = I$$

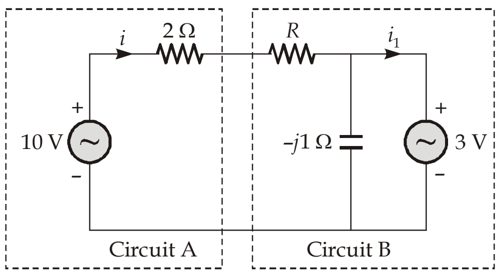
$$\Rightarrow \quad I = 200i_b$$

$$= 200\times 10^{-4} = 0.02$$

$$\therefore \quad Z_{Th} = \frac{1}{I} = \frac{1}{0.02} = 50\ \Omega$$

24. (a)

Redrawing the diagram,



Current through R will be

$$i = \frac{10-3}{2+R} = \left(\frac{7}{2+R}\right)\text{A}$$

Current through 3 V source is,

$$i_1 = i - \frac{3}{-j1} = i - 3j$$

So power delivered to circuit B by circuit A is,

$$P = i^2R + i_1 \times 3$$

$$P = \left(\frac{7}{2+R}\right)^2 \cdot R + \left(\frac{7}{2+R} - 3j\right)3$$

For P to be maximum $\frac{\partial P}{\partial R}$ will be zero,

$$\frac{\partial P}{\partial R} = 0$$

$$\left(\frac{7}{2+R}\right)^2 - \frac{98R}{(2+R)^3} - \frac{21}{(2+R)^2} = 0$$

$$49(2 + R) - 98R - 21(2 + R) = 0$$

$$98 - 42 = 49R + 21R$$

$$R = \frac{56}{70} = 0.8\ \Omega$$

25. (c)

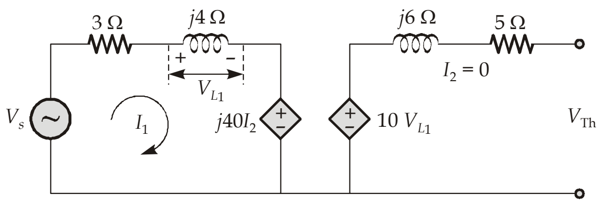
For pure resistive load to extract the maximum power,

$$R_L = |Z_s| = \sqrt{R_s^2 + X_s^2}$$

$$= \sqrt{4^2 + 3^2} = 5\ \Omega$$

26. (c)

To find V_{Th}, open-circuit the load voltage R_L then,



$$I_2 = 0$$

$$j40I_2 = 0$$

$$V_{L1} = \frac{Vs \cdot (j4)}{3 + j4}$$

$$= \frac{100\angle 53.13°}{5\angle 53.13°} \times 4\angle 90°$$

$$V_{L1} = 80\angle 90°$$

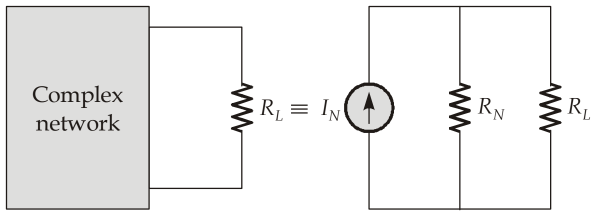
$$V_{Th} = 10V_{L1} + I_2 j6 + I_2 3$$

$$V_{Th} = 10 \times 80\angle 90° + 0 \times j6 + 0 \times 3$$

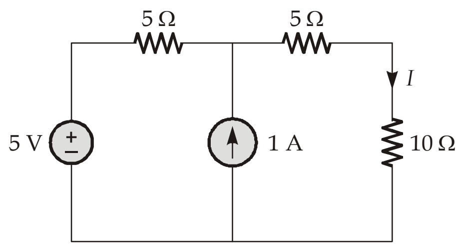
$$V_{Th} = 800\angle 90°\ \text{V}$$

27. (d)

Norton's theorem states that a complex network connected to a load can be replaced with an equivalent impedance in parallel with a current source.

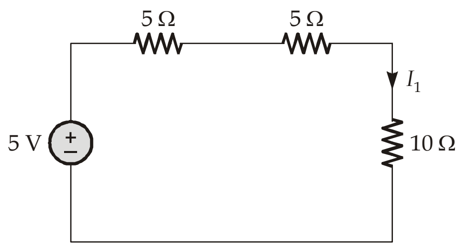


28. Sol.



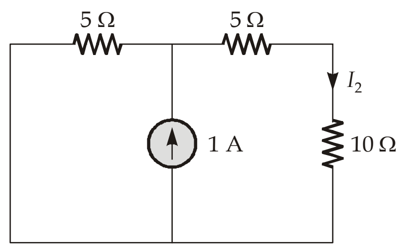
Using superposition theorem:

When 5 V source acting alone, we get



$$I_1 = \frac{V}{R_{eq}} = \frac{5}{10+5+5} = \frac{1}{4}\ \text{A} \quad \text{...(i)}$$

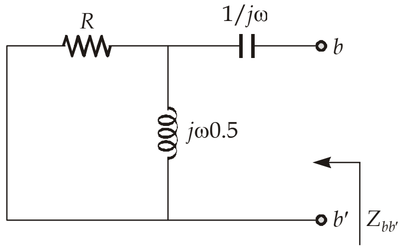
When 1 A source acting alone, we get



$$I_2 = \frac{1 \times 5}{5+10+5} = \frac{5}{20} = \frac{1}{4}\ \text{A} \quad \text{...(ii)}$$

Therefore, $I = I_1 + I_2 = \frac{1}{2}\ \text{A} = 0.5\ \text{A}$

29. Sol.



Finding Z_N:

$$Z'_{bb} = \frac{1 \times j0.5\omega}{1 + j0.5\omega} + \frac{1}{j\omega} = \frac{j\omega}{2 + j\omega} + \frac{1}{j\omega}$$

or, $$Z'_{bb} = \frac{2 - \omega^2 + j\omega}{2j\omega - \omega^2} \quad \text{...(i)}$$

Retionalizing equation (i), we get,

$$Z'_{bb} = \frac{(2-\omega^2) + j\omega}{2j\omega - \omega^2} \times \frac{-\omega^2 - j2\omega}{-\omega^2 - j2\omega}$$

$$= -\frac{2\omega^2 + \omega^4 + 2\omega^2}{\omega^4 + 2\omega^2} + j\frac{(\omega^3 - 4\omega)}{\omega^4 + 2\omega^2}$$

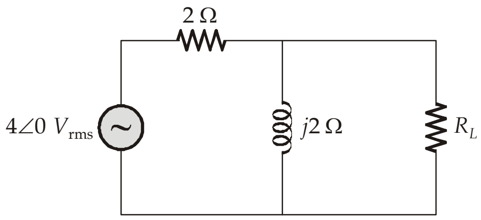
In order to have a purely resistive impedance Z'_{bb} the imaginary part of equation (ii) will be equaled to zero.

$$\therefore \quad \frac{-4\omega + \omega^3}{\omega^4 + 2\omega^2} = 0$$

or, $$\omega^3 = 4\omega$$

or, $$\omega = \sqrt{4} = 2 \text{ rad/sec.}$$

30. Sol.

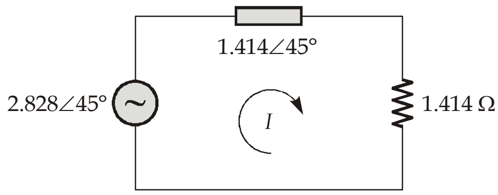


For maximum power transfer,

$$R_L = |Z_{Th}| = |2 || j2|$$

$$= \left|\frac{2 \times j2}{2 + j2}\right| = 1.414\ \Omega$$

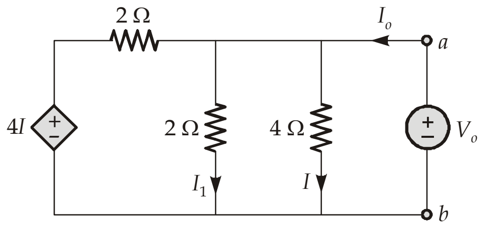
$$V_{Th} = \frac{8\angle 90^\circ}{2 + j2} = 2.828\angle 45^\circ$$



$$I = \frac{2.828\angle 45^\circ}{1.414\angle 45^\circ + 1.414} = 1.08\angle 22.5^\circ$$

$$\text{Power} = I^2R = (1.08)^2 \times \sqrt{2} = 1.649 \text{ W}$$

31. Sol.



$$I = \frac{V_o}{4}$$

$$I_1 = \frac{V_o}{2}$$

Applying KCL,

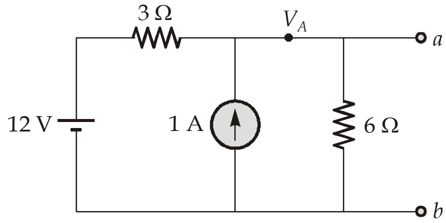
$$\frac{V_o - 4I}{2} + \frac{V_o}{2} + \frac{V_o}{4} = I_o$$

From there,

$$V_o \cdot \frac{3}{4} = I_o$$

$$R_N = \frac{V_o}{I_o} = \frac{4}{3} = 1.33\ \Omega$$

32. Sol.



$$V_{Th} = V_{6\Omega}$$

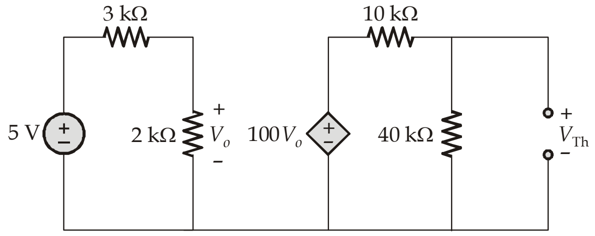
$$\frac{V_A - 12}{3} + \frac{V_A}{6} = 1$$

$$V_A\left[\frac{1}{3} + \frac{1}{6}\right] = 1 + 4$$

$$V_A \cdot \frac{3}{6} = 5$$

$$V_{Th} = V_{6\,\Omega} = V_A$$
$$= 10\text{ V}$$

33. Sol.



For maximum power transfer,

$$R = R_{Th}$$

$$V_o = 5\times\frac{2\text{ k}\Omega}{5\text{ k}\Omega} = 2\text{ V}$$

From output loop,

$$V_{Th} = 100\times 2\times\frac{40\text{ k}\Omega}{50\text{ k}\Omega}$$

$$V_{Th} = 160\text{ V}$$

and $$R_{Th} = 10\text{ k}\Omega \,||\, 40\text{ k}\Omega$$

$$= \frac{10\times 40}{50} = 8\text{ k}\Omega$$

$\therefore$ Max. power $$= \frac{V_{Th}^2}{4R_{Th}}$$

$$= \frac{160\times 160}{4\times 8000} = 0.8\text{ W}$$

34. (b)

In maximum power transformation, half of the voltage drops across source resistance, remaining half across the load.

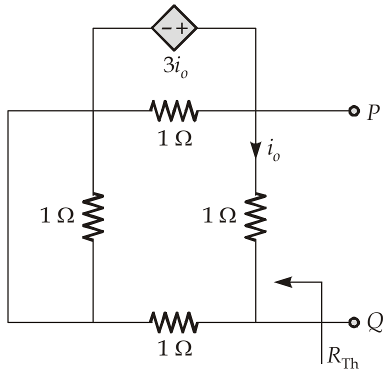
$\therefore$ Voltage across source (R),

$$I_L R = \frac{V_s}{2}$$

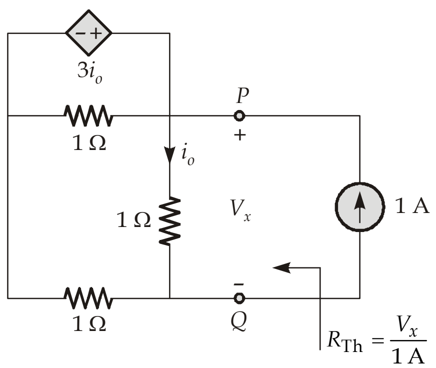
$$I_L = \frac{V_s}{2R}$$

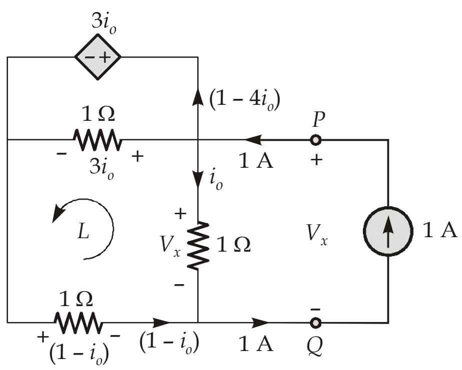
35. Sol.

- The equivalent circuit to calculate the Thevenin equivalent resistance (R_{Th}) is as follows:



- It can be further reduced as follows:





- By applying KVL in the Loop L,

$$V_x = 3i_o + (1 - i_o)$$
$$= 2i_o + 1$$

Also, $$V_x = i_o(1\,\Omega)$$

- So, $$2i_o + 1 = i_o$$

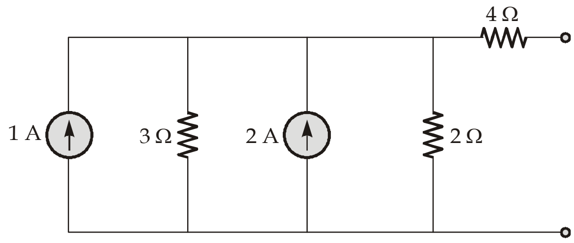
$$i_o = -1\text{ A}$$

and $$V_x = -1\text{ V}$$

So, $$R_{Th} = \frac{V_x}{1\text{ A}} = -1\,\Omega$$

36. **(c)**

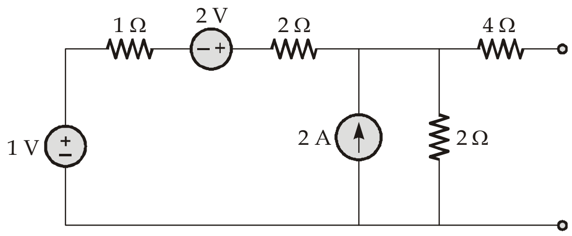
According to reciprocity theorem:
In a linear bilateral single source network the ratio of response to excitation remains the same even after their positions get interchanged.

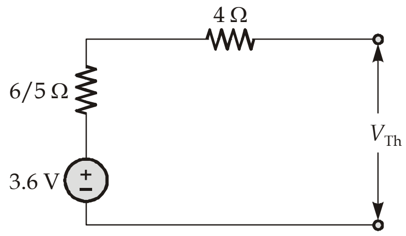


$$\therefore \quad \frac{I}{5} = \frac{1}{5} \Rightarrow I = 1\text{ A}$$

37. **(b)**

By applying source transformation,





$$V_{Th} = 3.6\text{ V}$$

❑❑❑❑

Answers — EE — Network Theorem (Section-A)

1. (b)	2. (d)	3. (0.032)	4. (d)	5. (a)	6. (d)	7. (a)	8. (d)
9. (a)	10. (c)	11. (a)	12. (b)	13. (c)	14. (d)	15. (a)	16. (d)
17. (a)	18. (c)	19. (c)	20. (b)	21. (b)	22. (14.14)	23. (3.03)	24. (50)
25. (b)							

Solutions — EE — Network Theorem (Section-A)

1. **(b)**

$$Z = 10 + \left(j4\omega - \frac{j}{\omega}\right) \Big\| \left(-\frac{j}{\omega}\right)$$

$$= 10 - j\left[\frac{4 - \dfrac{1}{\omega^2}}{4\omega - \dfrac{2}{\omega}}\right]$$

For circuit to be in resonance imaginary part of Z must be equal to zero.

Hence, $$4 - \frac{1}{\omega_{res}^2} = 0$$

$$\Rightarrow \quad \omega_{res} = 0.5\text{ rad/sec.}$$

2. **(d)**

$$Y = \frac{1}{R + j\omega L} \times \frac{R - j\omega L}{R - j\omega L} + \frac{1}{-jX_c}$$

$$Y = \frac{R - j\omega L}{R^2 + (\omega L)^2} + \frac{j}{X_c}$$

Imaginary parts are equal to zero for resonance,

$$\frac{\omega L}{R^2 + (\omega L)^2} = \omega C$$

From this we get 'ω_o'

At resonance,

$$Y = \frac{R}{R^2 + \omega_o^2 L^2} = \frac{1}{Y} = \frac{R^2 + \omega_o^2 L^2}{R}$$

$Z >> R$

3. Sol.

$$Q_0 = 0.032$$

For series RLC circuit

$$\text{Q-factor at resonance} = \frac{\omega_0 L}{R}$$

$$\omega_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(0.01)\times(100\times10^{-3})}}$$

$$= 10\sqrt{10} \text{ rad/sec.}$$

$$Q = \omega_0 \frac{L}{R} = \frac{10\sqrt{0}\times 0.01}{10} = 0.032$$

4. (d)

$$Q = \frac{\omega L}{R}$$

When frequency of operation is doubled,

$\omega = 2\pi f$, also get doubled

Consequently, Q also get doubled

$$P = I^2R\left[\frac{V}{\sqrt{R^2+(\omega L)^2}}\right]^2 \cdot R$$

$$= \frac{V^2}{R^2\left[1+\left(\frac{\omega L}{R}\right)^2\right]} = \frac{V^2}{R(1+Q^2)}$$

∵ It is given that Q is high.

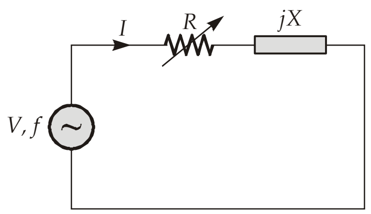
∴ $Q^2 >> 1$

$$\Rightarrow \quad P \simeq \frac{V^2}{RQ^2}$$

∵ Q is doubled.

∴ P decreased 4 times.

5. (a)



$$I = \frac{V}{R+jX}$$

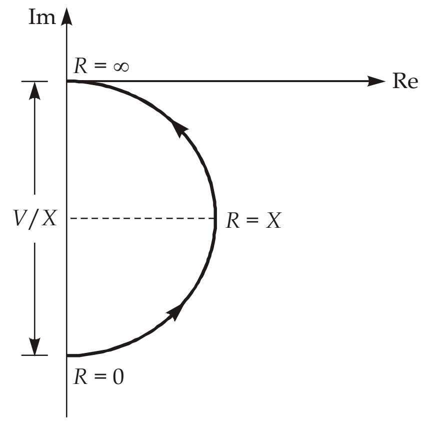
$$= \frac{V}{\sqrt{R^2+X^2}}\angle -\tan^{-1}\left(\frac{X}{R}\right)$$

For $R = 0$, $I = \frac{V}{X}\angle -90°$

For $R = X$, $I = \frac{V}{\sqrt{2}X}\angle -45°$

For $R = \infty$, $I = 0\angle 0°$

On plotting these three points we get,



Hence locus of $\vec{I}$ is a semi-circle having diameter of V/X.

6. (d)

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

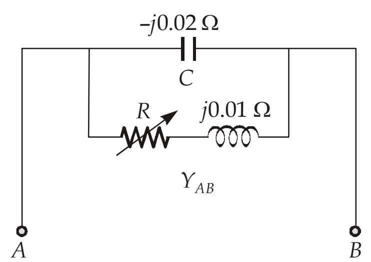
(for series RLC resonance)

$$f_{new} = \frac{1}{2\pi\sqrt{2L\times 2C}}$$

(when all the components values are doubled)

Hence, $f_{new} = \frac{f_0}{2}$

7. (a)



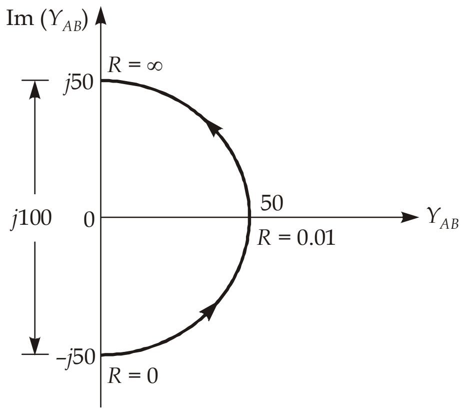
$$Y_{AB} = \frac{1}{-j0.02} + \frac{1}{R+j0.01}$$

For $R = 0$, $Y_{AB} = -j50 = 50\angle -90°$

For $R = 0.01$, $Y_{AB} = 50$

For $R = \infty$, $Y_{AB} = j50 = 50\angle 90°$

On plotting these three points,



Hence, locus of $\vec{Y}_{AB}$ is a semicircle of diameter $j100$ and center at zero.

8. (d)

$$Q = \frac{\text{Resonance frequency}}{\text{Bandwidth}}$$

$$= \frac{f_0}{\Delta f} = \frac{100}{5} = 20$$

$\because$ At resonance,

$$|V_L| = |V_C| = Q \cdot |V_{\text{source}}|$$

$$\therefore \quad |V_L| = 20 \times 10 = 200 \text{ V}$$

9. (a)

$\because \quad V_L = -V_C$ (Given)

So, this is a case of RLC series resonance.

Hence, $I = \dfrac{V}{R}$ (at resonance)

$$= \frac{100}{20} = 5 \text{ A}$$

10. (c)

In a series RLC circuit, at resonance

$$V_L = jQV_{\text{source}}$$

and $\quad V_C = -jQV\text{source}$

Also for $Q > 1$,

$$|V_C| = |V_{\text{source}}|$$

Hence option (c) is correct.

11. (a)

$$Y = j\omega C + \frac{1}{30\angle 40°}$$

$$= j\omega C + 0.0255 - j0.0214$$

$$= 0.0255 + j(\omega C - 0.0214)$$

$$= \text{Real}(Y) + j\text{Img}(Y)$$

To have a unity power factor at ac source i.e. resonance condition,

$$\text{Img}(Y) = 0$$

$$\Rightarrow \quad \omega C - 0.0214 = 0$$

$$\omega = 2\pi \times 50$$

$$\therefore \quad C = \frac{0.0214}{100\pi} = 68.1\ \mu\text{F}$$

12. (b)

$$\omega_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{100\times10^{-6}\times10^{-6}}} = 10^5 \text{ r/s}$$

$$\Delta\omega = \frac{R}{L} = \frac{50}{100\times10^{-6}} = 50\times10^4 \text{ r/s}$$

$$\omega_{\text{lower}} = \left[\sqrt{\omega_0^2 + \left(\frac{\Delta\omega}{2}\right)^2} - \frac{\Delta\omega}{2}\right]$$

$$= \left[\sqrt{(10^5)^2 + \left(\frac{5\times10^5}{2}\right)^2} - \frac{5\times10^5}{2}\right]$$

$$= 10^5\left[\sqrt{1+6.25} - 2.5\right]$$

$$= 0.193 \times 10^5 \text{ rad/sec}$$

Hence,

$$f_{\text{lower}} = \frac{\omega_{\text{lower}}}{2\pi} = \frac{0.193\times10^5}{2\pi}$$

$$= 3065 \text{ Hz} \simeq 3.055 \text{ kHz}$$

13. (c)

$$V = V_R + i(V_L - V_C)$$

Since, $\quad |V_L| = |V_C|$ and $|V_L|$

$$= 2|V_R|$$

Therefore, the circuit is at resonance and

$$V_R = V$$

$$\text{Quality factor} = \frac{V_L}{V} = \frac{V_L}{V_R} = \frac{2V_R}{V_R} = 2$$

As we know,

$$Q = \frac{\omega_o L}{R}$$

$$\Rightarrow \quad 2 = \frac{2\pi f \times L}{5} \Rightarrow L = 31.8 \text{ mH}$$

14. (d)

At resonance, the circuit should be in unity power factor.

$\therefore$ Hence 'Z' should be capacitive.

Admittance of the parallel circuit,

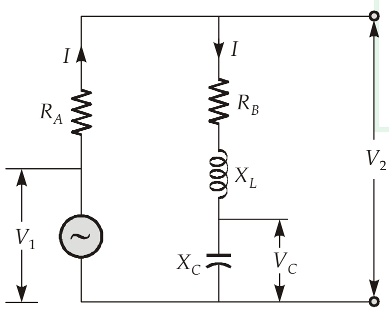
$$Y = \frac{1}{jL\omega} + \frac{1}{1/jC\omega} = 0$$

$$\frac{-1}{L\omega} + C\omega = 0$$

$$\therefore \quad C = \frac{1}{L \times \omega^2}$$

$$= \frac{1}{2 \times (2\pi \times 500)^2} = 0.05\ \mu\text{F}$$

15. (a)



$$Z = R_A + R_B + j(X_L - X_C)$$

At resonance, $X_L = X_C$

So, $Z = R_A + R_B$

Therefore, input impedance is purely resistive, is minimum, and the input voltage and output current are in phase.

So, V_1 and I are in phase.

$$V_2 = \frac{V_1}{R_A + R_B + j(X_L - X_C)} \times [R_B + j(X_L - X_C)]$$

But, $X_L = X_C$

$$V_2 = \frac{V_1}{R_A + R_B} \times R_B$$

Therefore, V_2 is in phase with V_1 and $V_2 < V_1$.

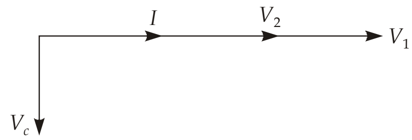
Voltage across the capacitor,

$$V_C = I \times X_C = I \times \frac{1}{j\omega C}$$

$$V_C = \frac{I}{\omega C}\angle{-90^\circ}$$

So, V_C lags the current by 90°.

The phasor diagram on the basis of above analysis.



16. (d)

Admittance of the series connected in RLC,

$$Y = \frac{1}{R + j\left(\omega L - \frac{1}{\omega C}\right)}$$

$$Y = \frac{R - j\left(\omega L - \frac{1}{\omega C}\right)}{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

[By rationalization]

Separating, real and imaginary part of admittance,

$$\text{Re}[Y] = \frac{R}{R^2 + \left(\omega L - \frac{1}{\omega L}\right)^2}$$

For any value of ω, the real part of always positive.

When, $\omega L = \frac{1}{\omega C}$

At, $\omega_o = \frac{1}{\sqrt{LC}}$ (Resonance)

$$\text{Re}[Y] = \frac{1}{R} \quad \text{(Maximum value)}$$

$$\text{Im}(Y) = \frac{-\left(\omega L - \frac{1}{\omega C}\right)}{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$= \frac{\left(\frac{1}{\omega C} - \omega L\right)}{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

At, $\omega_o = \frac{1}{\sqrt{LC}}$ (Resonance)

Imaginary part of zero

$\Rightarrow$ $\text{Im}(Y) = 0$

For, $0 < \omega < \omega_o$

$$\frac{1}{\omega C} > \omega L$$

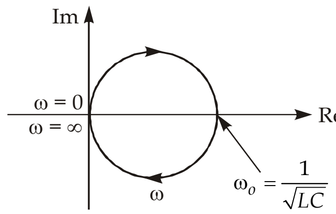
Therefore, $\text{Im}[Y] > 0$

For, $\omega_o < \omega < \infty$

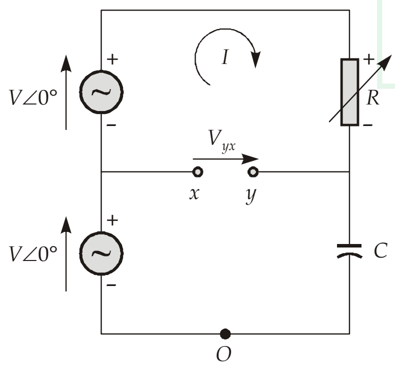
$$\frac{1}{\omega C} < \omega L$$

Therefore, $\text{Im}[Y] < 0$

On the basis of above analysis, the admittance locus is,



17. (a)



Let capacitive reactance = X_C

$$I = \frac{V\angle 0° + V\angle 0°}{R - jX_C} = \frac{2V}{R - jX_C}$$

Using KVL,

$$V_{YX} + IR - V = 0$$

$$\Rightarrow \quad V_{YX} = V - IR$$

$$V_{YX} = V - \left(\frac{2V}{R - jX_C}\right)R$$

$$= -\frac{V(R + jX_C)}{(R - jX_C)}$$

$$V_{YX} = -V\left[\frac{R + jX_C}{R - jX_C}\right]$$

When, $R = 0$

$$V_{YX} = -V\left[\frac{0 + jX_C}{0 - jX_C}\right] = V$$

$$V_{YX} = -V \times \left[\frac{1 + j\frac{X_C}{R}}{1 - j\frac{X_C}{R}}\right]$$

When, $R \to \infty$

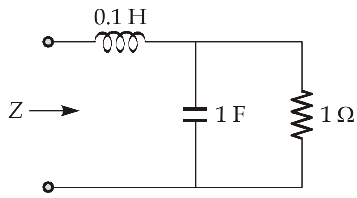
$$V_{YX} = -V$$

18. (c)

Input impedance,

$$z = j\omega L + R \,\|\, \frac{1}{j\omega C}$$

$$z = j\omega L + \frac{R}{1 + j\omega RC}$$



$$\therefore \quad z = j0.1\omega + \frac{1}{1 + j\omega} \times \frac{1 - j\omega}{1 - j\omega}$$

$$= j0.1\omega + \frac{1 - j\omega}{1 + \omega^2}$$

$$= \frac{1}{1 + \omega^2} + j \times \left(0.1\omega - \frac{\omega}{1 + \omega^2}\right)$$

At resonance, imaginary part must be zero,

$$0.1\omega - \frac{\omega}{1 + \omega^2} = 0$$

$$0.1 = \frac{1}{1 + \omega^2}$$

$$\omega^2 + 1 = 10$$

$$\therefore \quad \omega^2 = 9$$

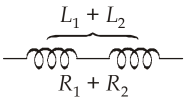
$$\therefore \quad \omega = 3 \text{ rad/sec}$$

19. (c)

$$q_1 = \frac{\omega L_1}{R_1}$$

$$\Rightarrow \quad L_1 = \frac{q_1 R_1}{\omega}$$

Similarly, $L_2 = \dfrac{q_2 R_2}{\omega}$



$$Q = \frac{\omega(L_1 + L_2)}{R_1 + R_2}$$

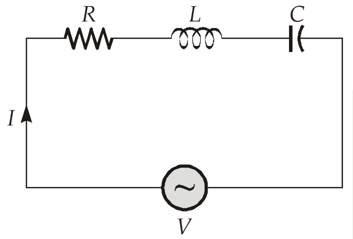
$$= \frac{q_1 R_1 + q_2 R_2}{R_1 + R_2}$$

20. (b)

Given:

At, $\omega_1 = 1$ k-rad/sec
$V_1 = 100\angle 0°$ V,
$I_1 = 0.03\angle 31°$ A

At, $\omega_2 = 2$ k-rad/sec
$V_2 = 100\angle 0°$ V
$I_2 = 2\angle 0°$ A



At $\omega_2 = 2$ k-rad/sec, voltage and current are in phase.

Thus, it is case of series resonance,

$$X_{L_{\omega_2}} = X_{C_{\omega_2}}$$

$$\therefore \quad Z = R = \frac{V_2}{I_2} = \frac{100\angle 0°}{2\angle 0°} = 50\ \Omega$$

∴ Resistance of circuit,

$$R = 50\ \Omega$$

Now at, $\omega_1 = 1$ k-rad/sec

$$Z = \frac{V_1}{I_1} = \frac{100\angle 0°}{0.03\angle 31°}$$

$$= \frac{100}{0.03}\angle -31°\ \Omega \quad \text{...(i)}$$

Also, $$Z = |Z| \cdot \tan^{-1}\left[\frac{X_L - X_C}{R}\right] \quad \text{...(ii)}$$

(at $\omega_1 = 1$ k-rad/sec)

Comparing equations (i) and (ii), we have

$$-31° = \tan^{-1}\left[\frac{X_L - X_C}{R}\right]$$

or, $$\tan(-31°) = \frac{X_L - X_C}{R}$$

or, $$X_L - X_C = R\tan(-31°)$$
$$= 50\ X - 0.6 = -30$$

$$\therefore \quad X_{L_{\omega_1}} - X_{C_{\omega_1}} = -30 \quad \text{...(iii)}$$

(at $\omega_1 = 1$ k-rad/sec)

Also at, $w_2 = 2$ k-rad/sec

$$X_{L_{\omega_2}} = X_{C_{\omega_2}} \quad \text{or} \quad \omega_2 L = \frac{1}{\omega_2 C}$$

or, $$L = \frac{1}{\omega_2^2 C} \quad \text{...(iv)}$$

From equation (iii),

$$\omega_1 L - \frac{1}{\omega_1 C} = -30$$

or, $$\omega_1\left(\frac{1}{\omega_2^2 C}\right) - \frac{1}{\omega_1 C} = -30 \quad \text{(Using (iv)}$$

or, $$\frac{1\times 10^3}{4\times 10^6 C} - \frac{1}{10^3 C} = -30$$

or, $$\left(\frac{10^{-3}}{4C} - \frac{10^{-3}}{C}\right) = -30$$

or, $$\frac{-3}{4C}\times 10^{-3} = -30$$

or, $$C = \frac{3\times 10^{-3}}{4\times 30}$$

or, $$C = 25\times 10^{-6}\ \text{F} = 25\ \mu\text{F}$$

Substituting the value of C in equation (iv), we get,

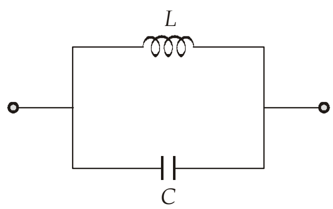
$$L = \frac{1}{\omega_2^2 C} = \frac{1}{(2\times 10^3)^2 \times 25\times 10^{-6}}$$

$$= \frac{1}{100} = 10\ \text{mH}$$

Therefore, values are

$R = 50\ \Omega$, $L = 10$ mH, $C = 25\ \mu$F

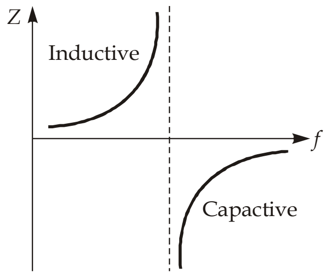
21. (b)



$$\Rightarrow Z = j\omega L \,||\, \frac{1}{j\omega C} = \frac{L/C}{j\omega L + \dfrac{1}{j\omega C}} = \frac{j\omega L}{1-\omega^2 LC}$$

For, $1 > \omega^2 LC$, $Z = +ve$

For, $1 < \omega^2 LC$, $Z = -ve$



22. Sol.

The resonance frequency for the circuit is

$$\omega_0 = \frac{1}{\sqrt{LC}}\sqrt{\frac{R_L^2 - L/C}{R_C^2 - L/C}}$$

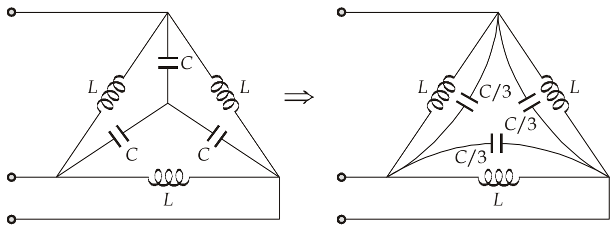
Since, ($R_L = R_C = R$)

So the circuit will have zero real part of admittance.

When, $R = \sqrt{\dfrac{L}{C}} = \sqrt{\dfrac{0.02}{100\ \mu F}} = 14.14\ \Omega$

23. Sol.

Using star to delta conversion,



Line current will be zero when the parallel pair of induction-capacitor is resonant at $f = 50$ Hz.

So, $50 \times 2\pi = \dfrac{1}{\sqrt{LC/3}}$

$$100\pi = \frac{1}{\sqrt{LC/3}}$$

C will be 3.03 mF.

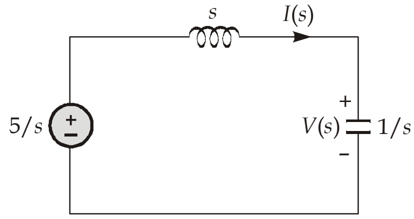
24. Sol.

At resonance imaginary part of $Z_{eq} = 0$

$$\text{Rea of } Z_{eq} = \frac{R_1 X_c^2}{R_1^2 + X_c^2}$$

$$= \frac{100 \times 100 \times 100}{100^2 + 100^2} = 50\ \Omega$$

25. (b)



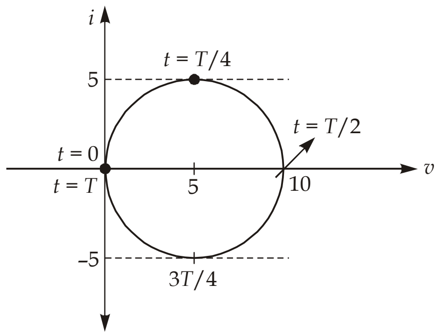
$$I(s) = \frac{5/s}{s + \dfrac{1}{s}} = \frac{5}{s^2+1}$$

$$i(t) = 5 \sin t$$

$$v(t) = \frac{1}{C}\int_0^t i\,dt = \int_0^t 5 \sin t\, dt$$

$$v(t) = 5[-\cos t]_0^t = 5[-\cos t + 1]$$

$$v(t) = 5 - 5 \cos t$$



t	$i(t)$	$v(t)$
0	0	0
$\frac{T}{4}$	5	5
$\frac{T}{2}$	0	10
$\frac{3T}{4}$	–5	5
T	0	0

Answers — EE — Network Theorem (Section-B)

1. (d)	**2.** (False)	**3.** (2, 4.5)	**4.** (b)	**5.** (a)	**6.** (d)	**7.** (a)	**8.** (d)
9. (b)	**10.** (b)	**11.** (d)	**12.** (a)	**13.** (a)	**14.** (a)	**15.** (c)	**16.** (c)
17. (a)	**18.** (c)	**19.** (1)	**20.** (a)	**21.** (3.36)	**22.** (10)	**23.** (0.545)	**24.** (3.025)
25. (d)	**26.** (a)	**27.** (3)	**28.** (0)	**29.** (14)	**30.** (a)		

Solutions — EE — Network Theorem (Section-B)

1. (d)

For d.c. supply of 5 V, the capacitor acts as open-circuit at the steady-state, consequently there will not be any current flowing in the circuit due to d.c. supply.

For a.c. supply of $V = 10\sin(t)$, $\omega = 1$ rad/sec.

$$Z = R + j\omega L - \frac{j}{\omega C} = 1 + j2 - j$$

$$= (1 + j) = \sqrt{2}\angle 45°\ \Omega$$

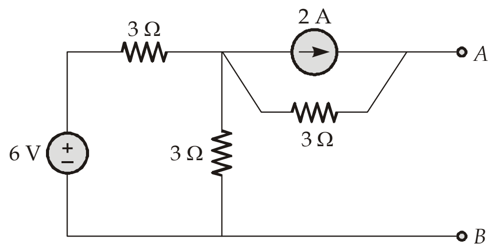
Hence, current, $I = \dfrac{V}{Z} = \dfrac{10\sin(t)}{\sqrt{2}\angle 45°}$

$$= 7.07\sin(t - 45°)\text{ A}$$

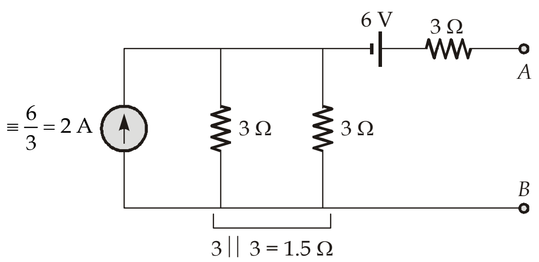
2. Sol.

False, superposition principle is applicable on both time variant and time invariant resistors.

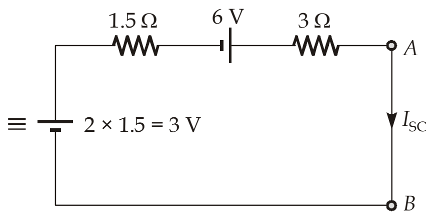
3. Sol.



Using source transformation,



Using source transformation,



$$I_{SC} = \frac{3+6}{1.5+3} = 2\text{ A}$$

$$R_N = 1.5 + 3 = 4.5\ \Omega$$

4. (b)

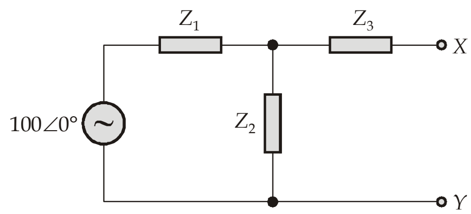
Using Millman's theorem,

$$V = \frac{V_1Y_1 + V_2Y_2}{Y_1 + Y_2} = \frac{\frac{10}{6} + \frac{5}{4}}{\frac{1}{6} + \frac{1}{4}} = 7\text{ V}$$

$$R = \frac{1}{Y_1 + Y_2} + \frac{1}{\frac{1}{6} + \frac{1}{4}} = 2.4\ \Omega$$

5. (a)

By Thevenin's theorem,



$$Z_{Th} = Z_{X-Y} = Z_1 || Z_2 + Z_3$$

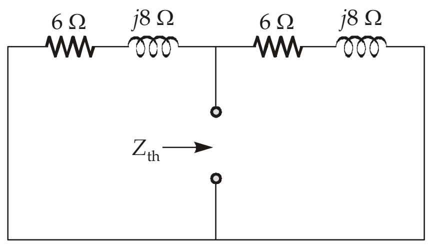
$$= \frac{Z_1 \times Z_2}{(Z_1 + Z_2)} + Z_3$$

$$= \frac{10\angle{-60} \times 10\angle 60}{(10\angle{-60} + 10\angle 60)} + (50\angle 53.13)$$

$$= 56.66\angle 45°\ \Omega$$

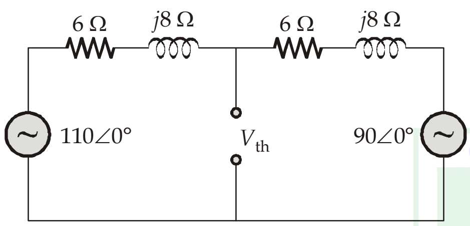
6. (d)

For obtaining power absorbed by R_L under maximum power transfer condition. We find Thevenin's equivalent circuit across R_L.



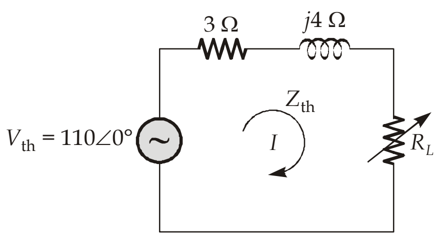
Z_{th} is calculated by short-circuiting the voltage sources,

$$Z_{th} = (6 + j8) || (6 + j8) = 3 + j4\ \Omega$$



$$\frac{V_{th} - 110\angle 0°}{6 + j8} + \frac{V_{th} - 90\angle 0°}{6 + j8} = 0$$

$$V_{th} = 100\angle 0°\ \text{V}$$



For the maximum power transfer,

$$R_L = \sqrt{R_{th}^2 + X_{th}^2} = \sqrt{3^2 + 4^2} = 5\ \Omega$$

$$I = \frac{V_{th}}{(3 + j4) + R_L} = \frac{100}{8 + j4}$$

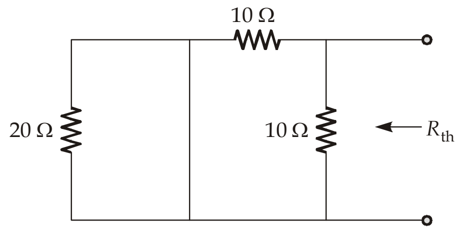
$$= 11.18\angle{-26.56°}\ \text{A}$$

Power absorbed by R_L(max)

$$= I^2 R_L = 11.18^2 \times 5 = 625\ \text{W}$$

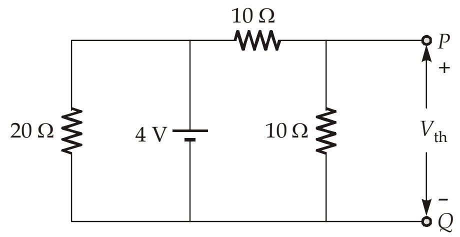
7. (a)

To calculate R_{th}, (seen at terminals P-Q), voltage source is short-circuit.



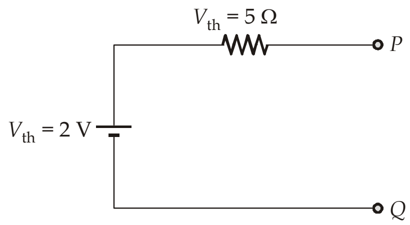
$$R_{th} = 10 || 10 = 5\ \Omega$$

V_{th} = open-circuit voltage at the terminals P-Q.



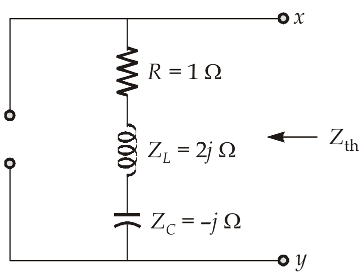
$$V_{th} = \frac{4}{10 + 10} \times 10 = 2\ \text{V}$$

Thevenin's equivalent circuit,



8. (d)

To calculate Thevenin's impedance, current-source is open-circuited,



$$Z_{th} = R + Z_L + Z_C$$
$$= 1 + 2j - j$$
$$= 1 + j\ \Omega$$

Open-circuited voltage at terminals X-Y

$$= I \times Z_{th}$$
$$= 1\angle 0 \times (1 + j)$$
$$= \sqrt{2}\angle 45°\ \text{Volt}$$

9. (b)

Thevenin's impedance:

$$Z_0 = 2.38 - j0.667\ \Omega$$

as real part is non-zero, so Z_0 has resistor

$$\text{Img}[Z_0] = -j0.667$$

Case-I:

Z_0 has capacitor (as Img$[Z_0]$ is negative)

Case-II:

Z_0 has both capacitor and inductor, but inductive reactance < capacitive reactance.

At, $\omega = 5$ rad/sec.

For minimal realization case-I is considered.

Therefore, Z_0 will have a resistor and a capacitor

10. (b)

To calculate Thevenin's resistance 5 V source is short-circuited and V_{dc} source is connected at terminals A and B.

Then, $$Z_{th} = \frac{1}{I_{th}}$$

By applying KCL at node B and A,

$$i_{AB} + 99i_b = I_{th}$$

$$i_b = i_A + i_{AB}$$

$$\Rightarrow \quad i_b - i_A + 99i_b = I_{th}$$

$$\Rightarrow \quad 100i_b - i_A = I_{th} \quad \text{...(i)}$$

By applying KVL in outer loop,

$$10 \times 10^3\, i_b = 1$$

$$i_b = 10^{-4}\text{ A}$$

and $$10 \times 10^3\, i_b = -100\, i_A$$

$$\Rightarrow \quad i_A = -100\, i_b$$

From equation (i),

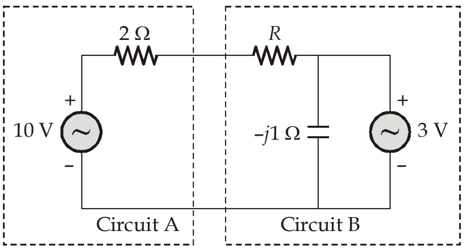
$$100i_b + 100i_b = I_{th}$$

$$\Rightarrow \quad I_{th} = 200i_b$$

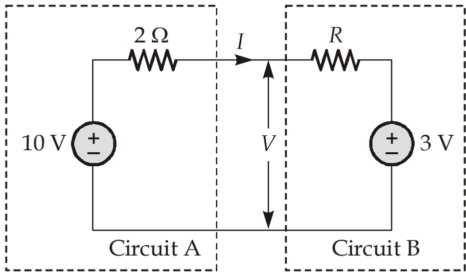
$$= 200 \times 10^{-4} = 0.02$$

$$\therefore \quad Z_{th} = \frac{1}{I_{th}} = \frac{1}{0.02} = 50\ \Omega$$

14. (a)



Thevenin equivalent circuit,



$$I = \frac{7}{R+2}$$

and $$V = 10 - 2I$$

$$= 10 - \frac{14}{R+2} = \frac{10R+6}{R+2}$$

Power transferred from circuit A to circuit B,

$$P = VI$$

$$= \frac{10R+6}{R+2} \times \frac{7}{R+2}$$

For P to be maximum $\frac{dP}{dR} = 0$

$$(R+2)^2(10) - (10R+6) \times 2(R+2) = 0$$

$$5R^2 + 20R + 20 - 10R^2 + 26R + 12 = 0$$

$$5R^2 + 6R = 8$$

$$\Rightarrow \quad R = 0.8\ \Omega$$

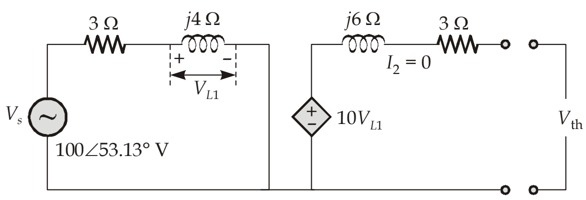
15. (c)

Using maximum power transfer theorem,

$$R_L = |Z| = |4 - j3|$$

$$= \sqrt{4^2 + 3^2} = 5\ \Omega$$

16. (c)



$$V_{L1} = \left(\frac{j4}{3+j4}\right)100\angle 53.13°$$

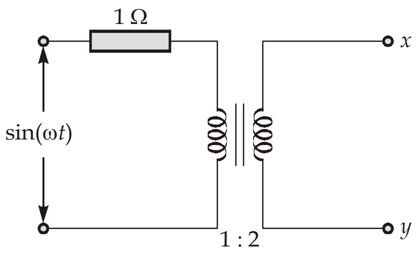
$$= 80\angle 90°\text{ V}$$

$$V_{th} = 10V_{L1} = 800\angle 90°\text{ V}$$

17. (a)

Thevenin's equivalent voltage = voltage referred to secondary.

We have, $\dfrac{\sin \omega t}{V_{th}} = \dfrac{1}{2}$



or, $V_{th} = 2\sin(\omega t)$ ...(Thevenin voltage)

Also, Thevenin's impedance seen from the x and y terminals = voltage referred to secondary side.

$$\therefore \quad Z_{th} = R_{th} = (2)^2 \times 1 = 4\ \Omega$$

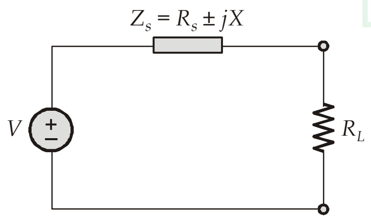
...(Thevenin's impedance)

So, $V_{th} = 2\sin(\omega t)$

and $Z_{th} = R_{th} = 4\ \Omega$

18. (c)

The situation of problem is shown in figure:



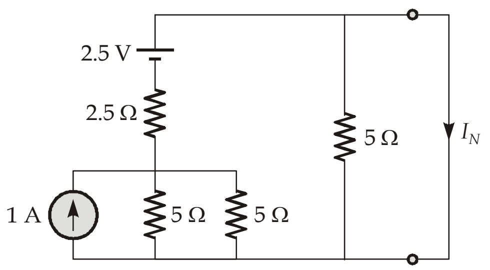
For the transfer of maximum power from source to load,

$$R_L = \sqrt{R_s^2 + X^2} = |Z|$$

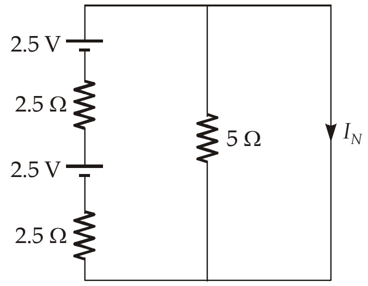
Hence, option (c) is correct.

19. Sol.

Using source transformation theorem,



or we can simply the network,



Now from the circuit, we get

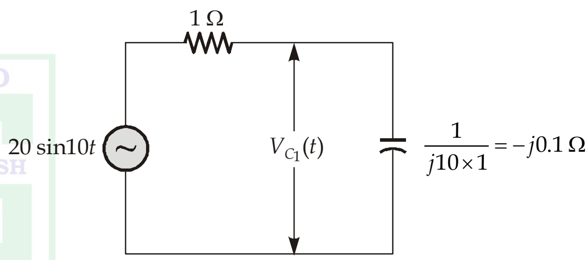
$$I_N = \frac{5}{5} = 1\ \text{A}$$

20. (a)

Let us apply superposition theorem.

Considering the voltage source 20 sin10*t* alone:

Then, 10 sin5t remain open-circuited.



Let, $V_{C_1}(t)$ be the voltage across capacitor.

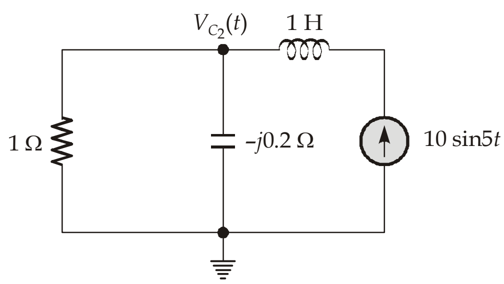
$$\therefore \quad V_{C_1}(t) = \left(\frac{-j0.1}{1 - j0.1}\right) \times 20 \sin 10t$$

$$= (1.99\angle -84.28°) \sin 10t$$

$$\therefore \quad V_{C_1}(t) = 2\sin(10t - 84.28°) \quad \text{...(i)}$$

Considering the current source 10 sin5*t* alone:

Then, 20 sin10t voltage source remain short-circuited.



Let voltage across capacitor = $V_{C_2}(t)$

Applying KCL at the node, we have

$$\frac{V_{C_2}}{1}+\frac{V_{C_2}}{(-j0.2)}-10\sin 5t=0$$

or, $$V_{C_2}(t) = \frac{10\sin 5t}{(1+j5)}$$

or, $$V_{C_2}(t) = 1.97\sin(5t-78.69°) \quad ...(ii)$$

Using superposition theorem, voltage across capacitor is,

$$V_C(t) = V_{C_1}(t)+V_{C_2}(t)$$
$$= 2\sin(10t-84.28°) + 1.97\sin(5t-78.69°)$$

$$\therefore \quad V_C(t) = 2\sin(10t-84.28°) + 1.97\sin(5t-78.69°) \quad ...(iii)$$

Given,

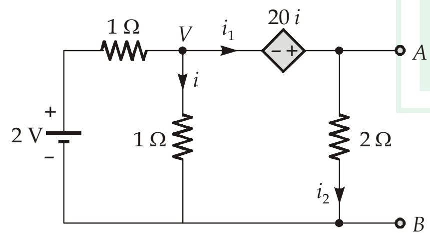
$$V_C(t) = A_1\sin(\omega_1 t-\theta_1) + A_2\sin(\omega_2 t-\theta_2) \quad ...(iv)$$

Comparing equations (iii) and (iv), we have

$$A = 2 \text{ and } B = 1.97 \approx 1.98$$

(closest answer)

21. Sol.



$$2-1(i_1+i)-i = 0$$
$$2-i_1-2i = 0$$
$$2i+i_1 = 2 \quad ...(i)$$

$$\frac{V-2}{1}+\frac{V}{1}+\frac{V-(-20i)}{2} = 0$$
$$2(V-2)+2V+V+20i = 0$$
$$4V+4+V+20i = 0$$
$$5V+20i = 4$$

where, $$\frac{V}{1} = i$$
$$25i = 2$$
$$i = \frac{4}{25}\text{ A}$$
$$i_1 = 2-2\times\frac{4}{25} = 1.68\text{ A}$$
$$V_{AB} = 1.68\times 2 = 3.36\text{ V}$$

22. Sol.

$$i(t) = \frac{8}{1}+\frac{12\sin t}{\sqrt{1+1}} = 8+6\sqrt{2}\sin t$$

$$i_{rms}(t) = \sqrt{8^2+\frac{1}{2}(6\sqrt{2})^2} = 10\text{ A}$$

23. Sol.

$V_1 = 10$ V, $I_2 = 4$ A, $V_2 = 0$ Cond. ...(i)
$V_1 = 5$ V, $I_2 = 1.25$ A,
$V_2 = 1.25\times 1 = 1.25$ Cond. ...(ii)
$V_1 = 3$ V, $I_2 = ?$, $R = 2\ \Omega$ Cond. ...(iii)

As we know from $ABCD$ parameter,

$$V_1 = AV_2-BI_2;\ I_1 = CV_2-DI_2$$

From condition (i),

$$10 = A(0)-B(4)$$
$$B = -\frac{10}{4}$$

From condition (ii),

$$5 = A(1.25)-\left(-\frac{10}{4}\right)\times(1.25)$$
$$A = \frac{\left(5-\frac{12.5}{4}\right)}{1.25} = 1.5$$

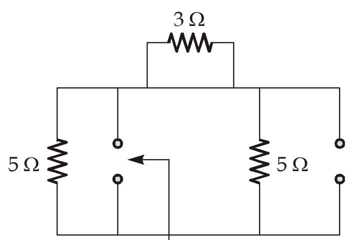
From condition (iii),

$$3 = 1.5(2I)-\left(-\frac{10}{4}\right)\times I$$
$$= 3I+2.5I = 5.5I$$
$$I = 0.545\text{ A}$$

24. Sol.

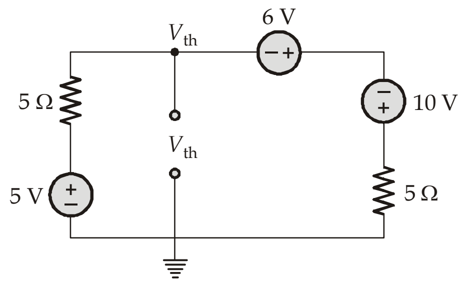
To get R_{th} and V_{th}, consider the following steps.

Case-1: For R_{th}



$$R_{th} = \frac{5\times 5}{5+5} = 2.5\ \Omega$$

Case-2: For V_{th}



Applying KCL at node,

$$\frac{V_{th}-5}{5}+\frac{V_{th}+16}{5} = 0$$

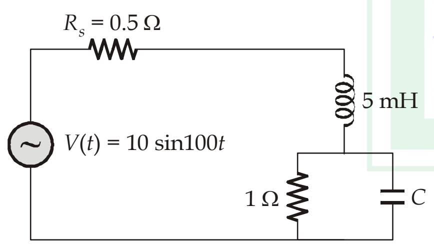
$$2V_{th} = -11$$

$$V_{th} = -5.5 \text{ V}$$

Maximum power transferred,

$$P_{max} = \frac{V_{th}^2}{4R_L} = 3.025 \text{ W}$$

25. (d)



The frequency at which the load is resistive and it is equal to 0.5 Ω i.e. The load is resistive means, the imaginary part of the is equal to zero and real part is equal to 0.5 Ω.

$$Z_{load} = \frac{1\times\frac{1}{Cs}}{1+\frac{1}{Cs}}+Ls = \frac{1}{1+Cs}+Ls$$

$$= \frac{(1-Cs)}{1-C^2s^2}+Ls$$

Put $s = j\omega$;

$$Z_{load} = \frac{1-j\omega C}{1+C^2\omega^2}+j\omega L$$

$$= \frac{1}{1+C^2\omega^2}+j\omega\left(L-\frac{C}{(1+C^2\omega^2)}\right)$$

Real part of the,

$$Z_{load} = \frac{1}{1+C^2\omega^2}$$

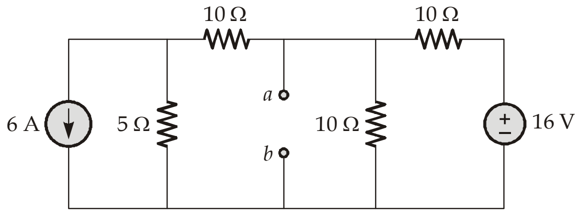
$$Z_{load} = \frac{1}{1+\omega^2C^2} = 0.5$$

Putting, $\omega = 100$ rad/sec.

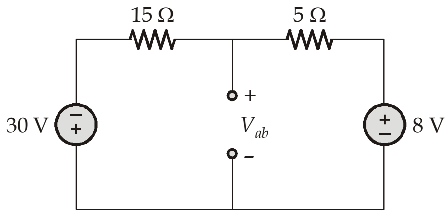
we get, $C = 10$ mF

26. (a)

Consider the following circuit,



After rearrangement we get,



From circuit using KCL,

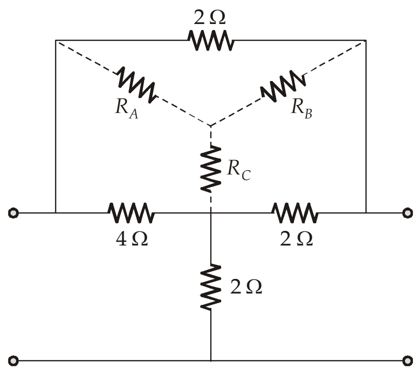
Voltage,

$$\frac{V_{ab}+30}{15}+\frac{V_{ab}-8}{5} = 0$$

$$V_{ab}+30+3V_{ab}-24 = 0$$

$$V_{ab} = -1.5 \text{ V}$$

27. Sol.

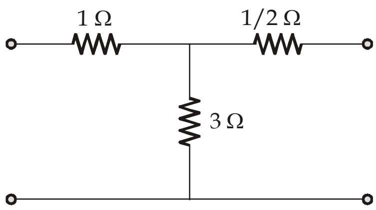


where, $R_A = 1\ \Omega$

$R_B = 1\ \Omega$

$R_C = \frac{1}{2}\ \Omega$

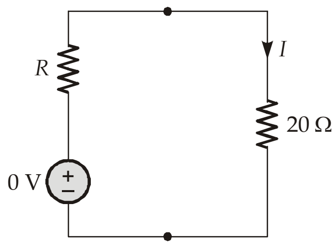
After rearrangement consider the following circuit,



From the circuit diagram we get,

$$Z_{21} = \frac{V_2}{I_1} = 3\,\Omega$$

28. Sol.



By Millman's theorem,

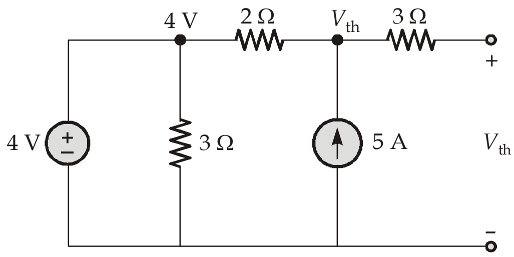
$$E = \frac{\frac{200}{50} + \frac{160}{40} - \frac{100}{25} - \frac{80}{20}}{\frac{1}{50} + \frac{1}{40} + \frac{1}{25} + \frac{1}{20}} = 0\text{ V}$$

$$\frac{1}{R} = \frac{1}{50} + \frac{1}{40} + \frac{1}{25} + \frac{1}{20}$$

Simplified circuit,

$\therefore \qquad I = 0\text{ A}$

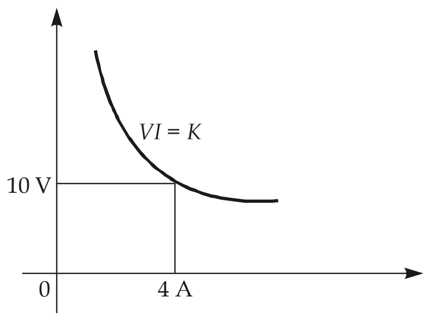
29. Sol.



$$\frac{V_{th} - 4}{2} = 5$$

$$V_{th} = 14\text{ V}$$

30. (a)



Maximum power transistor of VI product is maximum. If draw the curve, it intersect (10, 4) that will give maximum power. The terminal voltage is 10 V (Load voltage) and current is 4 A (Load current).

Load resistance is $\frac{10}{4} = 2.5\,\Omega$.

❑❑❑❑

4 Transient Analysis

ELECTRONICS ENGINEERING
(GATE Previous Years Solved Papers)

Q.1 A 10 Ω resistor, a 1 H inductor and 1 μF capacitor are connected in parallel. The combination is driven by a unit step current. Under the steady-state condition, the source current flows through

(a) the resistor
(b) the inductor
(c) the capacitor only
(d) all the three elements

[EC-1989 : 2 Marks]

Q.2 If the Laplace transform of the voltage across a capacitor of value of 1/2 F is

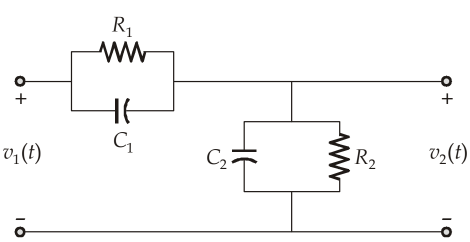
$$V_c(s) = \frac{s+1}{s^3+s^2+s+1}$$

The value of the current through the capacitor at $t = 0^+$ is,

(a) 0 A (b) 2 A
(c) $\left(\frac{1}{2}\right)$ A (d) 1 A

[EC-1989 : 2 Marks]

Q.3 For the compensated attenuator of figure, the impulse response under the condition $R_1C_1 = R_2C_2$ is



(a) $\frac{R_2}{R_1+R_2}[1-e^{1/R_1C_1}]\,u(t)$

(b) $\frac{R_2}{R_1+R_2}\delta(t)$

(c) $\frac{R_2}{R_1+R_2}u(t)$

(d) $\frac{R_2}{R_1+R_2}e^{t/R_1C_1}\,u(t)$

[EC-1992 : 2 Marks]

Q.4 A ramp voltage, $v(t) = 100t$ Volts, is applied to an RC differentiating circuit with $R = 5$ kΩ and $C = 4$ μF. The maximum output voltage is

(a) 0.2 Volt (b) 2.0 Volts
(c) 10.0 Volts (d) 50.0 Volts

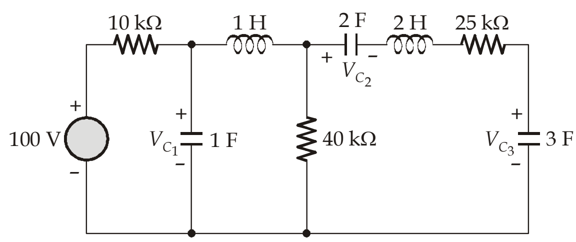
[EC-1994 : 1 Mark]

Q.5 The rms value of a rectangular wave of period T, having a value of $+V$ for duration, T_1 ($<T$) and $-V$ for the duration, $T - T_1 = T_2$ equals

(a) V (b) $\frac{T_1-T_2}{T}V$
(c) $\frac{V}{\sqrt{2}}$ (d) $\frac{T_1}{T_2}V$

[EC-1995 : 1 Mark]

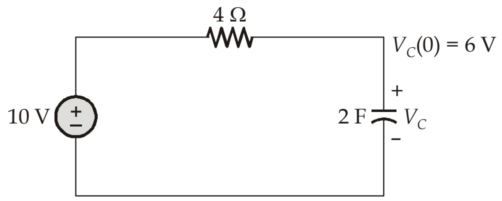
Q.6 The voltage V_{C_1}, V_{C_2} and V_{C_3} across the capacitors in the circuit in figure, under steady-state, are respectively



(a) 80 V, 32 V, 48 V (b) 80 V, 48 V, 32 V
(c) 20 V, 8 V, 12 V (d) 20 V, 12 V, 8 V

[EC-1996 : 2 Marks]

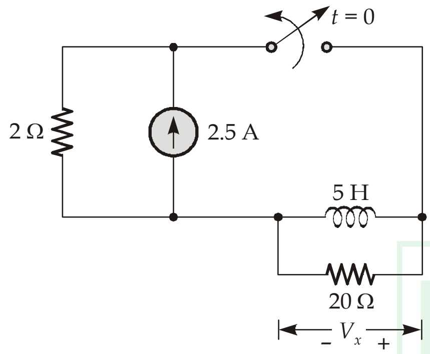
Q.7 In the circuit of figure the energy absorbed by the 4 Ω resistor in the time interval (0, ∞) is



(a) 36 Joules (b) 16 Joules
(c) 256 Joules (d) None of the above

[EC-1997 : 2 Marks]

Q.8 In the figure, the switch was closed for a long time before opening at $t = 0$. The voltage V_x at $t = 0^+$ is,

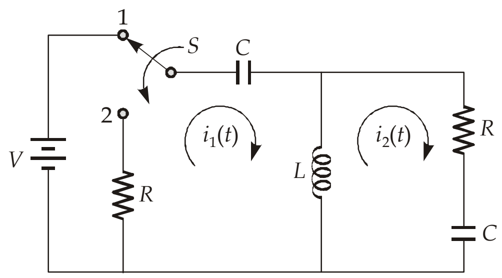


(a) 25 V (b) 50 V
(c) –50 V (d) 0 V

[EC-2002 : 1 Mark]

The circuit for **(Q. 9 and Q.10)** is given. Assume that the switch S is in position 1 for a long time and thrown to position 2 at $t = 0$.

Q.9 At $t = 0^+$, the current i_1 is



(a) $\frac{-V}{2R}$ (b) $\frac{-V}{R}$
(c) $\frac{-V}{4R}$ (d) zero

[EC-2003 : 2 Marks]

Q.10 $I_1(s)$ and $I_2(s)$ are the Laplace transforms of $i_1(t)$ and $i_2(t)$ respectively. The equations for the loop currents $I_1(s)$ and $I_2(s)$ for the circuit shown in the figure, after the switch is brought from position 1 to position 2 at $t = 0$, are

(a) $\begin{bmatrix} R+Ls+\frac{1}{Cs} & -Ls \\ -Ls & R+\frac{1}{Cs} \end{bmatrix}\begin{bmatrix} I_1(s) \\ I_2(s) \end{bmatrix} = \begin{bmatrix} V/s \\ 0 \end{bmatrix}$

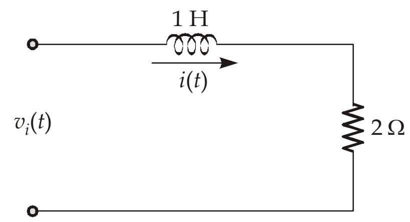
(b) $\begin{bmatrix} R+Ls+\frac{1}{Cs} & -Ls \\ -Ls & R+\frac{1}{Cs} \end{bmatrix}\begin{bmatrix} I_1(s) \\ I_2(s) \end{bmatrix} = \begin{bmatrix} -V/s \\ 0 \end{bmatrix}$

(c) $\begin{bmatrix} R+Ls+\frac{1}{Cs} & -Ls \\ -Ls & R+Ls+\frac{1}{Cs} \end{bmatrix}\begin{bmatrix} I_1(s) \\ I_2(s) \end{bmatrix} = \begin{bmatrix} -V/s \\ 0 \end{bmatrix}$

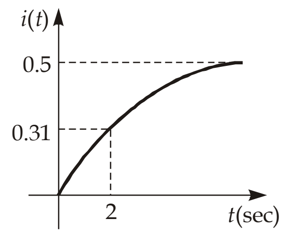
(d) $\begin{bmatrix} R+Ls+\frac{1}{Cs} & -Ls \\ -Ls & R+Ls+\frac{1}{Cs} \end{bmatrix}\begin{bmatrix} I_1(s) \\ I_2(s) \end{bmatrix} = \begin{bmatrix} V/s \\ 0 \end{bmatrix}$

[EC-2003 : 2 Marks]

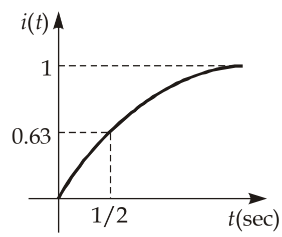
Q.11 For the R-L circuit shown in the figure, the input voltage $v_i(t) = u(t)$. The current $i(t)$ is

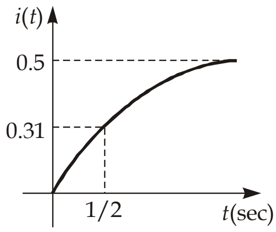


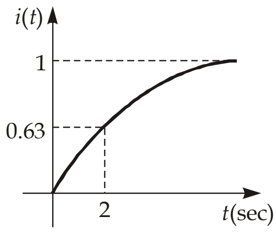
(a)



(b)

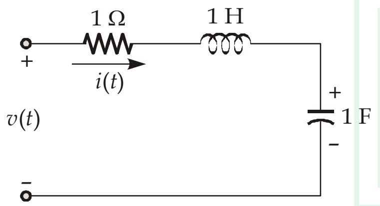


(c) 

(d) 

[EC-2004 : 1 Mark]

Q.12 The circuit shown in the figure has initial current $i_L(0^-) = 1$ A through the inductor and an initial voltage $v_C(0^-) = -1$ V across the capacitor. For input $v(t) = u(t)$, the Laplace transform of the current $i(t)$ for $t \geq 0$ is

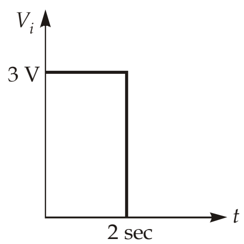


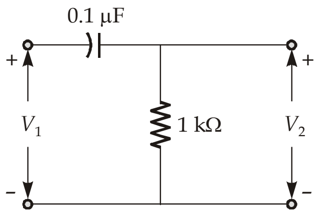
(a) $\frac{s}{s^2+s+1}$ (b) $\frac{s+2}{s^2+s+1}$

(c) $\frac{s-2}{s^2+s-1}$ (d) $\frac{s-2}{s^2+s+1}$

[EC-2004 : 2 Marks]

Q.13 A square pulse of 3 Volts amplitude is applied to C-R circuit shown in the figure. The capacitor is initially uncharged. The output voltage V_2 at time $t = 2$ sec is



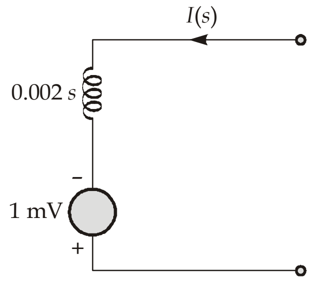


(a) 3 V (b) –3 V

(c) 4 V (d) –4 V

[EC-2005 : 2 Marks]

Q.14 A 2 mH inductor with some initial current can be represented as shown below, where 's' is the Laplace transform variable. The value of initial current is

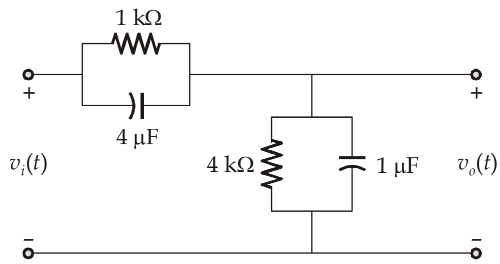


(a) 0.5 A (b) 2.0 A

(c) 1.0 A (d) 0.0 A

[EC-2006 : 1 Mark]

Q.15 In the figure shown below, assume that all the capacitors are initially uncharged. If $v_i(t) = 10\,u(t)$ Volts, $v_o(t)$ is given by

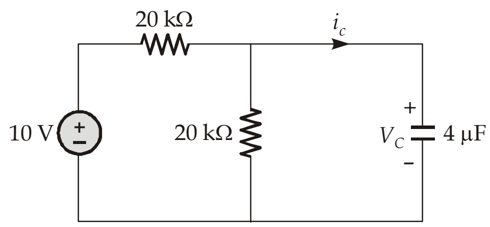


(a) $8e^{-t/0.004}$ Volts (b) $8(1 - e^{-t/0.004})$ Volts

(c) $8\,u(t)$ Volts (d) 8 Volts

[EC-2006 : 1 Mark]

Q.16 In the circuit shown, V_c is 0 Volts at $t = 0$ sec. For $t < 0$, the capacitor $i_c(t)$, where 't' is (in seconds), is given by



(a) 0.50 exp(–25t) mA

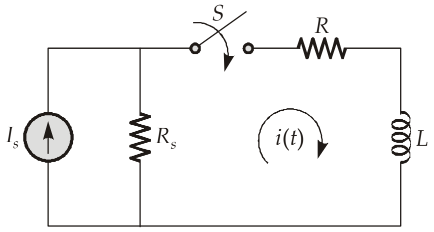
(b) 0.25 exp(–25t) mA

(c) 0.50 exp(–12.5t) mA

(d) 0.25 exp(–6.25t) mA

[EC-2007 : 2 Marks]

Q.17 In the following circuit, the switch S is closed at $t = 0$. The rate of change of current $\frac{di}{dt}(0^+)$ is given by



(a) 0 (b) $\frac{R_s I_s}{L}$

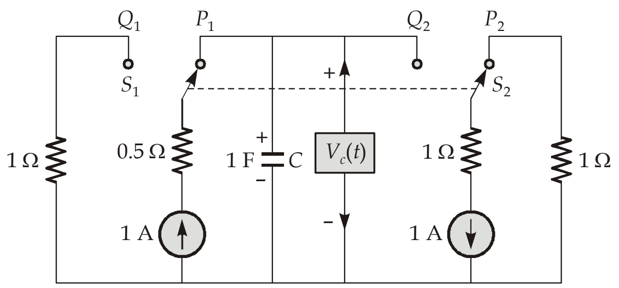
(c) $\frac{(R+R_s)I_s}{L}$ (d) ∞

[EC-2008 : 1 Mark]

Q.18 The circuit shown in the figure is used to charge the capacitor C alternately from two current sources as indicated. The switches S_1 and S_2 are mechanically coupled and connected as follows:

For $2nT \le t < (2n+1)T$, $(n = 0, 1, 2, ...)$ S_1 to P_1 and S_2 to P_2.

For $(2n+1)T \le t < (2n+2)T$, $(n = 0, 1, 2, ...)$ S_1 to Q_1 and S_2 to Q_2.



Assume that the capacitor has zero initial charge. Given that $u(t)$ is a unit step function, the voltage $V_c(t)$ across the capacitor is given by

(a) $\sum_{n=0}^{\infty} (-1)^n \, tu(t-nT)$

(b) $u(t) + 2\sum_{n=1}^{\infty} (-1)^n \, u(t-nT)$

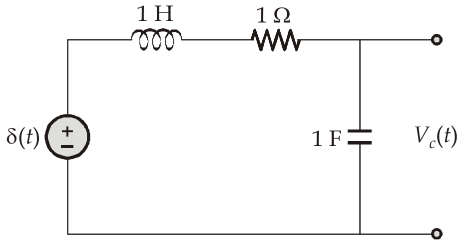
(c) $tu(t) + 2\sum_{n=1}^{\infty} (-1)^n \, (t-nT)\, u(t-nT)$

(d) $\sum_{n=0}^{\infty} [0.5 - e^{-(t-2nT)} + 0.5e^{-(t-2nT-T)}]$

[EC-2008 : 2 Marks]

Common Data for Questions (19 and 20):

The following series RLC circuit with zero initial conditions is excited by a unit impulse function $\delta(t)$.



Q.19 For $t > 0$, the output voltage $V_c(t)$ is

(a) $\frac{2}{\sqrt{3}}\left(e^{-1/2t} - e^{-\sqrt{3}/2t}\right)$

(b) $\frac{2}{\sqrt{3}} t\, e^{-1/2t}$

(c) $\frac{2}{\sqrt{3}} e^{-1/2t} \cos\left(\frac{\sqrt{3}}{2}t\right)$

(d) $\frac{2}{\sqrt{3}} e^{-1/2t} \sin\left(\frac{\sqrt{3}}{2}t\right)$

[EC-2008 : 2 Marks]

Q.20 For $t > 0$, the voltage across the resistor is

(a) $\frac{1}{\sqrt{3}}\left(e^{-\sqrt{3}/2t} - e^{-1/2t}\right)$

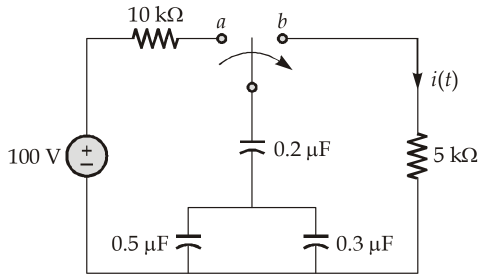
(b) $e^{-1/2t}\left[\cos\left(\frac{\sqrt{3}t}{2}\right) - \frac{1}{\sqrt{3}}\sin\left(\frac{\sqrt{3}t}{2}\right)\right]$

(c) $\frac{2}{\sqrt{3}} e^{-1/2t} \sin\left(\frac{\sqrt{3}t}{2}\right)$

(d) $\frac{2}{\sqrt{3}} e^{-1/2t} \cos\left(\frac{\sqrt{3}t}{2}\right)$

[EC-2008 : 2 Marks]

Q.21 The switch in the circuit shown was on a position a for a long time, and is moved to position 'b' at time $t = 0$. The current $i(t)$ for $t > 0$ is given by



(a) $0.2e^{-125t}\, u(t)$ mA (b) $20e^{-1250t}\, u(t)$ mA
(c) $0.2e^{-1250t}\, u(t)$ mA (d) $20e^{-1000t}\, u(t)$ mA

[EC-2009 : 2 Marks]

Q.22 The time domain behaviour of an RL circuit is represented by

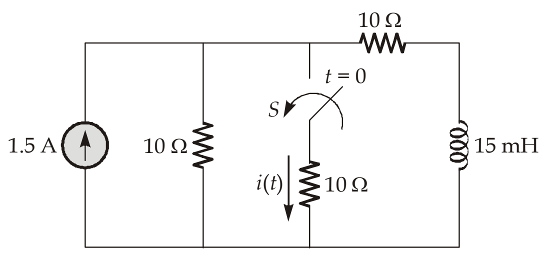
$$L\frac{di}{dt} + Ri = V_0(1 + Be^{-Rt/L}\sin t)\, u(t)$$

For an initial current of $i(0) = \frac{V_0}{R}$, the steady-state value of the current is given by

(a) $i(t) \to \frac{V_0}{R}$ (b) $i(t) \to \frac{2V_0}{R}$
(c) $i(t) \to \frac{V_0}{R}(1 + B)$ (d) $i(t) \to \frac{2V_0}{R}(1 + B)$

[EC-2009 : 2 Marks]

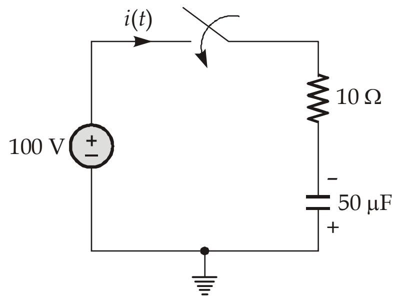
Q.23 In the circuit shown, the switch S is open for a long time and is closed at $t = 0$. The current $i(t)$ for $t \geq 0^+$ is



(a) $i(t) = 0.5 - 0.125\, e^{-1000t}$ A
(b) $i(t) = 1.5 - 0.125\, e^{-1000t}$ A
(c) $i(t) = 0.5 - 05\, e^{-1000t}$ A
(d) $i(t) = 0.375\, e^{-1000t}$ A

[EC-2010 : 2 Marks]

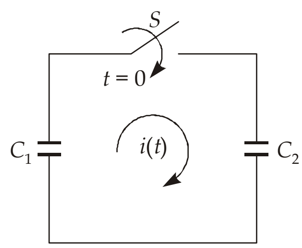
Q.24 In the circuit shown below, the initial charge on the capacitor is 2.5 mC, with the voltage polarity as indicated. The switch is closed at time $t = 0$. The current $i(t)$ at a time 't' after the switch is closed is



(a) $i(t) = 15 \exp(-2 \times 10^3 t)$ A
(b) $i(t) = 5 \exp(-2 \times 10^3 t)$ A
(c) $i(t) = 10 \exp(-2 \times 10^3 t)$ A
(d) $i(t) = -5 \exp(-2 \times 10^3 t)$ A

[EC-2011 : 2 Marks]

Q.25 In the following figure, C_1 and C_2 are ideal capacitors. C_1 had been charged to 12 V before the ideal switch S is closed at $t = 0$.
The current $i(t)$ for all 't' is



(a) zero
(b) a step function
(c) an exponentially decaying function
(d) an impulse function

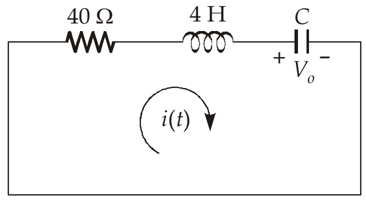
[EC-2012 : 1 Mark]

Q.26 For maximum power transfer between two cascaded sections of an electrical network, the relationship between the output impedance Z_1 of the first section to the input impedance Z_2 of the second section is

(a) $Z_2 = Z_1$ (b) $Z_2 = -Z_1$
(c) $Z_2 = Z_1^*$ (b) $Z_2 = -Z_1^*$

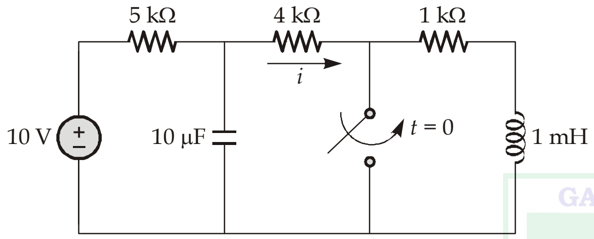
[EC-2014 : 1 Mark]

Q.27 In the circuit shown in the figure, the value of capacitor C (in mF) needed to have critically damped response $i(t)$ is ______ .



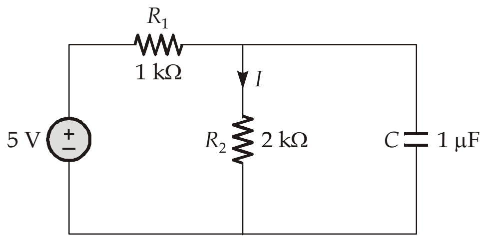
[EC-2014 : 2 Marks]

Q.28 In the figure shown, the idea switch has been open for a long time. If it is closed at $t = 0$, then the magnitude of the current (in mA) through the 4 kΩ resistor at $t = 0^+$ is ______ .



[EC-2014 : 1 Mark]

Q.29 In the figure shown, the capacitor is initially uncharged. Which one of the following expressions describes the current $I(t)$ (in mA) for $t > 0$?



(a) $I(t) = \frac{5}{3}(1 - e^{-t/\tau}),\ \tau = \frac{2}{3}$ msec

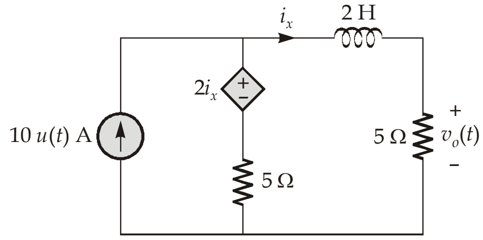
(b) $I(t) = \frac{5}{2}(1 - e^{-t/\tau}),\ \tau = \frac{2}{3}$ msec

(c) $I(t) = \frac{5}{3}(1 - e^{-t/\tau}),\ \tau = 3$ msec

(d) $I(t) = \frac{5}{2}(1 - e^{-t/\tau}),\ \tau = 3$ msec

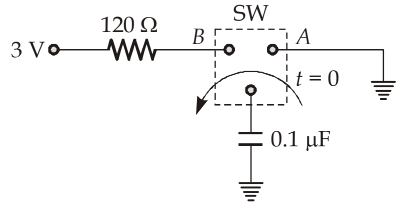
[EC-2014 : 2 Marks]

Q.30 In the circuit shown in the figure, the value of $v_o(t)$ (in Volts) for $t \to \infty$ is ______ .



[EC-2014 : 2 Marks]

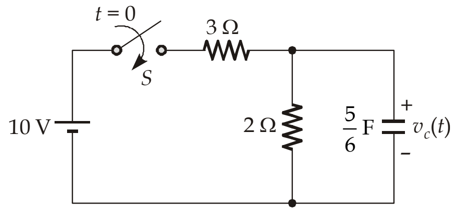
Q.31 In the circuit shown, the switch SW is thrown from position A to position B at time $t = 0$. The energy (in μJ) taken from the 3 V source to charge the 0.1 μF capacitor form 0 V to 3 V is



(a) 0.3
(b) 0.45
(c) 0.9
(d) 3

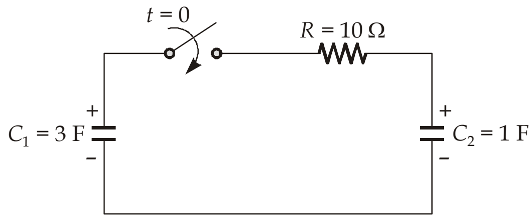
[EC-2015 : 1 Mark]

Q.32 In the circuit shown, switch SW is closed at $t = 0$. Assuming zero initial conditions, the value of $v_c(t)$ (in Volts) at $t = 1$ sec is ______ .



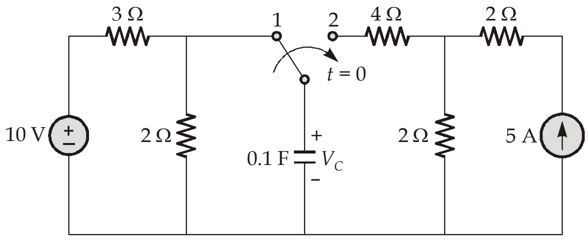
[EC-2015 : 2 Marks]

Q.33 In the circuit shown, the initial voltages across the capacitors C_1 and C_2 and 1 V and 3 V, respectively. The switch is closed at time $t = 0$. The total energy dissipated (in Joules) in the resistor R until steady-state is reached, is ____ .



[EC-2015 : 2 Marks]

Q.34 The switch has been in position 1 for a long time and abruptly changes to position 2 at $t = 0$.



If time 't' is in seconds, the capacitor voltage V_C (in Volts) for $t > 0$ is given by

(a) $4\left(1-\exp\left(-\dfrac{t}{0.5}\right)\right)$

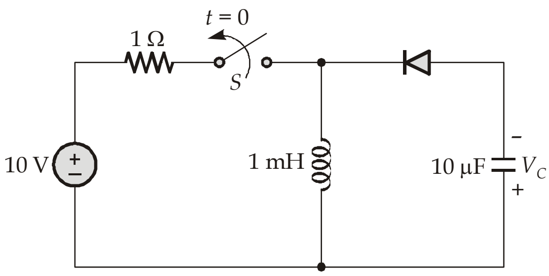
(b) $10-6\exp\left(-\dfrac{t}{0.5}\right)$

(c) $4\left(1-\exp\left(-\dfrac{t}{0.6}\right)\right)$

(d) $10-6\exp\left(-\dfrac{t}{0.6}\right)$

[EC-2016 : 1 Mark]

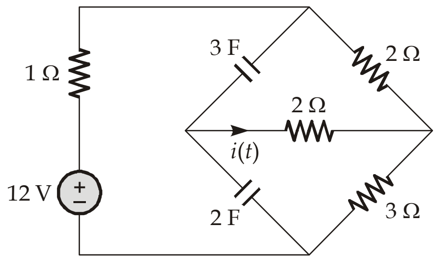
Q.35 The switch S in the circuit shown has been closed for a long time. It is opened at time $t = 0$ and remains open after that. Assume that the diode has zero reverse current and zero forward voltage drop.



The steady-state magnitude of the capacitor voltage V_C (in Volts), is ______ .

[EC-2016 : 2 Marks]

Q.36 Assume that the circuit in the figure has reached the steady-state before time $t = 0$ when the 3 Ω resistor suddenly burns out, resulting in an open-circuit. The current $i(t)$ (in Amperes) at $t = 0^+$ is _____ .

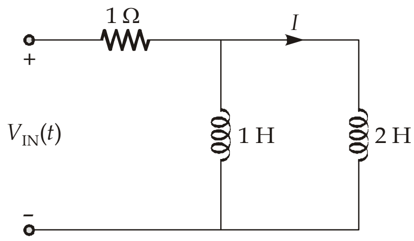


[EC-2016 : 2 Marks]

Q.37 In the circuit shown, the voltage $V_{IN}(t)$ is described by

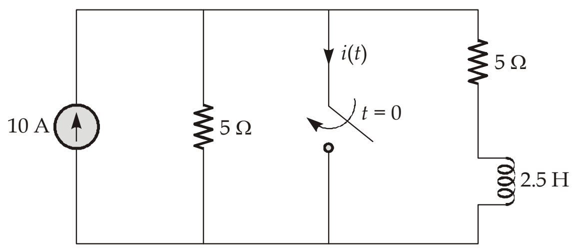
$$V_{IN}(t) = \begin{cases} 0, & \text{for } t < 0 \\ 15 \text{ Volts}, & \text{for } t \geq 0 \end{cases}$$

where 't' is in seconds. The time (in seconds) at which the current I in the circuit will reach the value 2 Ampere is _____ .



[EC-2017 : 2 Marks]

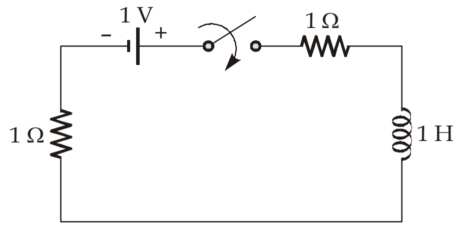
Q.38 The switch in the circuit, shown in the figure, was open for a long time and is closed at $t = 0$.



The current $i(t)$ (in Ampere) at $t = 0.5$ seconds is ______ .

[EC-2017 : 2 Marks]

Q.39 For the circuit given in the figure, the magnitude of the loop current (in amperes, correct to three decimal places) 0.5 seconds after closing the switch is _____ .

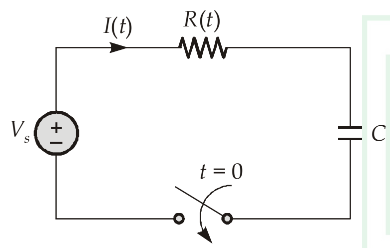


[EC-2018 : 2 Marks]

Q.40 The RC circuit shown below has a variable resistance $R(t)$ given by the following expression:

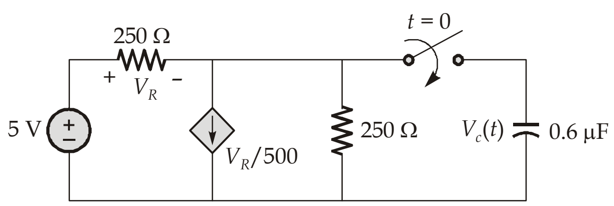
$$R(t) = R_0\left(t - \frac{t}{T}\right) \quad \text{for } 0 \le t < T$$

where $R_0 = 1\ \Omega$, and $C = 1$ F. We are also given that $T = 3R_0C$ and the source voltage is $V_s = 1$ V. If the current at time $t = 0$ is 1 A. Then the current $I(t)$, in amperes, at time $t = T/2$ is ____ .
(Rounded off to 2 decimal places).



[EC-2019 : 2 Marks]

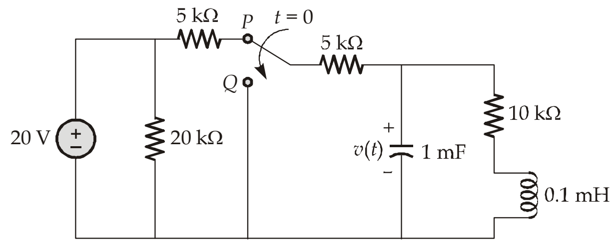
Q.41 In the circuit shown in the figure, the switch is closed at time $t = 0$, while the capacitor is initially charged to –5 V (i.e., $V_C(0) = -5$ V).



The time after which the voltage across the capacitor becomes zero (Rounded off to three decimal places) is ______ ms.

[EC-2021 : 2 Marks]

Q.42 The switch in the circuit in the figure is in position 'P' for a long time and then moved to position 'Q' at time $t = 0$.

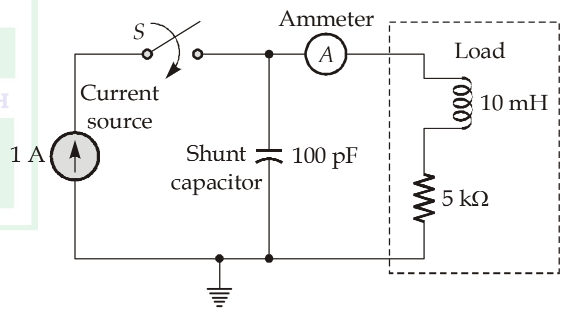


The value of $\frac{dv(t)}{dt}$ at $t = 0^+$ is

(a) –5 V/s (b) 3 V/s
(c) –3 V/s (d) 0 V/s

[EC-2021 : 2 Marks]

Q.43 The circuit in the figure contains a current source driving a load having an inductor and a resistor in series, with a shunt capacitor across the load. The ammeter is assumed to have zero resistance. The switch is closed at time, $t = 0$.

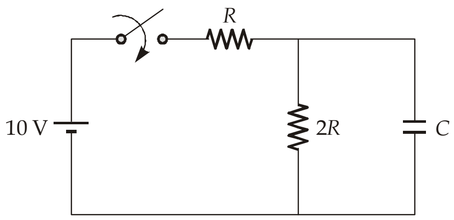


Initially, when the switch is open, the capacitor is discharged and the ammeter reads zero ampere. After the switch is closed, the ammeter reading keeps fluctuating for some time till it settles to a final steady value. The maximum ammeter reading that one will observe after the switch is closed (Rounded off to two decimal places) is _______ A.

[EC-2021 : 2 Marks]

ELECTRICAL ENGINEERING
(GATE Previous Years Solved Papers)

Q.1 The time constant of the network shown in figure is

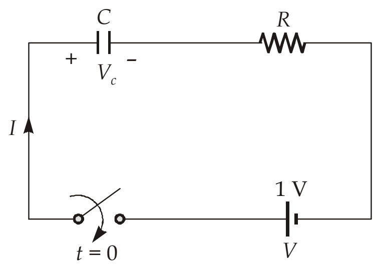


(a) 2 RC (b) 3 RC

(c) $\frac{RC}{2}$ (d) $\frac{2RC}{3}$

[EE-1992 : 1 Mark]

Q.2 In the series RC circuit shown in figure the voltage across C starts increasing when the dc source is switched ON. The rate of increase of voltage across C at the instant just after the switch is closed (i.e. at $t = 0^+$) will be



(a) Zero (b) Infinity

(c) RC (d) $\frac{1}{RC}$

[EE-1996 : 1 Mark]

Q.3 The v-i characteristic as seen from the terminal pair (A, B) of the network of Fig. (1) is shown in Fig. (2). If an inductance of value 6 mH is connected across the terminal - pair (A, B), the time constant of the system will be

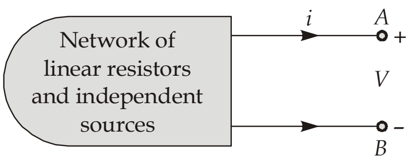


Fig. (1)

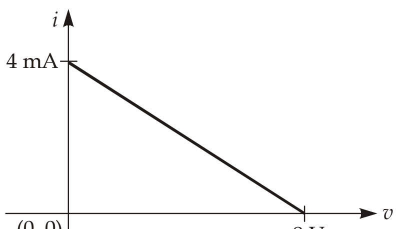


Fig. (2)

(a) 3 μ-sec

(b) 12 μ-sec

(c) 32 μ-sec

(d) unknown, unless the actual network is specified

[EE-1996 : 1 Mark]

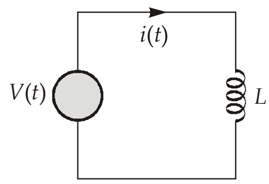
Q.4 An ideal voltage source will charge an ideal capacitor

(a) in infinite time (b) exponentially

(c) instantaneously (d) none of these

[EE-1997 : 1 Mark]

Q.5 In the circuit shown in figure, it is desired to have a constant direct current $i(t)$ through the ideal inductor L. The nature of the voltage source $v(t)$ must be



(a) constant voltage

(b) linearly increasing voltage

(c) an ideal impulse

(d) exponentially increasing voltage

[EE-1998 : 1 Mark]

Q.6 A rectangular voltage pulse of magnitude V and duration T is applied to a series combination of resistance R and capacitance C. The maximum voltage developed across the capacitor is

(a) $V\left(1-\exp\left(-\frac{T}{RC}\right)\right)$

(b) $\frac{VT}{RC}$

(c) V

(d) $V\exp\left(-\frac{T}{RC}\right)$

[EE-1999 : 2 Marks]

Q.7 A voltage waveform $v(t) = 12t^2$ is applied across a 1 H inductor for $t \geq 0$, with initial current through it being zero. The current through the inductor for $t \geq 0$ is given by

(a) $12t$ (b) $24t$

(c) $12t^3$ (d) $4t^3$

[EE-2000 : 1 Mark]

Q.8 A unit step voltage is applied at $t = 0$ to a series RL circuit with zero initial conditions.

(a) It is possible for the current to be oscillatory.

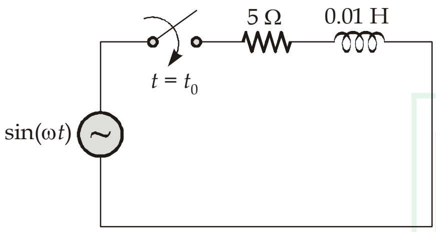
(b) The voltage across the resistor at $t = 0^+$ is zero.

(c) The energy stored in inductor in the steady-state is zero.

(d) The resistor current eventually falls to zero.

[EE-2000 : 1 Mark]

Q.9 Consider the circuit shown in figure. If the frequency of the source is 50 Hz, then the value of t_0 which results in a transient free response is

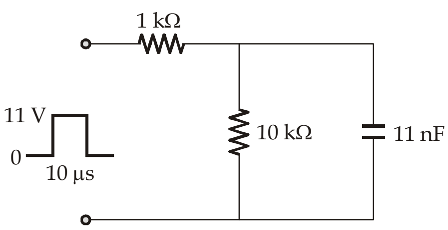


(a) 0 ms (b) 1.78 ms

(c) 2.71 ms (d) 2.91 ms

[EE-2002 : 2 Marks]

Q.10 An 11 V pulse of 10 μs duration is applied to the circuit shown in figure. Assuming that the capacitor is completely discharged prior to applying the pulse, the peak value of the capacitor voltage is

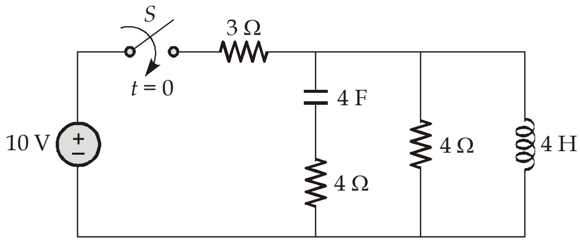


(a) 11 V (b) 5.5 V

(c) 6.32 V (d) 0.96 V

[EE-2002 : 2 Marks]

Q.11 In the circuit shown in figure, the switch 'S' is closed at time ($t = 0$). The voltage across the inductor at $t = 0^+$, is

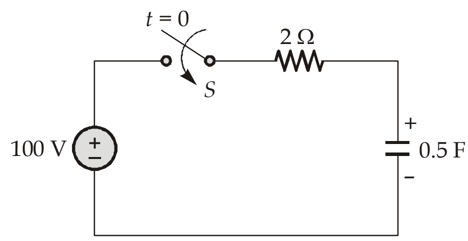


(a) 2 V (b) 4 V

(c) –6 V (d) 8 V

[EE-2003 : 2 Marks]

Q.12 In figure, the capacitor initially has a charge of 10 Coulomb. The current in the circuit one second after the switch 'S' is closed will be

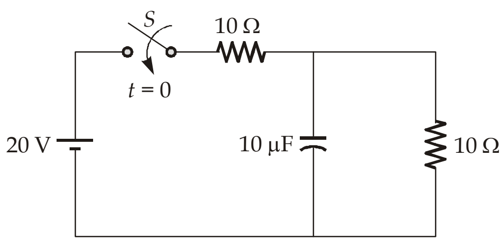


(a) 14.7 A (b) 18.5 A

(c) 40.0 A (d) 50.0 A

[EE-2004 : 2 Marks]

Q.13 In the figure given, for the initial capacitor voltage is zero. The switch is closed at $t = 0$. The final steady-state voltage across the capacitor is

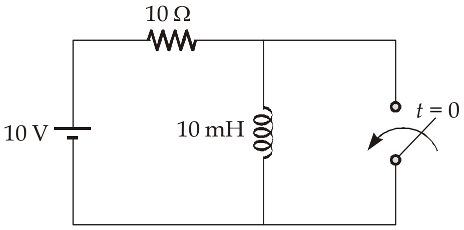


(a) 20 V (b) 10 V

(c) 5 V (d) 0 V

[EE-2005 : 1 Mark]

Q.14 The circuit shown in the figure is steady-state, when the switch is closed at $t = 0$. Assuming that the inductance is ideal, the current through the inductor at $t = 0^+$ equals.

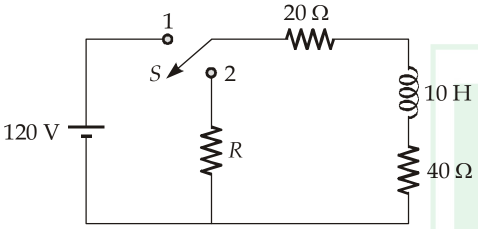


(a) 0 A (b) 0.5 A
(c) 1 A (d) 2 A

[EE-2005 : 2 Marks]

Statement for Linked Answer Questions (15 and 16):
A coil of inductance 10 H and resistance 40 Ω is connected as shown in the figure. After the switch '*S*' has been in contact with point 1 for a very long time, it is moved to point 2 at, $t = 0$.

Q.15 If at $t = 0^+$, the voltage across the coil is 120 V, the value of resistance *R* is



(a) 0 Ω (b) 20 Ω
(c) 40 Ω (d) 60 Ω

[EE-2005 : 2 Marks]

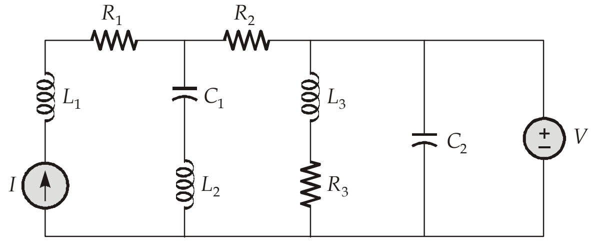
Q.16 For the value of resistance obtained in (a), the like taken for 95% of the stored energy to be dissipated is close to
(a) 0.10 sec (b) 0.15 sec
(c) 0.50 sec (d) 1.0 sec

[EE-2005 : 2 Marks]

Q.17 An ideal capacitor is charged to a voltage V_o and connected at $t = 0$ across an ideal inductor *L*. (The circuit now consists of a capacitor and inductor alone). If we let $\omega_0 = \frac{1}{\sqrt{LC}}$, the voltage across the capacitor at time $t > 0$ is given by
(a) V_o (b) $V_o \cos(\omega_o t)$
(c) $V_o \sin(\omega_o t)$ (d) $V_0 e^{-\omega_0 t} \cos(\omega_0 t)$

[EE-2006 : 2 Marks]

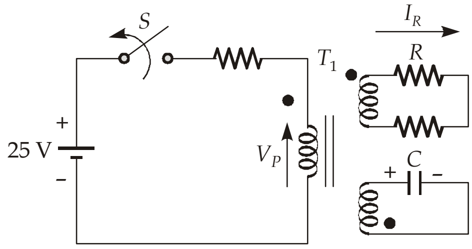
Q.18 In the circuit shown in the figure, the current source I = 1 A, the voltage source V = 5 V, $R_1 = R_2 = R_3 = 1\ \Omega$, $L_1 = L_2 = L_3 = 1$ H, $C_1 = C_2 = 1$ F. The currents (in A) through R_3 and the voltage source *V* respectively will be



(a) 1 and 4 (b) 5 and 1
(c) 5 and 2 (d) 5 and 4

[EE-2006 : 2 Marks]

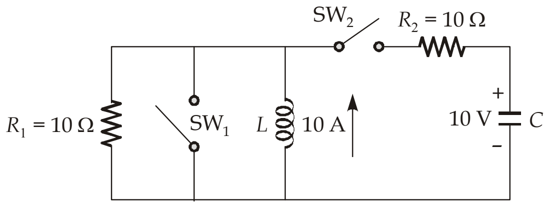
Q.19 In the figure, transformer T_1 has two secondaries, all three windings having the same number of turns and with polarities as indicated. One secondary is shorted by a 10 Ω resistor *R*, and the other by a 15 mF capacitor. The switch SW is opened ($t = 0$) when the capacitor is charged to 5 V with the left plate as positive. At ($t = 0^+$) the voltage V_P and current I_R are



(a) –25 V, 0.0 A
(b) very large voltage, very large current
(c) 5.0 V, 0.5 A
(d) –5.0 V, –0.5 A

[EE-2007 : 2 Marks]

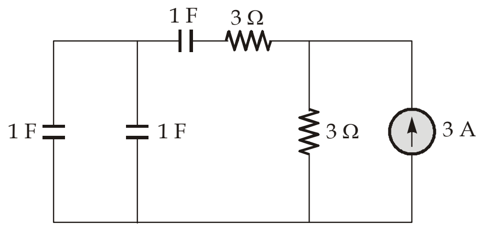
Q.20 In the circuit shown in figure. Switch SW_1 is initially closed and SW_2 is open. The inductor *L* carries a current of 10 A and the capacitor charged to 10 V with polarities as indicated. SW_2 is closed at $t = 0$ and SW_1 is opened at $t = 0$. The current through *C* and the voltage across *L* at ($t = 0^+$) is



(a) 55 A, 4.5 V (b) 5.5 A, 45 V
(c) 45 A, 5.5 A (d) 4.5 A, 55 V

[EE-2007 : 2 Marks]

Q.21 The time constant for the given circuit will be

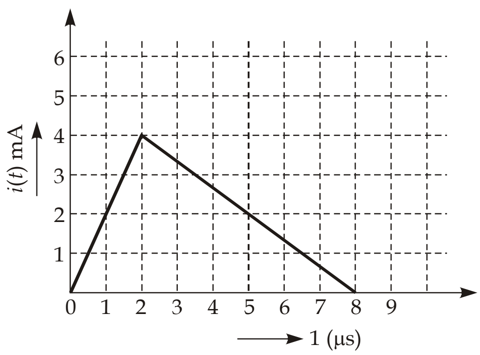


(a) $\frac{1}{9}$ sec (b) $\frac{1}{4}$ sec
(c) 4 sec (d) 9 sec

[EE-2008 : 2 Marks]

Statement for Linked Answer Questions (22 and 23):
The current $i(t)$ sketched in the figure flows through a initially uncharged 0.3 nF capacitor.

Q.22 The charge stored in the capacitor at t = 5 μs, will be



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

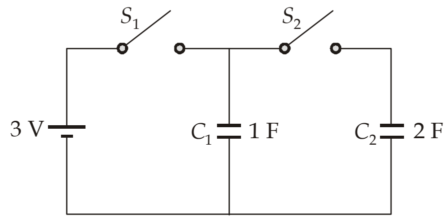
[EE-2008 : 2 Marks]

Q.23 The capacitor charged upto 5 μs, as per the current profile given in the figure, is connected across an inductor of 0.6 mH. Then the value of voltage across the capacitor after 1 μs will approximately be

(a) 18.8 V (b) 23.5 V
(c) –23.5 V (d) –30.6 V

[EE-2008 : 2 Marks]

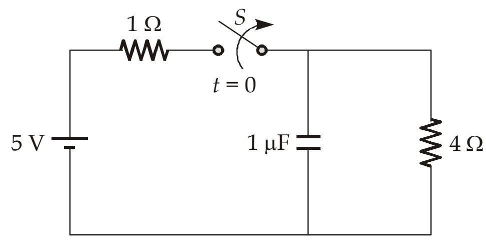
Q.24 In the figure shown, all elements used are ideal. For time $t < 0$, S_1 remained closed and S_2 open. At $t = 0$, S_1 is opened and S_2 is closed. If the voltage V_{o_2} across the capacitor C_2 at $t = 0^-$ is zero, the voltage across the capacitor combination at $t = 0^+$ will be



(a) 1 V (b) 2 V
(c) 1.5 V (d) 3 V

[EE-2009 : 2 Marks]

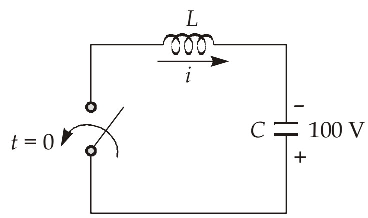
Q.25 The switch in the circuit has been closed for a long time. It is opened at $t = 0$. At $t = 0^+$, the current through the 1 μF capacitor is



(a) 0 A (b) 1 A
(c) 1.25 A (d) 5 A

[EE-2010 : 1 Mark]

Q.26 The L-C circuit shown in the figure has an inductance L = 1 mH and a capacitance C = 10 μF.

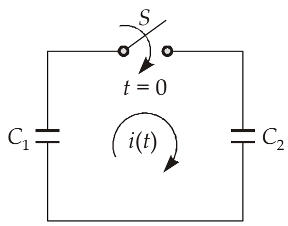


The initial current through the inductor is zero, while the initial capacitor voltage is 100 V. The switch is closed at $t = 0$. The current 'i' through the circuit is

(a) $5 \cos (5 \times 10^3 t)$ A
(b) $5 \sin (10^4 t)$ A
(c) $10 \cos (5 \times 10^3 t)$ A
(d) $10 \sin (10^4 t)$ A

[EE-2010 : 2 Marks]

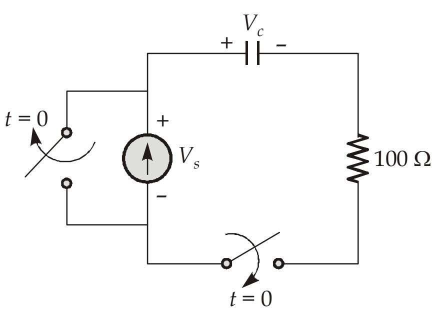
Q.27 In the following figure C_1 and C_2 are ideal capacitors. C_1 has been charged to 12 V before the ideal switch 'S' is closed at $t = 0$. The current $i(t)$ for all 't' is



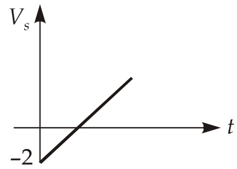
(a) zero
(b) a step function
(c) an exponentially decaying function
(d) an impulse function

[EE-2012 : 1 Mark]

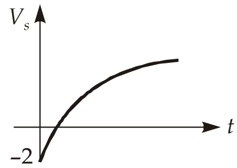
Q.28 A combination of 1 μF capacitor with an initial voltage $V_c(0) = -2$ V in series with a 100 Ω resistor is connected to a 20 mA ideal dc current source by operating both switches at $t = 0$ is as shown in the figure. Which of the following graphs shown in the options approximates the voltage V_s across the current source over the next few seconds?



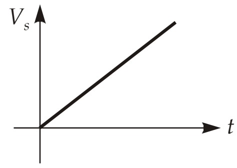
(a)



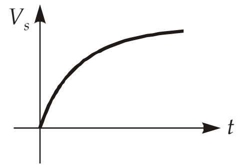
(b)



(c)

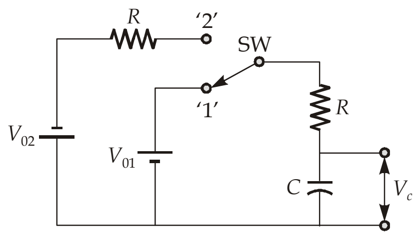


(d)



[EE-2014 : 1 Mark]

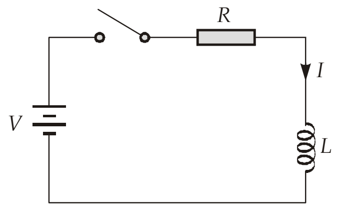
Q.29 The switch SW shown in the circuit is kept at position '1' for a long duration. At $t = 0^+$, the switch is moved to position '2'. Assuming $|V_{02}| > |V_{01}|$, the voltage $V_c(t)$ across the capacitor is



(a) $V_c(t) = V_{02}(1 - e^{-t/2RC}) - V_{01}$
(b) $V_c(t) = V_{02}(1 - e^{-t/2RC}) + V_{01}$
(c) $V_c(t) = -(V_{02} + V_{01})(1 - e^{-t/2RC}) - V_{01}$
(d) $V_c(t) = (V_{02} - V_{01})(1 - e^{-t/2RC}) + V_{01}$

[EE-2014 : 1 Mark]

Q.30 A series RL circuit is excited at $t = 0$ by closing a switch as shown in the figure. Assuming zero initial conditions, the value of $\frac{d^2 I}{dt^2}$ at $t = 0^+$ is

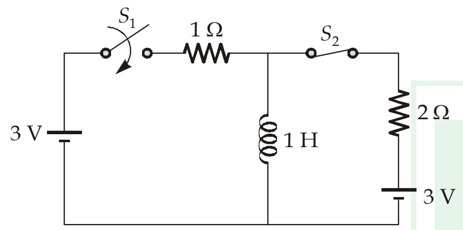


(a) $\frac{V}{L}$ (b) $\frac{-V}{R}$

(c) 0 (d) $\frac{-RV}{L^2}$

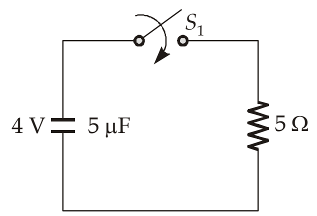
[EE-2015 : 1 Mark]

Q.31 In the circuit shown, switch S_2 has been closed for a long time. A time $t = 0$ switch S_1 is closed. At $t = 0^+$, the rate of change of current through the inductor, in amperes per second, is _____ .



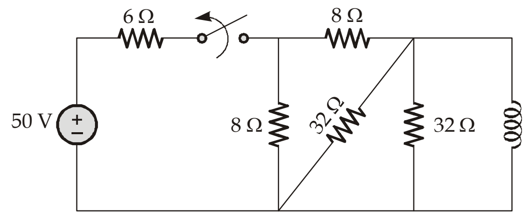
[EE-2016 : 2 Marks]

Q.32 In the circuit shown below, the initial capacitor voltage is 4 V. Switch S_1 is closed at $t = 0$. The charge (in μC) lost by the capacitor from $t = 25$ μs to $t = 100$ μs is _______ .



[EE-2016 : 2 Marks]

Q.33 The switch in the figure below was closed for a long time. It is opened at $t = 0$. The current in the inductor of 2 H for $t \geq 0$, is

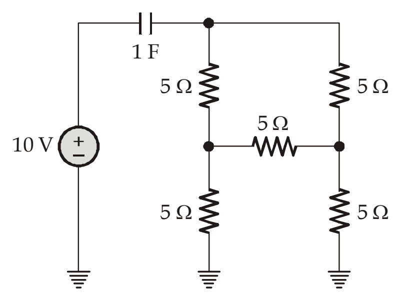


(a) $2.5\ e^{-4t}$ (b) $5\ e^{-4t}$

(c) $2.5\ e^{-0.25t}$ (d) $5\ e^{-0.25t}$

[EE-2017 : 2 Marks]

Q.34 The initial charge in the 1 F capacitor present in the circuit shown is zero. The energy in Joules transferred from the d.c. source until steady-state condition is reached equals ______ . (Give the answer upto one decimal place)



[EE-2017 : 1 Mark]

Q.35 A resistor and a capacitor are connected in series to a 10 V d.c. supply through a switch. The switch is closed at $t = 0$, and the capacitor voltage is found to cross 0 V at $t = 0.4\tau$, where τ is the circuit time constant. The absolute value of percentage change required in the initial capacitor voltage if the zero crossing has to happen at $t = 0.2\tau$ is _______ .

(Rounded off 2 decimal places).

[EE-2020 : 2 Marks]

❒❒❒❒

Electronics & Electrical Engineering

GATE Previous Years Solved Paper

Answers & Explanations

Answers — EC — Transient Analysis

1. (b)	**2.** (c)	**3.** (b)	**4.** (b)	**5.** (a)	**6.** (b)	**7.** (b)	**8.** (c)
9. (a)	**10.** (c)	**11.** (c)	**12.** (b)	**13.** (b)	**14.** (a)	**15.** (c)	**16.** (a)
17. (b)	**18.** (c)	**19.** (d)	**20.** (b)	**21.** (b)	**22.** (a)	**23.** (a)	**24.** (a)
25. (d)	**26.** (c)	**27.** (10)	**28.** (1.25)	**29.** (a)	**30.** (31.25)	**31.** (c)	**32.** (2.528)
33. (1.5)	**34.** (d)	**35.** (100)	**36.** (–1)	**37.** (0.3405)	**38.** (8.16)	**39.** (0.316)	**40.** (0.25)
41. (0.1386)	**42.** (c)	**43.** (1.44)					

Solutions — EC — Transient Analysis

1. (b)

At steady state:
Inductor behave as short-circuit.
So, under steady state condition the source current flows through the inductor.

2. (c)

$$Z_C(s) = \frac{1}{Cs} = \frac{2}{s}$$

$$I_C(s) = \frac{V_C(s)}{Z_C(s)} = \frac{s(s+1)}{2(s^3+s^2+s+1)}$$

$$= \frac{s(s+1)}{2(s^2+1)(s+1)}$$

$$I_C(s) = \frac{s}{2(s^2+1)}$$

$$i(0^+) = \lim_{s\to\infty} sI_C(s) = \lim_{s\to\infty} \frac{s^2}{2(s^2+1)}$$

$$= \frac{1}{2+0} = \frac{1}{2}\text{ Ampere}$$

3. (b)

$$Z_2(s) = \frac{R_2 \times \frac{1}{C_2 s}}{R_2 \times \frac{1}{C_1 s}} = \frac{R_2}{R_2C_2s+1}$$

$$Z_1(s) = \frac{R_1 \times \frac{1}{C_1 s}}{R_1 \times \frac{1}{C_1 s}} = \frac{R_1}{R_1C_1s+1}$$

$$\frac{V_2(s)}{V_1(s)} = \frac{Z_2(s)}{Z_1(s)+Z_2(s)}$$

$$R_1C_1 = R_2C_2$$

$$\frac{V_2(s)}{V_1(s)} = \frac{\frac{R_2}{R_2C_2s+1}}{\frac{R_1}{R_2C_2s+1}+\frac{R_2}{R_2C_2s+1}} = \frac{R_2}{R_1+R_2}$$

$$V_2(s) = \frac{R_2}{R_1+R_2}V_1(s)$$

For impulse response,

$$V_1(s) = 1$$

$$v_1(t) = \delta(t)$$

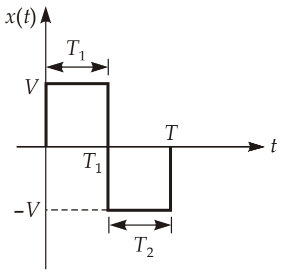
$$v_2(t) = \frac{R_2}{R_1 + R_2}\delta(t)$$

4. (b)

$$V_o = RC\frac{dV_i}{dt}$$

$$V_o = (5\times10^3)(4\times10^{-6})\frac{d}{dt}(100t) = 2\text{ V}$$

5. (a)



$$T = T_1 + T_2$$

$$\text{Rms} = \sqrt{\frac{1}{T}\int_0^T x^2(t)\,dt}$$

$$= \sqrt{\frac{1}{T}\left[\int_0^{T_1} V^2 dt + \int_{T_1}^{T} (-V)^2\,dt\right]}$$

$$\text{Rms} = \sqrt{\frac{1}{T}[V^2[T_1 - 0] + V^2[T - T_1]]}$$

$$= \sqrt{\frac{1}{T}[V^2][T_1 + T - T_1]}$$

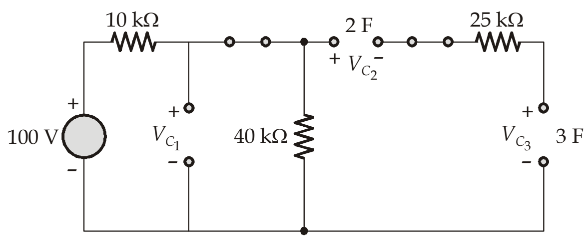
$$\text{Rms} = \sqrt{\frac{1}{T}V^2 T} = \sqrt{V^2} = V$$

6. (b)

At steady-state:

Inductor behave as short-circuit.

Capacitor behave as open-circuit,



$$V_{C_1} = 100\times\frac{40}{10+40} = 80\text{ V}$$

$$V_{C_2} = 80\times\frac{3}{2+3} = 48\text{ V}$$

$$V_{C_3} = 80\times\frac{2}{2+3} = 32\text{ V}$$

7. (b)

$$V_{(0^-)} = V_{(0^+)} = 6\text{ V}$$

So at $t = 0^+ \rightarrow$

$$V_R = 10 - 6 = 4\text{ V}$$

$$I_{R(0^+)} = \frac{4}{4} = 1\text{ Ampere}$$

$$I_{R(\infty)} = 0\text{ Ampere}$$

$$\tau = RC = 8\text{ sec.}$$

$$i(t) = i_\infty + (i_{0^+} - i_\infty)\,e^{-t/\tau}$$

$$= 0 + (1 - 0)\,e^{-t/8}$$

$$i(t) = e^{-t/8}$$

Energy absorbed by 4 Ω resistor in $(0, \infty)$

$$E = \int_0^\infty i^2 R\,dt = \int_0^\infty 4e^{-t/4}\,dt$$

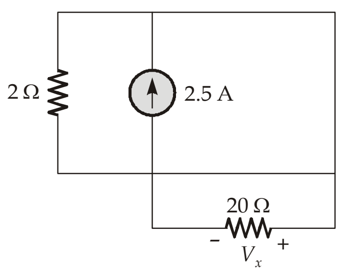
$$= 4\int_0^\infty e^{-t/4}\,dt$$

$$E = 4\left.\frac{e^{-t/4}}{-1/4}\right|_0^\infty = -16[e^{-t/4}]_0^\infty$$

$$E = -16[0 - 1] = 16\text{ J}$$

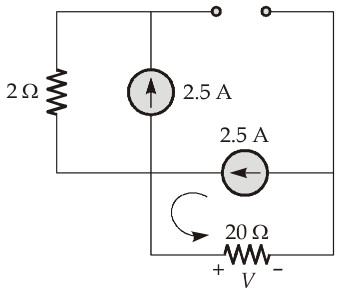
8. (c)

When switch was closed circuit was in steady state,



$$i_L(0^-) = 2.5\text{ A}$$

At $t = 0^+$;



$\Rightarrow \quad V = IR$

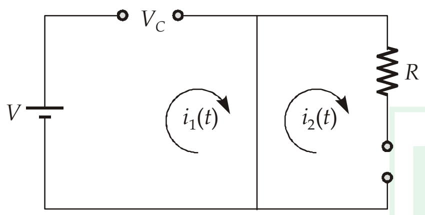
$= 2.5 \times 20 = 50$ V

$\therefore \quad V_x = -50$ V

(Polarity of V_x is given reverse of V)

9. **(a)**

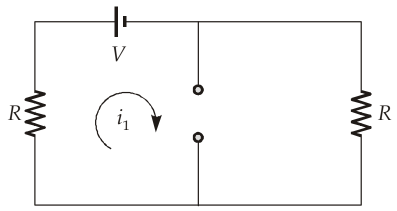
At $t = 0^-$ in steady state,



$i_1(t) = i_2(t) = 0$

$V_C(0^-) = $ V

At $t = 0^+$;

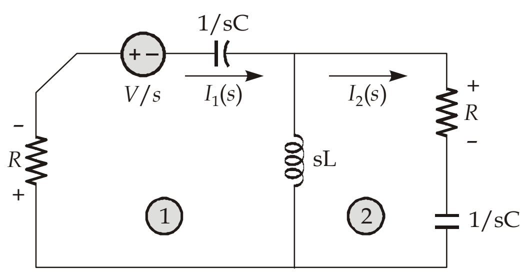


$-i_1R - V - i_1R = 0$

$\therefore \quad i_1 = -\dfrac{V}{2R}$

10. **(c)**

When switch is in position 2,



KVL in loop (1),

$$I_1(s)\cdot R + \frac{V}{s} + I_1(s)\cdot\frac{1}{sC} + [I_1(s) - I_2(s)]\,sL = 0$$

$$\Rightarrow \quad I_1(s)\left[R + \frac{1}{sC} + sL\right] - I_2(s)\cdot sL = \frac{-V}{s}$$

KVL in loop (2),

$$[I_2(s) - I_1(s)]\,sL + I_2(s)R + I_2(s)\cdot\frac{1}{sC} = 0$$

$$\Rightarrow \quad -I_1(s)\cdot sL + I_2(s)\left[R + sL + \frac{1}{sC}\right] = 0$$

$$\begin{bmatrix} R + sL + \dfrac{1}{sC} & -sL \\ -sL & R + sL + \dfrac{1}{sC} \end{bmatrix}\begin{bmatrix} I_1(s) \\ I_2(s) \end{bmatrix} = \begin{bmatrix} -V/s \\ 0 \end{bmatrix}$$

11. **(c)**

$$I(s) = \frac{V(s)}{s+2} = \frac{1}{s(s+2)}$$

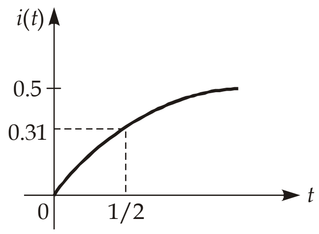
$$I(s) = \frac{1}{s(s+2)} = \frac{1}{2}\left[\frac{1}{s} - \frac{1}{s+2}\right]$$

$$i(t) = \frac{1}{2}(1 - e^{-2t})$$

At $t = 0$, $\quad i(t) = 0$

$t = \infty$, $\quad i(t) = 0.5$

$t = \dfrac{1}{2}$, $\quad i(t) = 0.31$



Graph (c) satisfies all conditions.

12. **(b)**

KVL :

$$v(t) = Ri(t) + \frac{L\,di(t)}{dt} + \frac{1}{C}\int_0^\infty i(t)\,dt$$

Taking Laplace transform on both sides,

$$V(s) = RI(s) + LsI(s) - LI(0^+) + \frac{I(s)}{sC} + \frac{V_c(0^+)}{s}$$

$$\Rightarrow \quad \frac{1}{s} = I(s) + sI(s) - 1 + \frac{I(s)}{s} - \frac{1}{s}$$

$$\frac{2}{s}+1 = \frac{I(s)}{s}[s^2+s+1]$$

$$I(s) = \frac{s+2}{s^2+s+1}$$

13. (b)

$$RC = 0.1 \times 10^{-6} \times 10^{3} = 10^{-4}$$
$$= 100\ \mu s$$

As RC is very small, so steady state will be reached in 2 second,

$$V_c = 3\ V$$
$$V_2 = -V_c = -3\ V$$

14. (a)

$$V = \frac{LdI}{dt}$$

$$V(s) = sLI(s) - LI(0^+)$$

$\Rightarrow$ $-LI(0^+) = -1$ mV (Given in question)

$$I(0^+) = \frac{1\ \text{mV}}{2\ \text{mH}} = 0.5\ A$$

15. (c)

$$Z_1 = \frac{R_1 \times \frac{1}{C_1 s}}{R_1 \times \frac{1}{C_1 s}} = \frac{R_1}{R_1 C_1 s + 1}$$

$$= \frac{1\ k\Omega}{4 \times 10^{-3} s + 1}$$

$$Z_2 = \frac{R_2 \times \frac{1}{C_2 s}}{R_2 \times \frac{1}{C_2 s}}$$

$$= \frac{R_2}{R_2 C_2 s + 1} = \frac{4\ k\Omega}{4 \times 10^{-3} s + 1}$$

$$V_o(t) = \left(\frac{Z_2}{Z_1 + Z_2}\right) V_i(t)$$

$$Z_2 = 4Z_1$$

$$\frac{Z_2}{Z_1 + Z_2} = \frac{4Z_1}{Z_1 + 4Z_1} = \frac{4Z_1}{5Z_1} = 0.8$$

$$v_o(t) = 0.8\, v_i(t) = 0.8 \times 10\, u(t)$$
$$v_o(t) = 8\, u(t)$$

16. (a)

At $t = 0^+$, capacitor is short-circuit and at $t = \infty$, capacitor is open-circuit.

So, $$I_c(0^+) = \frac{10\ V}{20\ k\Omega} = 0.5\ \text{mA}$$

$$I_c(\infty) = 0$$

Time constant of the circuit,

$$\tau = R_{eq} C$$
$$\tau = 4\ \mu F \times 20\ k\Omega \,||\, 20\ k\Omega$$
$$\Rightarrow \quad \tau = 40\ \text{m-sec}$$

Using direct formula,

$$I_c(t) = I_c(\infty) - [I_c(\infty) - I_c(0)]\, e^{-t/\tau}$$
$$I_c(t) = 0 - (0 - 0.5)\, e^{-t/40\ \text{m-sec}}$$
$$I_c(t) = 0.5\, e^{-25t}\ \text{mA}$$

17. (b)

At $t = 0$, the inductor behaves as an open-circuit.

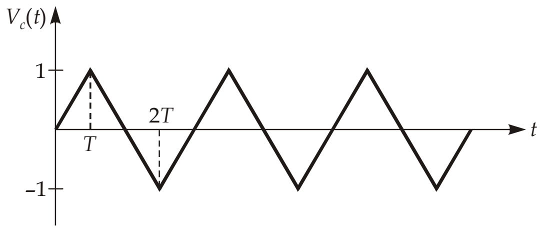
So, $$V_L = I_s R_s$$

$$V_L = L\frac{di}{dt}(0^+)$$

$$\Rightarrow \quad \frac{di}{dt}(0^+) = \frac{V_L}{L} = \frac{I_s R_s}{L}$$

18. (c)

The waveform of voltage $V_c(t)$ is shown below.



In mathematical form,

$0 < t < T$,

$$C = 1\ F, I = 1\ A$$

$$V_c = \int_0^t dt = t$$

At $t = T$, $\quad V_c = T$

$T < t < 2T$, $\quad V_c = T - \int_0^t dt = 2T - t$

At $t = 2T$, $\quad V_c = 0$

$2T < t < 3T$, $\quad V_c = \int_{2T}^{t} dt = t - 2T$

At $t = 3T$, $V_c = T$

$3T < t < 4T$,

$$V_c = T - \int_{3T}^{t} dt = 4T - t$$

$$\therefore \quad V_c(t) = tu(t) - 2(t-T)\,u(t-2T) + 2(t-2T)\,u(t-2T) \ldots$$

$$= t\,u(t) + 2\sum_{n=1}^{\infty} (-1)^n\,(t-nT)\,u(t-nT)$$

19. (d)

$$V_c(s) = \frac{1}{\left(s+1+\frac{1}{s}\right)}\cdot\left(\frac{1}{s}\right) = \frac{1}{s^2+s+1}$$

$$= \frac{1}{\left(s+\frac{1}{2}\right)^2 + \left(\frac{\sqrt{3}}{2}\right)^2}$$

$$V_c(t) = \frac{2}{\sqrt{3}}\,e^{-t/2}\sin\left(\frac{\sqrt{3}}{2}t\right)$$

20. (b)

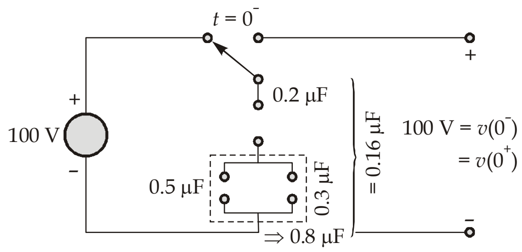
$$V_R(s) = \frac{1}{\left(s+1+\frac{1}{s}\right)}\cdot 1 = \frac{s}{s^2+s+1}$$

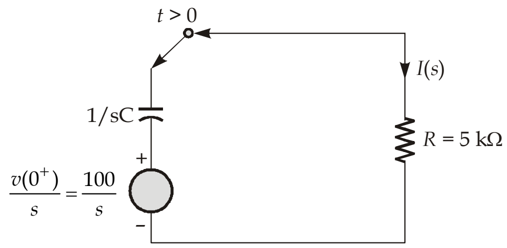
$$= \frac{\left(s+\frac{1}{2}\right)}{\left(s+\frac{1}{2}\right)^2+\left(\frac{\sqrt{3}}{2}\right)^2} - \frac{\frac{1}{2}\cdot\frac{\sqrt{3}}{2}\cdot\frac{2}{\sqrt{3}}}{\left(s+\frac{1}{2}\right)^2+\left(\frac{\sqrt{3}}{2}\right)^2}$$

$$V_R(t) = e^{-t/2}\cos\left(\frac{\sqrt{3}}{2}t\right) - \frac{1}{\sqrt{3}}e^{-t/2}\sin\left(\frac{\sqrt{3}}{2}t\right)$$

$$V_R(t) = e^{-t/2}\left[\cos\left(\frac{\sqrt{3}}{2}t\right) - \frac{1}{\sqrt{3}}\sin\left(\frac{\sqrt{3}}{2}t\right)\right]$$

21. (b)





$$C = 0.16\ \mu\text{F}$$

$$i(t) = \frac{v(0^+)}{R}\,e^{-t/RC}\cdot u(t)$$

$$v(0^+) = 100\ \text{V}$$

$$\frac{1}{RC} = \frac{1}{5\times10^3\times0.16\times10^{-6}}$$

$$R = 5\ \text{k}\Omega$$

$$i(t) = 20\,e^{-1250t}\,u(t)\ \text{mA}$$

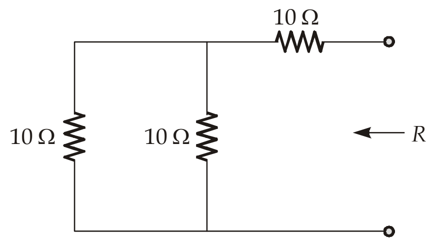
23. (a)

$$i(0^+) = \frac{0.75}{2} = 0.375\ \text{A}$$

$$i(\infty) = 0.5\ \text{A}$$

$$i(t) = i(\infty) - \{i(\infty) - i(0^+)\}\,e^{-Rt/L}$$

where, R = equivalent resistance seen across L with current source opened,



$$R = 10 + (10\,||\,10) = 15\ \Omega$$

$$i(t) = 0.5 - \{0.5 - 0.375\}\,e^{-15t/15\times10^{-3}}$$

$$= 0.5 - 0.125\,e^{-1000t}\ \text{A}$$

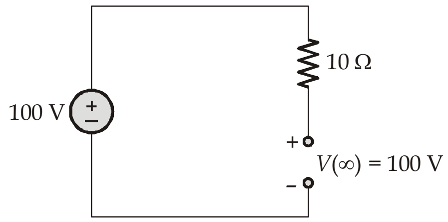
24. (a)

$$V(0^-) = V(0^+) = \frac{Q}{C}$$

$$= \frac{2.5\times10^{-3}}{50\times10^{-6}} = -50\ \text{V}$$

($\because$ direction given is opposite)

$$V(\infty) = 100\ \text{V}$$



$$V(t) = V(\infty) + [V(0^+) - V(\infty)]\,e^{-t/\tau}$$
$$= 100 + (-50 - 100)\,e^{-t/\tau}$$
$$V(t) = 100 - 150\,e^{-t/\tau}$$
$$i(t) = C\frac{dV}{dt} = C\frac{150}{\tau}\,e^{-t/\tau}$$

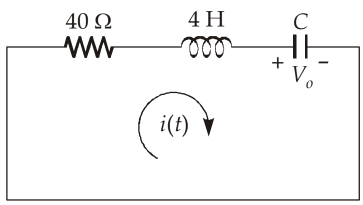
and $\tau = 10 \times 50 \times 10^{-6}$
$= 5 \times 10^{-4}$

$$i(t) = 50\times10^{-6}\times\frac{150}{10\times50\times10^{-6}}\,e^{-2\times10^{3}t}$$
$$= 15\,e^{-2\times10^{3}t} \text{ Ampere}$$

25. (d)

Since there is no resistance so time constant will be zero. That means as soon as the switch will be closed voltages at C_1 and C_2 will become equal and capacitor allows sudden change of voltage only if impulse of current will pass through it.

27. Sol.



For critically damped system,

$$\xi = 1 = \frac{1}{2Q} \quad ...(i)$$

where, ξ = Damping factor
Q = Quality factor

For series RLC circuit,

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} \quad ...(ii)$$

From equation (i) and (ii),

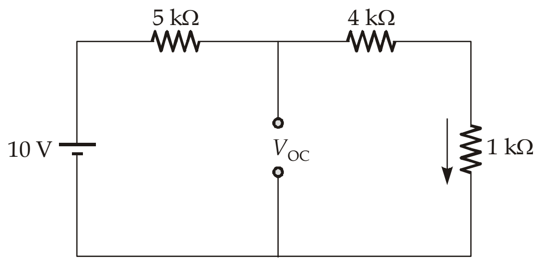
$$\frac{1}{\frac{2}{R}\sqrt{\frac{L}{C}}} = 1$$

or, $C = \left(\frac{2}{R}\right)^2$

$$L = \left(\frac{2}{40}\right)^2 \times 4 = 10 \text{ mF}$$

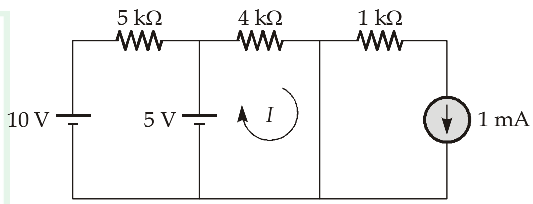
28. Sol.

At steady state $t = 0^-$,



$\therefore$ $V_c(0) = V_c(0^+) = 5\text{ V}$
$I_L(0^-) = I_L(0^+) = 1\text{ mA}$

At $t = 0$, switch get closed,

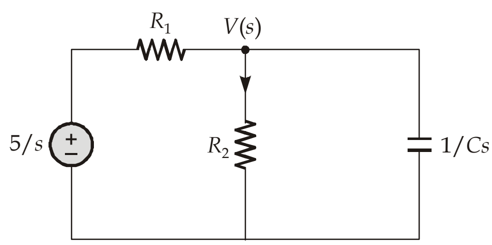


Thus, the current through 4 Ω resistance is,

$$I = \frac{5}{4\times10^3} = 1.25 \text{ mA}$$

29. (a)

Converting the given circuit into frequency domain and applying KCL at $V(s)$,



we get,

$$\frac{V(s)-\frac{5}{s}}{R_1} + \frac{V(s)}{R_2} + \frac{V(s)}{1/Cs} = 0 \quad ...(i)$$

$\because$ $R_1 = 1\text{ k}\Omega$, $R_2 = 2\text{ k}\Omega$
and $C = 1\ \mu\text{F}$

Using the components value we get,

$$V(s)\left[\frac{1}{1}+\frac{1}{2}+s\right] = \frac{5}{s}$$

or, $$V(s) = \frac{5}{s\left(s+\frac{3}{2}\right)} \quad \text{...(ii)}$$

Using partial fraction on equation (i),

$$V(s) = \frac{10}{3s}-\frac{10}{3\left(s+\frac{3}{2}\right)} \quad \text{...(iii)}$$

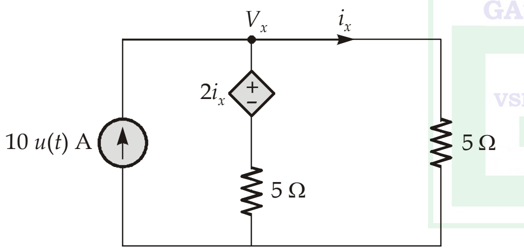
Using inverse Laplace transform,

$$v(t) = \frac{10}{3s}[1-e^{-3/2t}] \quad \text{...(iv)}$$

$\therefore$ Current, $$I = \frac{V(t)}{R_2}=\frac{5}{3}[1-e^{-3/2t}]\,\text{mA}$$

30. Sol.

At steady state the inductor act as a short-circuit,



$\therefore$ $V_x = 5i_x$

By KCL,

$$-10+\frac{V_x-2i_x}{5}+i_x = 0$$

$$-10+\frac{5i_x-2i_x}{5}+i_x = 0$$

or, $$\frac{8i_x}{5} = 10$$

$\Rightarrow$ $$i_x = \frac{50}{8}\,\text{A}$$

$\therefore$ $$v_o(t) = 5i_x(t)$$

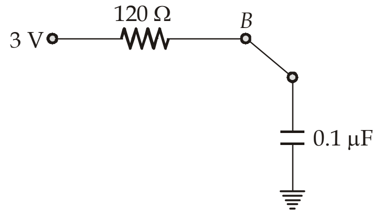
$$= \frac{5\times 50}{8} = 31.25\text{ V}$$

31. (c)

$v_c(0^-) = 0$ V

$v_c(0^+) = 0$ V

$v_c(\infty) = 3$ V



Time constant,

$t = RC = 120 \times 0.1 \times 10^{-6}$

$v_c(t) = 3 + (0 - 3)\, e^{-t/\tau}$

$= 3\,(1 - e^{-t/\tau})$

$$I_c(t) = \frac{C\,dv_c(t)}{dt} = \frac{0.1\times10^{-6}\times3\times e^{-t/\tau}}{\tau}$$

$$= \frac{0.1\times10^{-6}\times3\,e^{-t/\tau}}{120\times0.1\times10^{-6}}=\frac{1}{40}e^{-t/\tau}$$

$$\text{Energy} = \int_0^\infty VI\,dt$$

$$= \int_0^\infty 3\cdot\frac{1}{40}\times e^{-t/\tau} = -\frac{3}{40}\times\tau\,e^{-t/\tau}\Big|_0^\infty$$

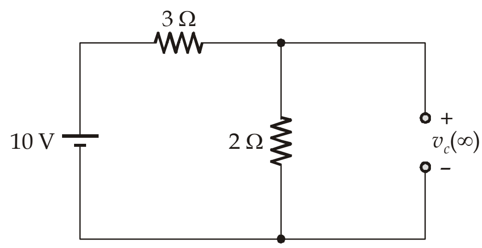
$$= \frac{3}{40}\times12\times10^{-6} = 0.9\text{ µJ}$$

32. Sol.

$v_c(0^-) = 0$ V

$v_c(0^+) = 0$ V

At $t=\infty$,



$$v_c(\infty) = \frac{2}{2+3}\times10 = 4\text{ V}$$

[By voltage divider]

$v_c(t) = 4[1 - e^{-t/\tau}]$

$$\tau = R_{eq}C = \frac{3\times2}{3+2}\times\frac{5}{6} = 1\text{ sec.}$$

$v_c(1) = 4[1 - e^{-1/1}] = 2.528$ Volts

33. Sol.

$$\text{Initial energy} = \frac{1}{2}(C_1V_1^2 + C_2V_2^2)$$

$$= \frac{1}{2}(3\times1^2 + 1\times3^2) = 6\text{ J}$$

Final energy stored in capacitor

$$= \frac{1}{2}(C_1 + C_2)\,V^2$$

$$C_1V_1 + C_2V_2 = (C_1 + C_2)\,V$$

$$1\times3 + 3\times1 = (1+3)\,V$$

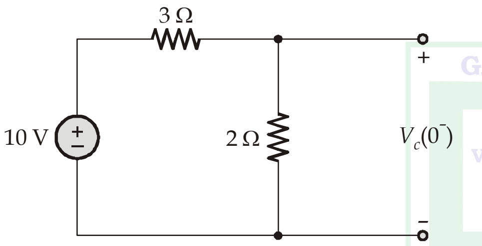
$$V = 1.5\text{ V}$$

$$\text{Final energy} = \frac{1}{2}(1+3)\times(1.5)^2 = 4.5\text{ J}$$

Energy dissipated = 6 – 4.5 = 1.5 J

34. (d)

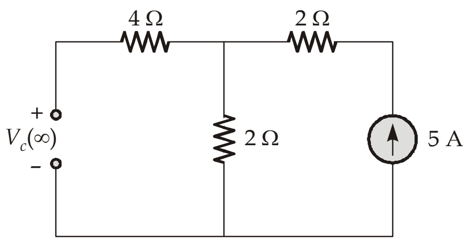
At $t = 0^-$, switch is at position-1.



where, $V_c(0^-) = \dfrac{10\times2}{2+3} = 4\text{ V}$ ...(i)

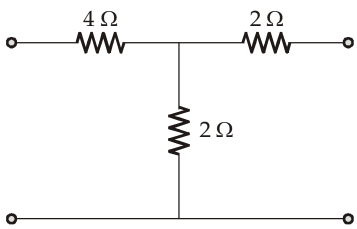
$\therefore$ $V_c(0^-) = V_c(0^+) = 4\text{ V}$

At $t = \infty$,



$$V_c(\infty) = 5\times2 = 10\text{ V} \qquad \text{...(ii)}$$

The time constant of the circuit is,



$$\tau = R_{eq}C_{eq}$$

$$= (4+2)\times0.1 = 0.6\text{ sec.}$$

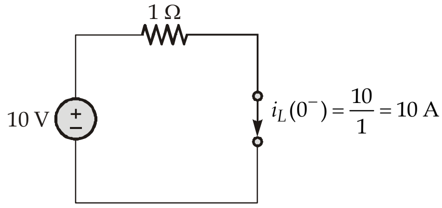
$$\therefore \quad V_c(t) = V_c(\infty) + [V_c(0^+) - V_c(\infty)]\,e^{-t/\tau}$$

$$= 10 + (4-10)\,e^{-t/0.6}$$

$$V_c(t) = (10 - 6\,e^{-t/0.6})\text{ V}$$

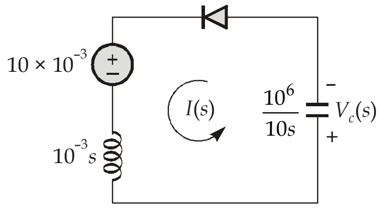
35. Sol.

At $t = 0^-$;



$$i_L(0^-) = \frac{10}{1} = 10\text{ A}$$

For $t > 0$ (using Laplace transform)



$$I(s) = \frac{10\times10^{-3}}{10^{-3}s + \dfrac{10^6}{10s}}$$

$$V_c(s) = I(s)\times\frac{10^6}{10s}$$

$$V_c(s) = \frac{10^6}{s^2 + 10^8}$$

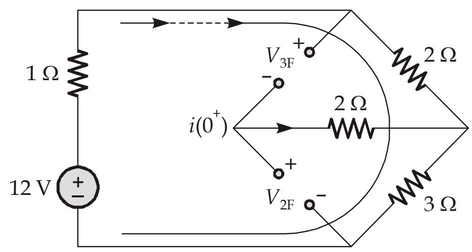
Taking inverse Laplace, we get,

$$V_c(t) = 100\sin10^4t\text{ V}$$

$\therefore$ Steady state magnitude voltage across capacitor is 100 V.

36. Sol.

At $t = 0^-$;

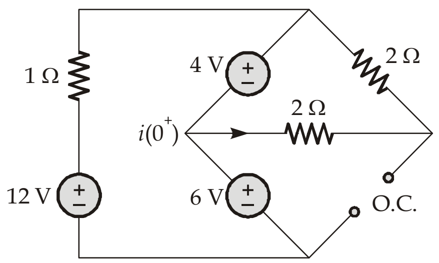


$$I = \frac{12}{6} = 2\text{ A}$$

$$V_{3F} = 10 \times \frac{2}{5} = 4\text{ V}$$

$$V_{2F} = 10 \times \frac{3}{5} = 6\text{ V}$$

At $t = 0^+$;



$$i(0^+) = \frac{-4}{2+2} = -1\text{ A}$$

Note: As the current direction is not mentioned in the question, thus by reversing the current direction 1 A can also be the answer.

37. Sol.

$$i_s(t) = \frac{V}{R}\left[1 - e^{-\frac{Rt}{L}}\right]$$

$$i_s(t) = \frac{15}{1}\left[1 - e^{-\frac{3t}{2}}\right]\text{A}$$

Current through 2 H,

$$i(t) = i_s(t)\frac{1}{1+2}$$

$$i(t) = 5\left[1 - e^{-\frac{3t}{2}}\right]\text{A}$$

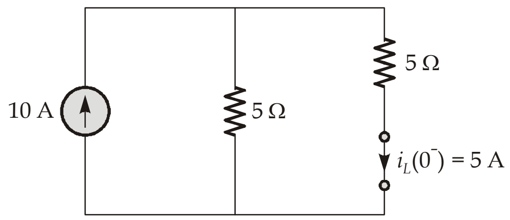
At $i(t) = 2$ A,

$$2 = 5\left[1 - e^{-\frac{3t}{2}}\right]$$

By solving, $t = 0.3405$ sec.

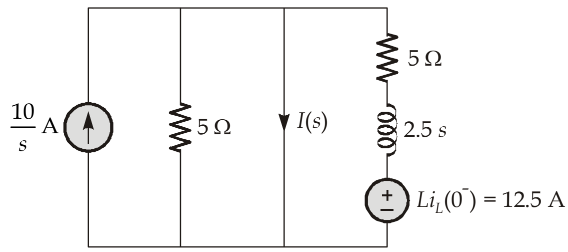
38. Sol.

- The equivalent circuit at $t = 0^-$ is as follows:



$$i_L(0^-) = i_L(0^+) = 5\text{ A}$$

- The Laplace transform model of the circuit for $t > 0$ is as follows:



$$I(s) = \frac{10}{s} - \frac{12.5}{5+2.5s} = \frac{10}{s} - \frac{5}{s+2}$$

- By taking inverse Laplace transform,

$$i(t) = (10 - 5e^{-2t})\,u(t)\text{ A}$$

- At $t = 0.5$ seconds,

$$i(t) = \left(10 - \frac{5}{e}\right)\text{A} = 8.16\text{ A}$$

39. Sol.

Loop current,

$$i(t) = \frac{1}{1+1}(1 - e^{-t/\tau})\text{ A}; \quad t > 0$$

$$\tau = \frac{L}{R_{eq}} = \frac{1}{1+1} = \frac{1}{2}\text{ sec.}$$

$$i(t) = \frac{1}{2}(1 - e^{-2t})\text{ A}; \quad t > 0$$

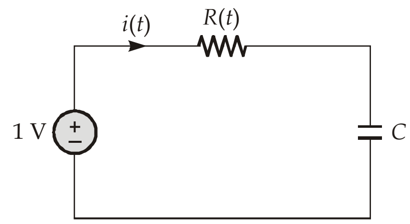
At $t = 0.5$ sec,

$$i(t) = \frac{1}{2}(1 - e^{-1})\text{ A} = 0.316\text{ A}$$

40. Sol.

$$T = 3R_0C = 3\text{ sec.}$$

$$R(t) = \left(1 - \frac{t}{3}\right); \quad 0 \le t \le 3\,\text{sec}$$



$$R(t)i(t)+\frac{1}{C}\int i(t)\,dt = 1$$

$$\left(1-\frac{t}{3}\right)i(t)+\int i(t)\,dt = 1$$

Differentiating both sides, we get,

$$\left(1-\frac{t}{3}\right)\frac{di}{dt}-\frac{i}{3}+i = 0$$

$$(3-t)\frac{di}{dt}+2i = 0$$

$$\frac{di}{i} = -\frac{2}{(3-t)}dt$$

Integrating on both sides, we get,

$$\ln(i) = 2\ln(3-t)+\ln(c)$$

$$i(t) = c(3-t)^2;\quad t\ge 0$$

Given that, $i(0) = 1$ A

So, $c(3-0)^2 = 1$ A

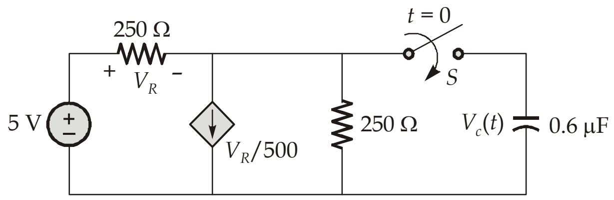
$$c = \frac{1}{9}\text{ A}$$

$$i(t) = \frac{1}{9}(3-t)^2\text{ A}$$

At, $t = \frac{T}{2} = 1.5$ sec

$$i(t) = \frac{1}{9}(1.5)^2 = 0.25\text{ A}$$

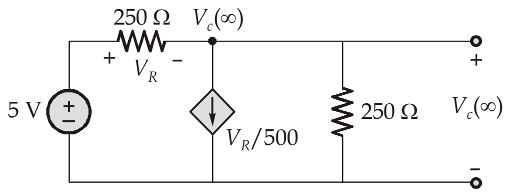
41. (0.1386)



$$V_c(0) = -5\text{ V} = V_o$$

For $t > 0$, S is closed.

For final value at $t = \infty$ (S.S), $C \to$ O.C.



By KCL at $V_c(\infty)$,

$$\frac{V_c(\infty)-5}{250}+\frac{V_R}{500}+\frac{V_c(\infty)}{250} = 0$$

$$\frac{V_c(\infty)-5}{250}+\frac{5-V_c(\infty)}{500}+\frac{V_c(\infty)}{250} = 0$$

$$(V_R = 5 - V_c(\infty))$$

$$V_c(\infty)\left[\frac{1}{250}-\frac{1}{500}+\frac{1}{250}\right] = \frac{5}{250}-\frac{5}{500}$$

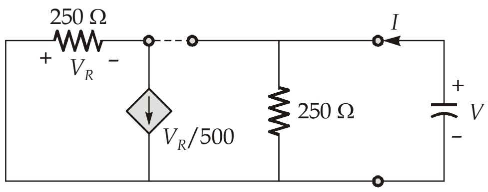
$$V_c(\infty)\,[2-1+2] = 5(2-1)$$

$$V_c(\infty) = \frac{5}{3}\text{ Volts}$$

For time constant, $\tau = R_{eq}C$

For $R_{eq}(V \to \text{S.C})$

V-I method:



By KCL at (V),

$$I+\frac{V_R}{250} = \frac{V_R}{500}+\frac{V}{250}$$

$$I = \frac{V_R}{500}-\frac{V_R}{250}+\frac{V}{250}$$

$$I = -\frac{V}{500}+\frac{V_R}{250}+\frac{V}{250}\qquad (V = -V_R)$$

$$I = V\left[\frac{2}{500}-\frac{1}{500}\right] = V\left[\frac{3}{500}\right]$$

$$\frac{V}{I} = \frac{500}{3} = R_{eq}$$

$$\tau = R_{eq}C = \frac{500}{3}\times 0.6\ \mu\text{F}$$

$$= \frac{50\times 6}{3}\text{ H} = 10^{-4}\text{ sec}$$

$$V_c(t) = V_C(\infty)+(V_C(0)-V_C(\infty))\,e^{-t/\tau}$$

$$= \frac{5}{3} + \left(-5 - \frac{5}{3}\right) e^{-10^4 t}$$

$$V_c(t) = \frac{5}{3} - 5\left(\frac{4}{3}\right) e^{-10^4 t}$$

$$V_c(t) = \left(\frac{5 - 20e^{-10^4 t}}{3}\right) \text{Volts} \quad t \geq 0$$

If, $V_c(t) = 0$

$$5 = 20e^{-10^4 t} \Rightarrow \frac{1}{4} = e^{-10^4 t}$$

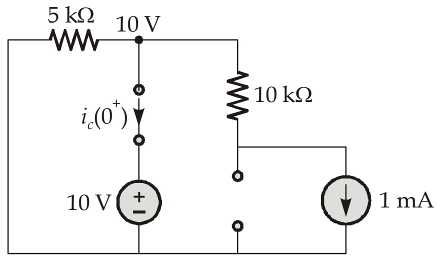
$$\ln\frac{1}{4} = -10^4 t$$

$$+1.386 = +10^4 t$$

$$\Rightarrow t = 1.386 \times 10^{-4}$$

$$t = 0.1386 \times 10^{-3}$$

$$t = 0.1386 \text{ msec}$$



By KCL at (10 V)

$$\frac{10}{5k} + i_C(0^+) + 1 \text{ mA} = 0$$

$$i_C(0^+) = -3 \text{ mA}$$

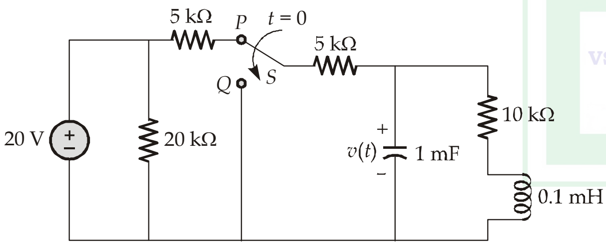
$$C\frac{dv_C(0^+)}{dt} = -3 \text{ mA}$$

$$\Rightarrow \frac{dv_C(0^+)}{dt} = \frac{-3\text{ m}}{C} = \frac{-3\text{ m}}{1\text{ m}}$$

$$\frac{dv_C(0^+)}{dt} = -3 \text{ V/sec}$$

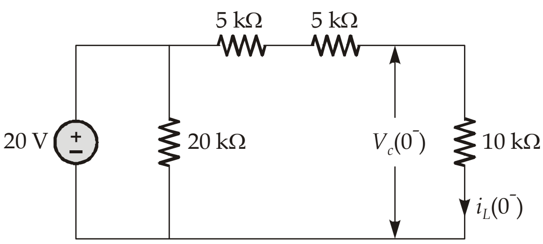
42. (c)

Given:



For $t < 0$, 'S' is in position (P).

At $t = 0-$ (S.S), $L \rightarrow$ S.C, $C \rightarrow$ O.C



$$i_L(0^-) = \frac{20}{20k} = 1 \text{ mA} = i_L(0^+) = I_o$$

By VDR,

$$V_C(0^-) = \frac{20 \times 10k}{(5+5+10)k}$$

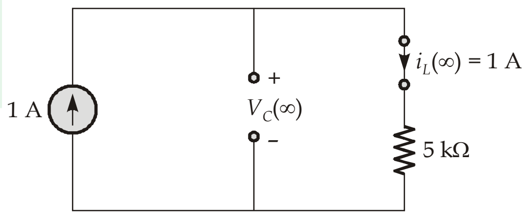
$$10 \text{ V} = V_C(0^+) = V_o$$

At $t = 0+$, 'S' is in position (Q)

$L \rightarrow$ O.C. with I_o, $C \rightarrow$ S.C. with V_o

43. (1.44)

In steady state the circuit is,

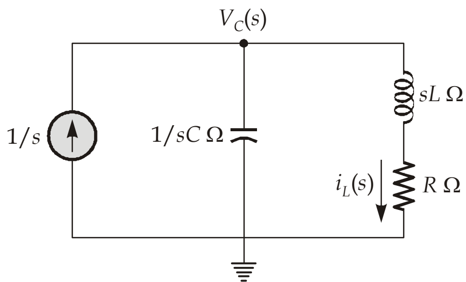


$$\Rightarrow i_L(\infty) = 1 \text{ A}$$

= Ammeter current in steady state

$$\Rightarrow V_C(\infty) = 5\text{ k} \cdot 1 \text{ A} = 5 \text{ kV}$$

During the transient period the Laplace domain transformed circuit with zero initial conditions,



Nodal equation in s-domain

$$\Rightarrow -\frac{1}{s} + \frac{V_C(s)}{1/sC} + \frac{V_C(s)}{R + sL} = 0$$

$$\Rightarrow \quad V_C(s) = \frac{1}{s}\cdot\frac{R+sL}{s^2LC+RCs+1}$$

$$\Rightarrow \quad I_L(s) = \frac{V_C(s)}{R+sL} = \frac{1/LC}{s\left(s^2+\frac{R}{L}s+\frac{1}{LC}\right)}$$

$$\omega_n^2 = \frac{1}{LC}$$

and $$2\xi\omega_n = \frac{R}{L} \Rightarrow \xi = \frac{R}{2}\sqrt{\frac{C}{L}}$$

$$\Rightarrow \quad \xi = \frac{5\times10^3}{2}\sqrt{\frac{100\times10^{-12}}{10\times10^{-3}}}$$

$$= 2.5\times10^{+3}\sqrt{10^{-8}}$$

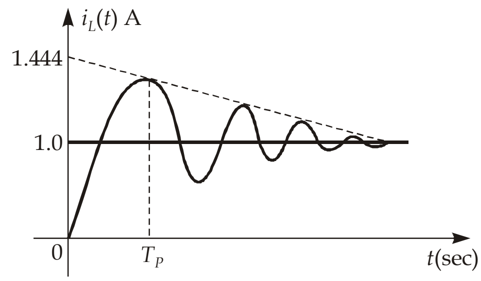
$$= 2.5 \times 10^3 \times 10^{-4}$$

$$= 0.25$$

$\Rightarrow$ Peak overshoot (or) First maxima

$$= e^{-\xi\pi/\sqrt{1-\xi^2}}$$

$$= e^{-\frac{0.25\times3.14}{\sqrt{1-(0.25)^2}}} = 0.4443$$



So, the maximum ammeter reading just after the switch closed is,

$$i_L(t)|_{max} = 1 + 0.444 = 1.444 \text{ A}$$

❑❑❑❑

Answers — EE Transient and Steady-State Response

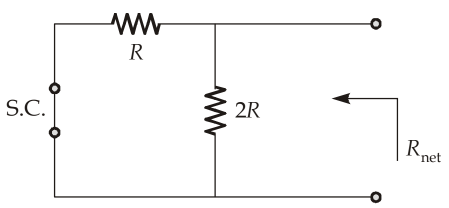
1. (d)	**2.** (d)	**3.** (a)	**4.** (c)	**5.** (c)	**6.** (a)	**7.** (d)	**8.** (b)
9. (b)	**10.** (c)	**11.** (b)	**12.** (a)	**13.** (b)	**14.** (c)	**15.** (c)	**16.** (b)
17. (b)	**18.** (d)	**19.** (d)	**20.** (d)	**21.** (c)	**22.** (c)	**23.** (d)	**24.** (a)
25. (b)	**26.** (d)	**27.** (d)	**28.** (c)	**29.** (*)	**30.** (d)	**31.** (2)	
32. (6.99×10^{-6})		**33.** (a)	**34.** (100)	**35.** (54.99)			

Solutions — EE Transient and Steady-State Response

1. (d)

Time constant, $\tau = R_{net}\cdot C$

R_{net} = Net resistance across capacitor when all the independent voltage sources are short-circuited and all independent current sources are open-circuited.



$$R_{net} = R\,||\,2R = \frac{2}{3}R$$

Hence time constant,

$$\tau = \frac{2}{3}RC\text{ sec}.$$

2. (d)

When switch is closed, current through capacitor,

$$I = C\frac{dV_c(t)}{dt}$$

$$\therefore \quad V = RI + V_c(t)$$

$$1 = RC\frac{dV_c(t)}{dt} + V_c(t)$$

$\because$ At $t = 0^+$,

$$V_c(0^+) = 0$$

$$\therefore \quad 1 = RC\frac{dV_c(t)}{dt} + 0$$

Hence, $$\frac{dV_c(0^+)}{dt} = \frac{1}{RC}$$

3. (a)

$$R = \frac{V_{OC}}{I_{SC}} = \frac{8}{4\times10^{-3}} = 2\text{ k}\Omega$$

$$L = 6\text{ mH}$$

Time constant, $$\tau = \frac{L}{R} = \frac{6\times10^{-3}}{2\times10^{3}} = 3\ \mu\text{sec}.$$

4. (c)

$\because$ Ideal voltage has zero internal resistance,

$\therefore$ Time constant,

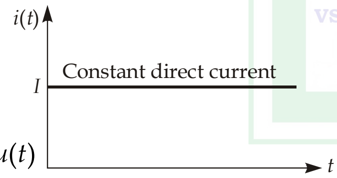
$$\tau = RC = 0$$

Hence capacitor will charge instantaneously.

5. (c)

$$V = L\frac{di(t)}{dt}$$

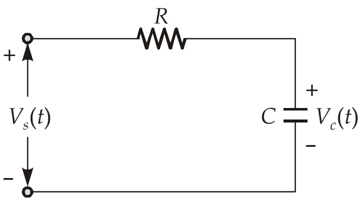
For $i(t) = I\,u(t)$



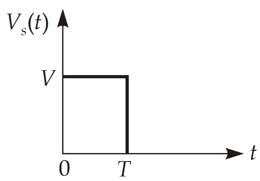
$$V = L\frac{d}{dt}I\,u(t)$$

$= LI\,\delta(t)$ viz an ideal impulse function

6. (a)



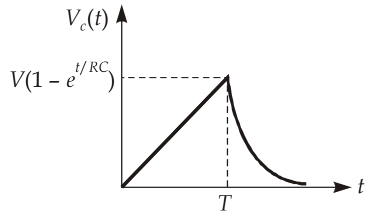
Given,



i.e., $V_s = V[u(t) - u(t - T)]$

$\because$ $V_c(t) = V_s(t) \times (1 - e^{-t/RC})$

$= V(1 - e^{-t/RC}) \times [u(t) - u(t - n)]$



i.e., capacitor charges till $t = T$ and then discharges.

Hence, $V_{c(\max)} = V(1 - e^{-\tau/RC})$

7. (d)

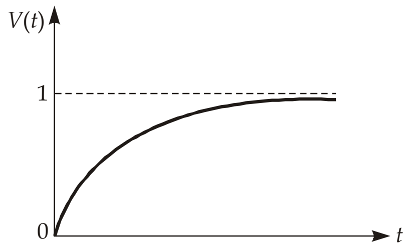
Current through inductor,

$$i(t) = \frac{1}{L}\int_{-\infty}^{t} v(t)\,dt$$

$$= \frac{1}{1}\int_{0}^{t} 12t^2\,dt \text{ for } t \geq 0 = 4t^3\text{ A}$$

8. (b)

At $t = 0^+$ inductor works as open-circuit, hence complete source voltage drops across it and consequently, current through the resistor R is zero. Hence, voltage across the resistor at $t = 0^+$ is zero, and further with time it rises according to $V_R(t) = (1 - e^{-Rt/L})\,u(t)$.



9. (b)

For transient free response,

$$\tan(\omega t_0) = \frac{\omega L}{R}$$

$$\tan(2\pi \times 50 \times t_0) = \frac{2\pi\times50\times0.01}{5}$$

$$2\pi \times 50 \times t_0 = \tan^{-1}\left(\frac{\pi}{5}\right)$$

$$= 32.14° = 0.561\text{ rad}$$

$$t_0 = \frac{0.561}{100\pi} = 1.786\text{ ms}$$

10. (c)

$$V_c(t) = V_c(\infty) - [V_c(\infty) - V_c(0)]\, e^{-t/RC}$$

$$V_c(\text{peak}) = 10 - (10-0)\, e^{-\frac{10\times10^{-6}}{\frac{10}{11}\times10^{3}\times11\times10^{-9}}}$$

$$= 10 - (1 - e^{-1}) = 6.32 \text{ V}$$

$$\left[\text{where, } R_{net} = 10\,||\,1 = \frac{10}{11}\text{ k}\Omega\right]$$

$$V_c(\infty) = 11\times\frac{10}{10+1} = 10 \text{ V}$$

and

∵ pulse of duration 10 μs is applied.

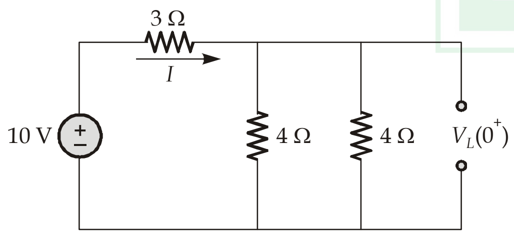
Hence capacitor charges till 10 μs and then starts discharging, so V_c will be maximum at t = 10 μs.

11. (b)

Before closing the switch, the circuit was not energized, therefore, current through inductor and voltage across capacitor are zero.

After closing the switch, at $t = 0^+$ inductor acts as open-circuit and capacitor acts as short-circuit.

Equivalent circuit at $t = 0^+$.



$$I = \frac{10}{3+4\,||\,4} = 2 \text{ A}$$

$$V_L(0^+) = I\times(4\,||\,4) = 2\times2 = 4 \text{ V}$$

12. (a)

Using KVL,

$$100 = R\frac{dq}{dt} + \frac{q}{C}$$

$$100\,C = RC\frac{dq}{dt} + q$$

$$\int_{q0}^{q}\frac{dq}{100C-q} = \frac{1}{RC}\int_0^t dt$$

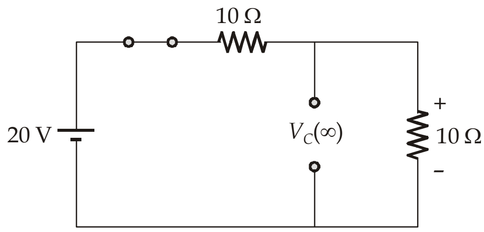
$$100\,C - q = (100C - q_0)\, e^{-t/RC}$$

$$i = \frac{dq}{dt} = \frac{(100C-q_0)}{RC}e^{-1/RC}$$

$$e^{-t/RC} = 40e^{-1} = 14.7 \text{ A}$$

13. (b)

At ($t \to 0^+$), the capacitor act as short-circuit. At ($t \to \infty$), the capacitor will become open-circuit.

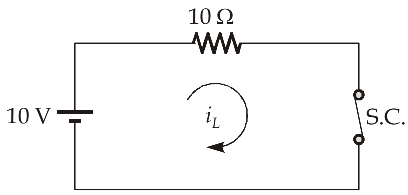


∴ Voltage across capacitor

$$= \frac{20}{10+10}\times10 = 10 \text{ V}$$

14. (c)

Before closing the switch, at $t = 0^-$, the circuit is in steady-state. So, inductor behaves as short-circuit.



$$i_L(0^-) = \frac{10}{10} = 1 \text{ A}$$

After closing the switch, at $t = 0^+$

Current through inductor can not change abruptly.

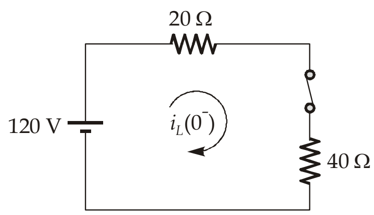
$$\therefore \quad i_L(0^+) = i_L(0^-) = 1 \text{ A}$$

15. (c)

Before moving the switch, at $t = 0^-$

The circuit is in steady-state and inductor behaves as short-circuit.

The circuit at $t = 0^-$,



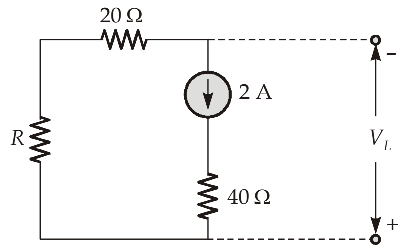
$$i_L(0^-) = \frac{120}{20+40} = 2\text{ A}$$

After moving the switch,

At $t = 0^+$

Current through inductor can not change abruptly.

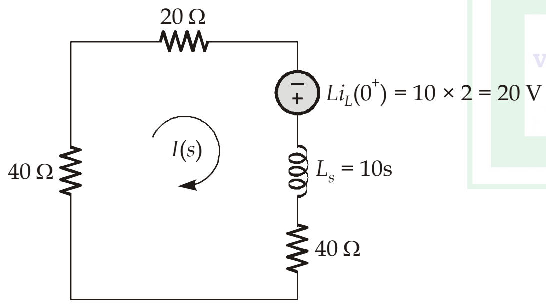
So, $\quad i_L(0^+) = i_L(0^-) = 2\text{ A}$



$$V_L = i_L(0^+) \times \{20 + R\}$$
$$120 = 2 \times (20 + R)$$
$$R = 40\ \Omega$$

16. (b)

The circuit (in s-domain)



$$I(s) = \frac{20}{(20+40+40)+10s}$$
$$= \frac{20}{10s+100} = \frac{2}{s+10}$$
$$i(t) = L^{-1}[I(s)] = L^{-1}\left[\frac{2}{s+10}\right] = 2e^{-10t}$$

or, $$i(t) = i_L(0^+)\, e^{-\frac{R_{eff}}{L}t}$$
$$= 2e^{-\frac{(20+40+40)}{10}t} = 2e^{-10t}$$

Initial stored energy in inductor

$$W_0 = \frac{1}{2}Li_L^2(0^+)$$
$$= \frac{1}{2}\times 10\times 2^2 = 20\text{ Joules}$$

Remaining $\frac{1}{2}Li_1^2$ energy in inductor

$$W_1 = 0.05\, W_0$$
$$= 0.05 \times 20 = 1\text{ Joule}$$
$$\frac{1}{2}Li_1^2 = 1$$
$$\frac{1}{2}\times 10\times i_1^2 = 1$$
$$i_1 = \frac{1}{\sqrt{5}} = 0.4472\text{ A}$$

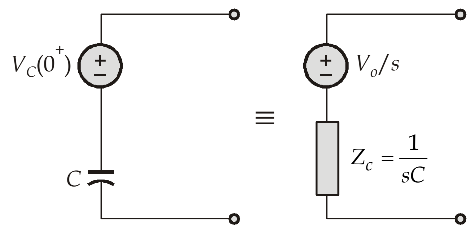
Let at $t = T$, current decrease to i1,

$$0.4472 = 2e^{-10T}$$
$$T \approx 0.15\text{ sec.}$$

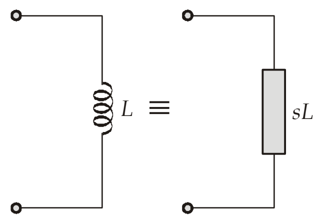
17. (b)

Voltage across capacitor will discharge through inductor upto voltage across the capacitor becomes zero. During this period, electrostatic energy stored in capacitor is transferred into magnetic energy which is stored in inductor. Now inductor will start charging capacitor, magnetic energy in inductor is converted into electrostatic energy in capacitor.

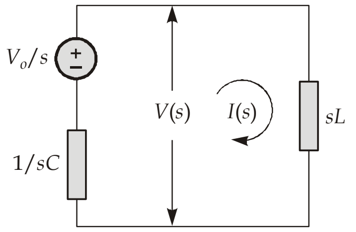
Expression for $V_c(t)$ can be obtained in s-domain. As capacitor is charged initially to voltage V_0, then representation of capacitor in s-domain.



As current though the inductor is zero at $t = 0$, then



The circuit at $t > 0$,



$$I(s) = \frac{V_0/s}{\frac{1}{sC}+sL} = \frac{V_0}{s^2L+\frac{1}{C}}$$

$$I(s) = \frac{V_0}{L}\left(\frac{1}{s^2+\frac{1}{LC}}\right)$$

Voltage across capacitor = Voltage across inductor = $V(s)$,

$$V(s) = I(s) \times (sL)$$

$$= \frac{V_0}{L}\left[\frac{1}{s^2+\frac{1}{LC}}\right] \times (sL) = V_0\left[\frac{s}{s^2+\frac{1}{LC}}\right]$$

As, $$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$V(s) = V_0\left[\frac{s}{s^2+\omega_0^2}\right]$$

Voltage across the capacitor

$$= V(t) = L^{-1}[(V(s)] = L^{-1}\left[\frac{V_0 s}{s^2+\omega_0^2}\right]$$

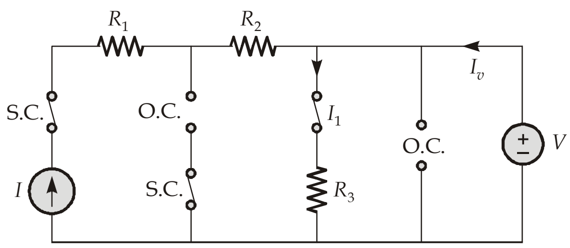
$$V(t) = V_0 \cos\omega_0 t$$

where,

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

18. (d)

In steady-state, inductor behaves as short-circuit and capacitor behaves as open-circuit.



Voltage across,

$$R_3 = V = 5\text{ V}$$

Current through,

$$R_3 = I_1 = \frac{V}{R_3} = \frac{5}{1} = 5\text{ A}$$

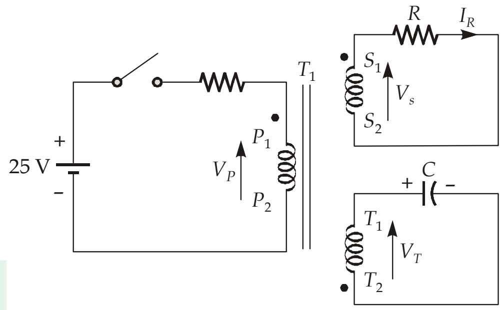
Apply KCL,

$$-I + I_1 - I_V = 0$$

Current through voltage source

$$= I_V = I_1 - I$$
$$= 5 - 1 = 4\text{ A}$$

19. (d)



All the three windings has same number of turns, so magnitude of induced emf's in all the three windings will be same i.e.

$$|V_P| = |V_S| = |V_T|$$

Polarity of the windings is decided on the basis of dot-convention. As capacitor is charged to 5 V with left plates as positive.

So, T_1 is positive w.r.t T_2,

$$V_T = V_{T_1} - V_{T_2} = 5\text{ V}$$

As T_2 has negative polarity. So, P_1 has negative polarity.

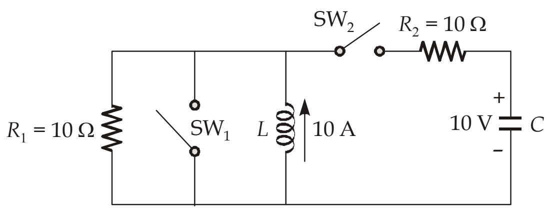
Therefore, $$V_P = V_{P_1} - V_{P_2} = -5\text{ V}$$

Similarly, S_1 has negative polarity.

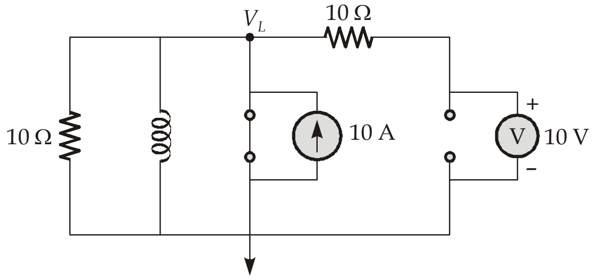
So, $$V_S = V_{S_1} - V_{S_2} = -5\text{ V}$$

$$I_R = \frac{V_s}{R} = \frac{-5}{10} = -0.5\text{ A}$$

20. (d)



At ($t = 0^+$), the circuit becomes,



By KCL,

$$\frac{V_L}{10} - 10 + \frac{V_L - 10}{10} = 0$$

$$\therefore \quad 2V_L = 110$$

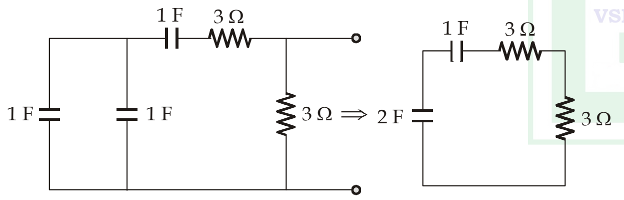
$$\therefore \quad V_L = 55 \text{ V}$$

$$I_C = \frac{55-10}{10} = 4.5 \text{ A}$$

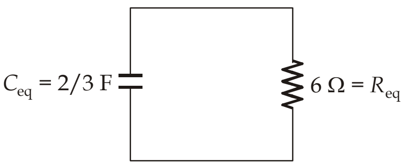
21. (c)

For finding time constant, we neglect current source as a open-circuit.

∴ Circuit becomes,



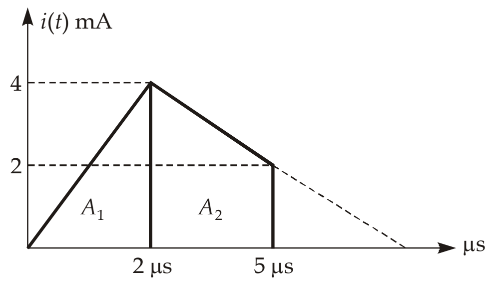
∴



$$\therefore \quad \text{Time constant} = R_{eq}\, C_{eq}$$

$$= 6 \times \frac{2}{3} = 4 \text{ sec.}$$

22. (c)



Charged stored in the capacitor = Area under i - t curve,

$$Q = A_1 + A_2$$

$$= \frac{1}{2}(2\times10^{-6})\times(4\times10^{-3})$$

$$+\frac{1}{2}(4+2)\times10^{-3}\times(5-2)\times10^{-6}$$

$$= \left[4+\frac{6\times3}{2}\right]\times10^{-9} = 13 \text{ nC}$$

23. (d)

Capacitor charged upto 5 μs, so total charge stored in capacitor = Q = 13 nC.

Voltage across the capacitor before connecting to inductor,

$$V_0 = \frac{Q}{C} = \frac{13\times10^{-9}}{0.3\times10^{-9}} = 43.33 \text{ V}$$

Voltage across the capacitor at time t,

$$V_c(t) \text{ at } t = 1 \text{ μs}$$

$$V_c(t)\big|_{t=1\mu s} = [V_0 \cos\omega_0 t]_{t=1\,\mu s}$$

$$\omega_0 t = \frac{1}{\sqrt{0.6\times10^{-3}\times0.3\times10^{-9}}}\times1\times10^{-6}$$

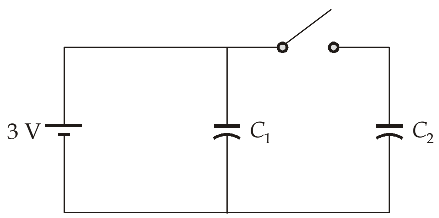
$$= 2.357 \text{ rad} = 135°$$

$$V_c(t)\big|_{t=1\mu s} = 43.33 \times \cos135°$$

$$\approx -30.6 \text{ V}$$

24. (a)

At $t = 0^-$, S_1 is closed, S_2 is open.



C_1 gets charged upto 3 V

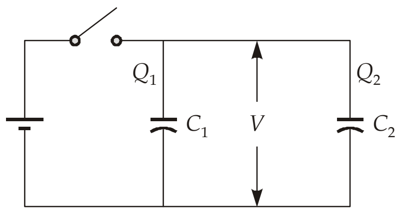
Charge stored in C_1,

$$Q_0 = C_1 V = 1 \times 3 = 3C$$

Voltage across C_2 is zero at $t = 0^-$, so no charge is stored in C_2.

At $t > 0$, S_1 is open and S_2 is closed.

Charge stored (Q_0) initially in C_1 gets redistributed between C_1 and C_2.



Let charge stored in $C_1 = Q_1$
Charge stored in $C_2 = Q_2$
According to conservation of charge

$$Q_1 + Q_2 = Q_0 = 3 \quad \text{...(i)}$$

Voltage across C_1 = Voltage across C_2,

$$\frac{Q_1}{C_1} = \frac{Q_2}{C_2} \Rightarrow \frac{Q_1}{1} = \frac{Q_2}{2}$$

$$Q_2 = 2Q_1$$

Solving equation (i) and (ii) we get,

$$Q_1 = 1\ C \text{ and } Q_2 = 2C$$

Voltage across combination

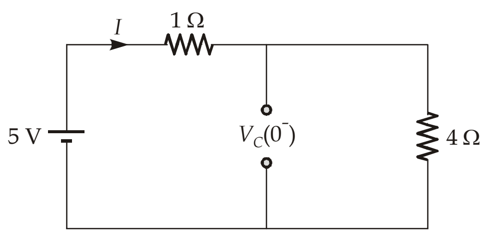
$$= \frac{Q_1}{C_1} = \frac{1}{1} = 1\text{ V}$$

Alternate method:

$$V_{C_1} = V_{C_2} = \frac{V_{C_1}C_1 + V_{C_2}C_2}{C_1 + C_2}$$

25. (b)

As the switch has been closed for a long time, the circuit is in steady-state. At steady-state, capacitor is open-circuit,



Circuit at $t = 0^-$

Using KVL,

$$5 - I - 4I = 0$$

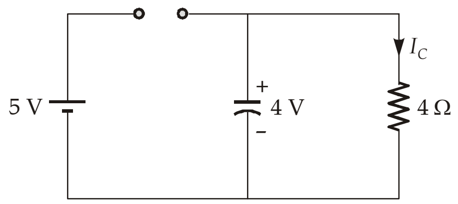
$$\Rightarrow \quad I = 1\text{ A}$$

$$V_C(0^-) = 4 \times 1 = 4\text{ V}$$

As the voltage across capacitor can not change abruptly.

So, $\quad V_C(0^+) = V_C(0^-) = 4\text{ V}$

Circuit at $t = 0^+$



Current through capacitor at $t = 0^+$

$$I_C(0^+) = \frac{4}{4} = 1\text{ A}$$

26. (d)

Initial current through the inductor is zero and capacitor voltage is charged upto voltage,

$$V_C(0^-) = 100\text{ V}$$

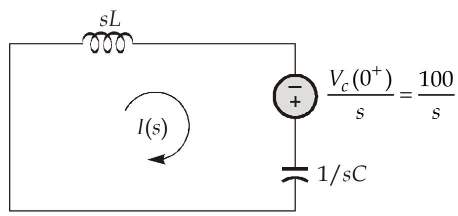
As current through inductor and voltage across capacitor can not change abruptly.

So, after closing the switch,

$$i_L(0^+) = i_L(0^-) = 0$$

and $\quad V_C(0^+) = V_C(0^-) = 100\text{ V}$

The circuit is s-domain,



$$I(s) = \frac{100/s}{\left(sL + \frac{1}{sC}\right)} = \frac{100}{L}\left(\frac{1}{s^2 + \frac{1}{LC}}\right)$$

$$= 100\sqrt{\frac{C}{L}}\left(\frac{1/\sqrt{LC}}{s^2 + \left(\frac{1}{\sqrt{LC}}\right)^2}\right)$$

Taking inverse Laplace transform,

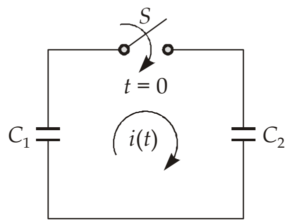
$$i(t) = L^{-1}[I(s)]$$

$$= 100\sqrt{\frac{C}{L}}\sin\frac{1}{\sqrt{LC}}t$$

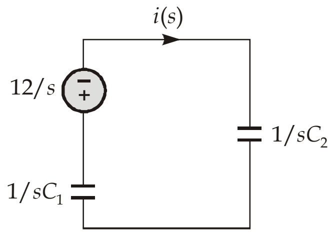
$$= 100 \times \sqrt{\frac{10\times10^3}{1\times10^{-3}}} \times \sin\left(\frac{1}{\sqrt{1\times10^{-3}\times10\times10^{-6}}}t\right)$$

$$i(t) = 10\sin(10^4 t)\text{ A}$$

27. (d)



Circuit is s-domain,



By applying KVL,

$$\frac{12}{s}+\frac{I(s)}{s}\left(\frac{1}{C_1}+\frac{1}{C_2}\right)=0$$

$$I(s) = -\frac{12C_1C_2}{C_1+C_2}=k \quad \text{(constant)}$$

$\Rightarrow$ $i(t) = k\delta(t)$

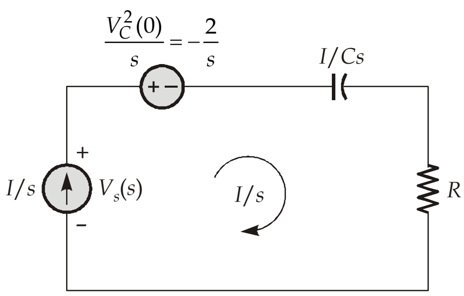
$\therefore$ Current $i(t)$ is an impulse function.

28. (c)

Given: $C = 1\ \mu F,\ v_c(0) = -2\text{ V}$

$R = 100\ \Omega,\ I = 20\text{ mA}$

Circuit for the given condition at time $t > 0$ is shown below.



Applying KVL we have,

$$V_s(s) = \left(\frac{-2}{s}\right)+\frac{1}{s}\left(R+\frac{1}{Cs}\right)$$

$$= \frac{1}{s}\left[-2+IR+\frac{I}{Cs}\right]=\frac{1}{s}\left[(IR-2)+\frac{I}{Cs}\right]$$

Putting values of R, C and I we get,

$$V_s(s) = \frac{1}{s}\left[(20\times10^{-3}\times200-2)+\left(\frac{20\times10^{-3}}{10^{-6}}\right)\times\frac{1}{s}\right]$$

$$= \frac{1}{s}\left[(2-2)+20\times10^{-3}\times\frac{1}{s}\right]=\frac{20\times10^{3}}{s^2}$$

$$\therefore \quad V_s(s) = \frac{20\times10^3}{s^2}$$

or, $V_s(t) = 20000t\,u(t)$

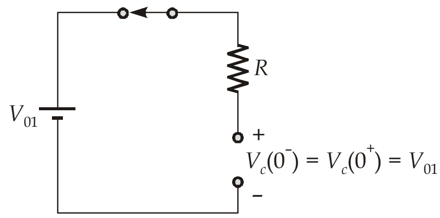
$\therefore$ $V_s(s) = (20000)t\,u(t)$...

which is the equation of a straight line passing through origin.

Hence, option (c) is correct.

29. (*)

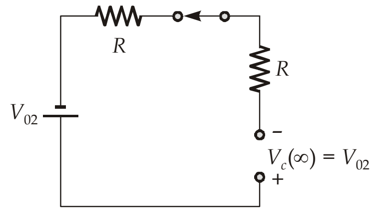
Circuit for $t < 0$,



Circuit for $t = \infty$:

In steady-state capacitor becomes open-circuit.

$\therefore$ $V_c(\infty) = -V_{02}$



We know that,

$$V_c(t) = V_c(\infty) - [V_c(\infty) - V_c(0^+)]\,e^{-t/\tau}$$

τ = Time constant of given circuit

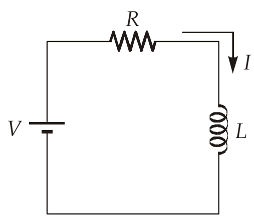
$= 2\,RC$

$$\therefore \quad V_c(t) = -V_{02} - (V_{02} - V_{01})\,e^{-t/2RC}$$

$$= (V_{02} - V_{01}) - (V_{02} - V_{01})\,e^{-t/2RC} - V_{01}$$

or, $V_c(t) = (V_{02} + V_{01})\,(e^{-t/2RC} - 1) + V_{01}$

30. (d)



Initially (t = 0^-) the inductor would be uncharged.

So, $I(0^+) = 0$

The KVL in the loop will be

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

At $t = 0^+$, $V = RI(0^+) + L\frac{dI}{dt}(0^+)$

Since, $I(0^+) = 0$

So, $\frac{dI}{dt}(0^+) = \frac{V}{L}$

Now, lets differentiate the above equation,

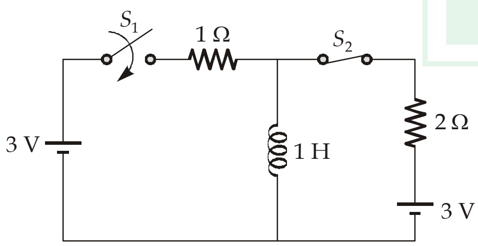
So, $\frac{dV}{dt} = R\frac{dI}{dt} + L\frac{d^2I}{dt^2}$

$$0 = R\frac{dI}{dt} + L\frac{d^2I}{dt^2}$$

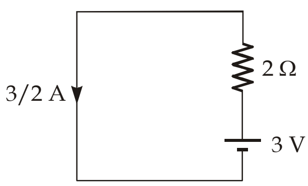
At $t = 0^+$, $0 = R\frac{dI}{dt}(0^+) + L\frac{dI^2}{dt^2}(0^+)$

So, $\frac{d^2I}{dt^2}(0^+) = \left\{-\frac{R}{L^2}\cdot V\right\}$

31. Sol.

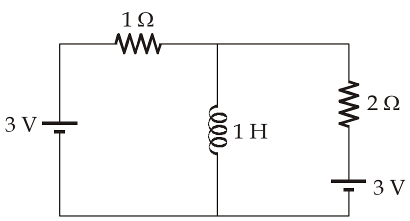


At $t = 0^-$,



$$i_L(0^+) = i_L(0^-) = 1.5 \text{ A}$$

At $t = 0^+$,



KCL at node A,

$$\frac{V_A - 3}{1} + \frac{3}{2} + \frac{V_A - 3}{2} = 0$$

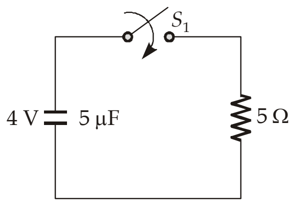
$2(V_A - 3) + 3 + (V_A - 3) = 0$

$3V_A = 6, \; V_A = 2$

$$V_A = L\frac{di(0^+)}{dt} = 2$$

$$\frac{di(0^+)}{dt} = \frac{2}{L} = \frac{2}{1} = 2 \text{ A/sec}$$

32. Sol.



$$i(t) = \left(\frac{4}{5}e^{-t/\tau}\right)$$

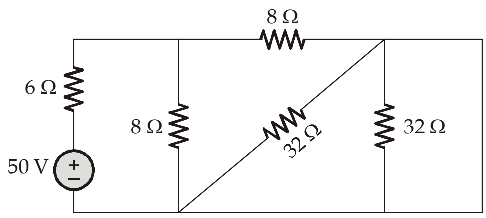
$t = RC = 25 \times 10^{-6}$ sec.

Change lost by capacitor from t = 25 μs to 100 μs is

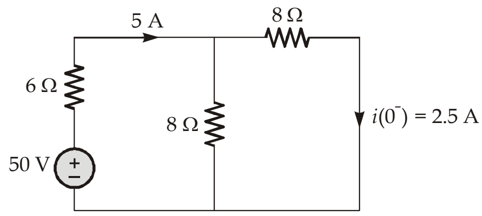
$$\int_{25\,\mu\text{sec}}^{100\,\mu\text{sec}} i(t)\,dt = 6.99 \times 10^{-6} \text{ C}$$

33. (a)

From the given circuit, consider the following circuit diagram,



After rearrangement,



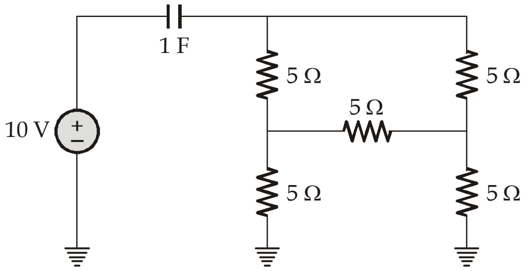
For $t \geq 0$, $I_0 = i(0^-) = 2.5$ A

we can write, $i(t) = I_0 e^{-Rt/L}$

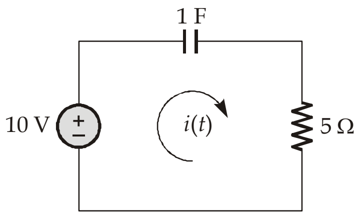
$i(t) = 2.5\, e^{-4t}$ A

34. Sol.

Consider the following circuit diagram,



After minimizing circuit elements we can have the following circuit,



Here, $\tau = RC = 5$ sec.

Now current,

$$i(t) = \frac{V}{R}e^{-t/\tau} = \frac{10}{5}e^{-t/5} = 2e^{-0.2t}$$

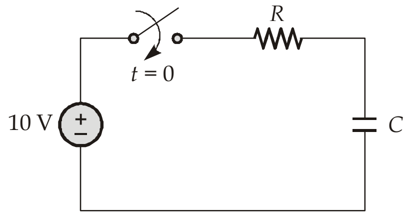
Energy supplied by the source,

$$E = \int_0^{\infty} 10 \times 2e^{-0.2t}\,dt$$

$$= 100 \text{ J}$$

35. Sol.

If initial charge polarities on the capacitor is opposite to the supply voltage then only the capacitor voltage crosses the zero line.



$V_c(t) \Rightarrow$ Final value + (Initial value – Final value) $e^{-t/\tau}$,

$$0 = 10 + (-V_0 - 10)\,e^{-0.4}$$

$$10 = (V_0 + 10)\,e^{-0.4}$$

$$V_0 = 4.918 \text{ V}$$

Now, $t = 0.2\tau$

$$0 = 10 + (-V_0' - 10)\,e^{-0.2}$$

$$V_0' = 2.214$$

% change in voltage

$$= \frac{4.918 - 2.214}{4.918} \times 100\%$$

$$= 54.99\%$$

❏❏❏❏

5 Two Port Networks

ELECTRONICS ENGINEERING
(GATE Previous Years Solved Papers)

Q.1 Two 2-port networks are connected in parallel. The combination is to be represented as a single two-port network. The parameters of this network are obtained by addition of the individual
(a) z-parameters
(b) h-parameters
(c) y-parameters
(d) ABCD parameters

[EC-1988 : 2 Marks]

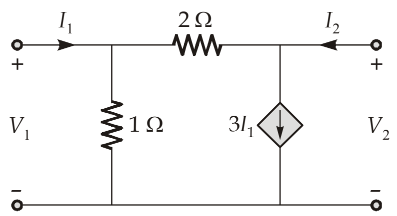
Q.2 For the transfer function of a physical two-port network:
(a) all the zeros must lie only in the left half of the s-plane.
(b) the poles may lie anywhere in the s-plane.
(c) the poles lying on the imaginary axis must be simple.
(d) a pole may lie at origin.

[EC-1989 : 2 Marks]

Q.3 The condition $AD - BC = 1$ for a two-port network implies that the network is a
(a) reciprocal network
(b) lumped element network
(c) lossless network
(d) unilateral element network

[EC-1989 : 2 Marks]

Q.4 The open-circuit impedance matrix of the two-port network shown in figure is



(a) $\begin{bmatrix} -2 & 1 \\ -8 & 3 \end{bmatrix}$
(b) $\begin{bmatrix} -2 & -8 \\ -8 & 3 \end{bmatrix}$
(c) $\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$
(d) $\begin{bmatrix} 2 & -1 \\ -1 & 3 \end{bmatrix}$

[EC-1990 : 2 Marks]

Q.5 Two 2-port networks are connected in cascade. The combination is to the represented as a single two-port network. The parameters of the network are obtained by multiplying the individual
(a) z-parameter matrics
(b) h-parameter matrics
(c) y-parameter matrics
(d) ABCD parameter matrics

[EC-1991 : 2 Marks]

Q.6 For a two-port network to be reciprocal
(a) $z_{11} = z_{22}$
(b) $y_{21} = y_{12}$
(c) $h_{21} = -h_{12}$
(d) $AD - BC = 0$

[EC-1992 : 2 Marks]

Q.7 The condition, that a two-port network is reciprocal, can be expressed in terms of its *ABCD* parameters as ________ .

[EC-1994 : 1 Mark]

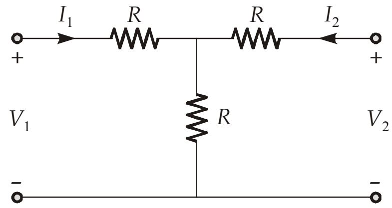
Q.8 The short-circuit admittance matrix of a two-port network is

$$\begin{bmatrix} 0 & -1/2 \\ 1/2 & 0 \end{bmatrix}$$

The two-port network is
(a) non-reciprocal and passive
(b) non-reciprocal and active
(c) reciprocal and passive
(c) reciprocal and active

[EC-1998 : 1 Mark]

Q.9 A two-port network is shown in the figure. The parameters h_{21} for this network can be given by

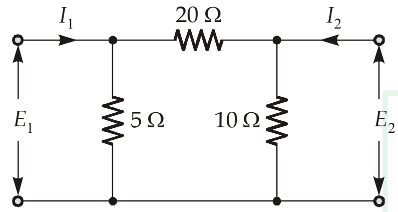


(a) $-\frac{1}{2}$ (b) $+\frac{1}{2}$

(c) $-\frac{3}{2}$ (d) $+\frac{3}{2}$

[EC-1999 : 1 Mark]

Q.10 The admittance parameter y_{12} in the two-port network in figure is

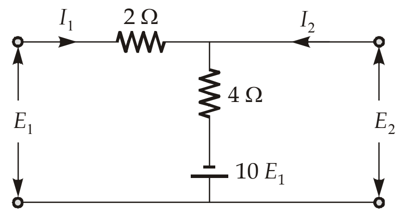


(a) –0.2 ℧ (b) 0.1 ℧

(c) –0.05 ℧ (d) 0.05 ℧

[EC-2001 : 1 Mark]

Q.11 The *Z*-parameters Z_{11} and Z_{21} for the two-port network in the figure are



(a) $Z_{11} = \frac{-6}{11}\,\Omega;\ Z_{21} = \frac{16}{11}\,\Omega$

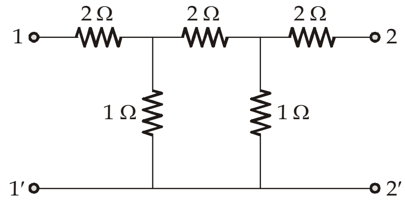
(b) $Z_{11} = \frac{6}{11}\,\Omega;\ Z_{21} = \frac{4}{11}\,\Omega$

(c) $Z_{11} = \frac{6}{11}\,\Omega;\ Z_{21} = \frac{-16}{11}\,\Omega$

(d) $Z_{11} = \frac{4}{11}\,\Omega;\ Z_{21} = \frac{4}{11}\,\Omega$

[EC-2001 : 2 Marks]

Q.12 The impedance parameters Z_{11} and Z_{12} of the two-port network in the figure are



(a) Z_{11} = 2.75 Ω and Z_{12} = 0.25 Ω

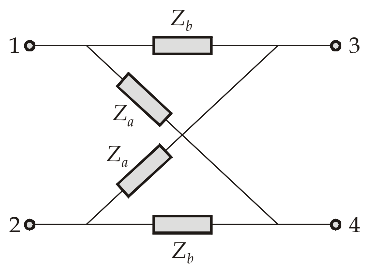
(b) Z_{11} = 3 Ω and Z_{12} = 0.5 Ω

(c) Z_{11} = 3 Ω and Z_{12} = 0.25 Ω

(d) Z_{11} = 2.25 Ω and Z_{12} = 0.5 Ω

[EC-2003 : 2 Marks]

Q.13 For the lattice circuit shown in the figure, $Z_a = j2\ \Omega$ and $Z_b = 2\ \Omega$. The value of the open-circuit impedance parameters, $\begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$ are



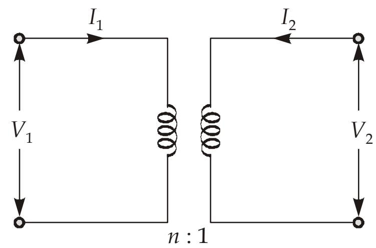
(a) $\begin{bmatrix} 1-j & 1+j \\ 1+j & 1+j \end{bmatrix}$ (b) $\begin{bmatrix} 1-j & 1+j \\ -1+j & 1-j \end{bmatrix}$

(c) $\begin{bmatrix} 1+j & 1+j \\ 1-j & 1-j \end{bmatrix}$ (d) $\begin{bmatrix} 1+j & -1+j \\ -1+j & 1+j \end{bmatrix}$

[EC-2004 : 2 Marks]

Q.14 The ABCD parameters of an ideal *n* : 1 transformer shown in the figure are $\begin{bmatrix} n & 0 \\ 0 & X \end{bmatrix}$.

The value of *X* will be

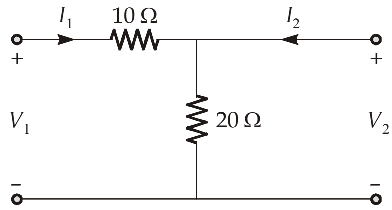


(a) n (b) $1/n$

(c) n^2 (d) $1/n^2$

[EC-2005 : 1 Mark]

Q.15 The h-parameters of the circuit shown in the figure are



(a) $\begin{bmatrix} 0.1 & 0.1 \\ -0.1 & 0.3 \end{bmatrix}$ (b) $\begin{bmatrix} 10 & -1 \\ 1 & 0.05 \end{bmatrix}$

(c) $\begin{bmatrix} 30 & 20 \\ 20 & 20 \end{bmatrix}$ (d) $\begin{bmatrix} 10 & 1 \\ -1 & 0.05 \end{bmatrix}$

[EC-2005 : 2 Marks]

Q.16 A two-port network is represented by $ABCD$ parameters given by

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

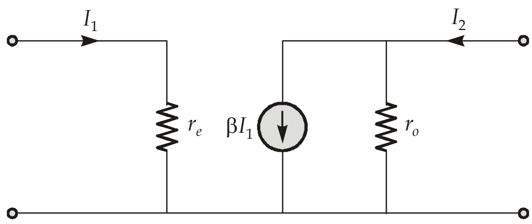
If port-2 terminated by R_L, the input impedance seen at port-1 is given by

(a) $\dfrac{A+BR_L}{C+DR_L}$ (b) $\dfrac{AR_L+C}{BR_L+D}$

(c) $\dfrac{DR_L+A}{BR_L+C}$ (d) $\dfrac{B+AR_L}{D+CR_L}$

[EC-2006 : 1 Mark]

Q.17 In the two-port network shown in the figure below, Z_{12} and Z_{21} are, respectively



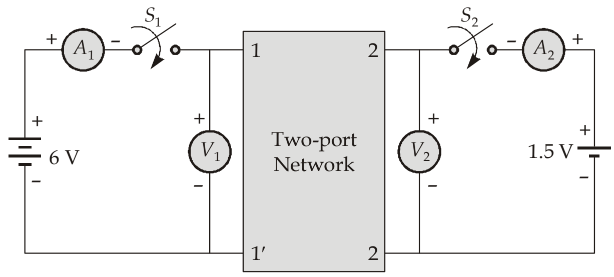
(a) r_e and βr_o (b) 0 and $-\beta r_o$

(c) 0 and βr_o (d) r_e and $-\beta r_o$

[EC-2006 : 1 Mark]

Linked Answer Questions (18 and 19):

A two-port network shown below is excited by external dc sources. The voltages and currents are measured with voltmeters V_1, V_2 and ammeters A_1, A_2 (all assumed to be ideal) as indicated. Under following switch conditions, the readings obtained are:



(i) S_1 – open, S_2 – closed $A_1 = 0$ A, $V_1 = 4.5$ V, $V_2 = 1.5$ V, $A_2 = 1$ A

(ii) S_1 – closed, S_2 – open $A_1 = 4$ A, $V_1 = 6$ V, $V_2 = 6$ V, $A_2 = 0$ A

Q.18 The Z-parameter matrix for this network is

(a) $\begin{bmatrix} 1.5 & 1.5 \\ 4.5 & 1.5 \end{bmatrix}$ (b) $\begin{bmatrix} 1.5 & 4.5 \\ 1.5 & 4.5 \end{bmatrix}$

(c) $\begin{bmatrix} 1.5 & 4.5 \\ 1.5 & 1.5 \end{bmatrix}$ (d) $\begin{bmatrix} 4.5 & 1.5 \\ 1.5 & 4.5 \end{bmatrix}$

[EC-2008 : 2 Marks]

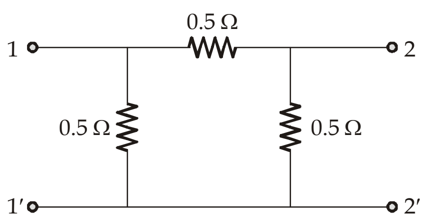
Q.19 The h-parameter matrix for this network is

(a) $\begin{bmatrix} -3 & 3 \\ -1 & 0.67 \end{bmatrix}$ (b) $\begin{bmatrix} -3 & -1 \\ 3 & 0.67 \end{bmatrix}$

(c) $\begin{bmatrix} 3 & 3 \\ 1 & 0.67 \end{bmatrix}$ (d) $\begin{bmatrix} 3 & 1 \\ -3 & -0.67 \end{bmatrix}$

[EC-2008 : 2 Marks]

Q.20 For the two-port network shown below, the short-circuit admittance parameter matrix is



(a) $\begin{bmatrix} 4 & -2 \\ -2 & 4 \end{bmatrix} S$ (b) $\begin{bmatrix} 1 & -0.5 \\ -0.5 & 1 \end{bmatrix} S$

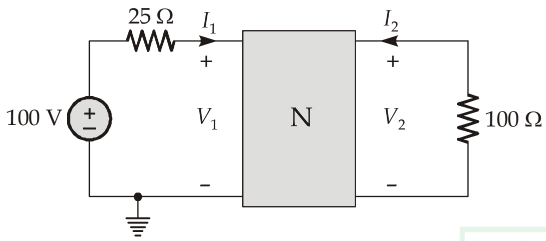
(c) $\begin{bmatrix} 1 & 0.5 \\ 0.5 & 1 \end{bmatrix} S$ (d) $\begin{bmatrix} 4 & 2 \\ 2 & 4 \end{bmatrix} S$

[EC-2010 : 1 Mark]

Q.21 In the circuit shown below, the network N is described by the following Y matrix:

$$Y = \begin{bmatrix} 0.1S & -0.01S \\ 0.01S & 0.1S \end{bmatrix}$$

The voltage gain V_2/V_1 is



(a) $\frac{1}{90}$ (b) $-\frac{1}{90}$

(c) $-\frac{1}{99}$ (d) $-\frac{1}{11}$

[EC-2011 : 2 Marks]

Common Data Questions (22 and 23):

With 10 V dc connected at port A in the linear non-reciprocal two-port network shown below, the following were observed.

(i) 1 Ω connected at port B draws a current of 3 A.

(ii) 2.5 Ω connected at port B draws a current of 2 A.

Q.22 For the same network, with 6 V dc connected at port A, 1 Ω connected at port B draws 7/3 A. If 8 V dc is connected to port A, the open-circuit voltage at port B is

(a) 6 V (b) 7 V

(c) 8 V (d) 9 V

[EC-2012 : 2 Marks]

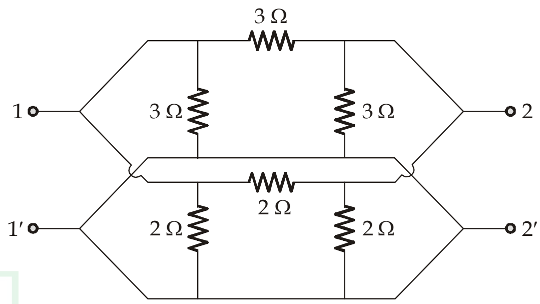
Q.23 With 10 V dc connected at port A, the current drawn by 7 Ω connected at port B is

(a) $\frac{3}{7}$ A (b) $\frac{5}{7}$ A

(c) 1 A (d) $\frac{9}{7}$ A

[EC-2012 : 2 Marks]

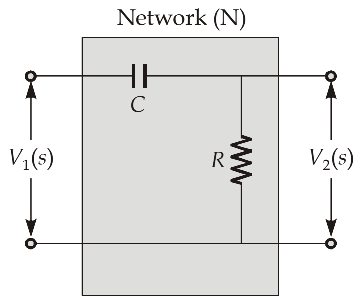
Q.24 In the h-parameter model of the two-port network given in the figure shown, the value of h_{22} (in S) is _______ .



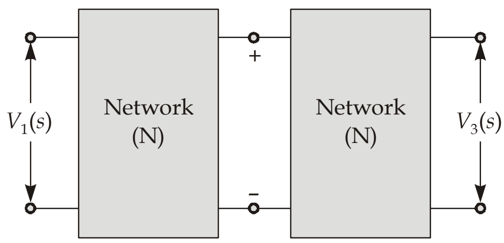
[EC-2014 : 2 Marks]

Q.25 Consider the building block called 'Network N' shown in the figure.

Let, C = 100 μF and R = 10 kΩ.



Two such blocks are connected in cascade, as shown in the figure.



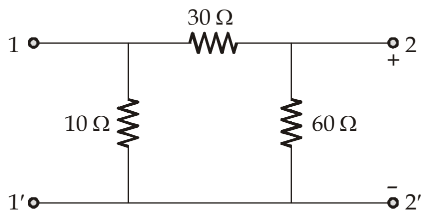
The transfer function $V_3(s)/V_1(s)$ of the cascaded network is

(a) $\frac{s}{1+s}$ (b) $\frac{s^2}{1+3s+s^2}$

(c) $\left(\frac{s}{1+s}\right)^2$ (d) $\frac{s}{2+s}$

[EC-2014 : 2 Marks]

Q.26 For the two-port network shown in the figure, the impedance (Z) matrix (in Ω) is

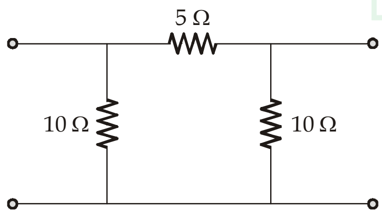


(a) $\begin{bmatrix} 6 & 24 \\ 42 & 9 \end{bmatrix}$ (b) $\begin{bmatrix} 9 & 8 \\ 8 & 24 \end{bmatrix}$

(c) $\begin{bmatrix} 9 & 6 \\ 6 & 24 \end{bmatrix}$ (d) $\begin{bmatrix} 42 & 6 \\ 6 & 60 \end{bmatrix}$

[EC-2014 : 2 Marks]

Q.27 The two-port admittance matrix of the circuit shown is given by

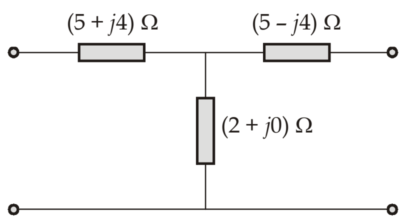


(a) $\begin{bmatrix} 0.3 & 0.2 \\ 0.2 & 0.3 \end{bmatrix}$ (b) $\begin{bmatrix} 15 & 5 \\ 5 & 15 \end{bmatrix}$

(c) $\begin{bmatrix} 3.33 & 5 \\ 5 & 3.33 \end{bmatrix}$ (d) $\begin{bmatrix} 0.3 & 0.4 \\ 0.4 & 0.3 \end{bmatrix}$

[EC-2015 : 1 Mark]

Q.28 The *ABCD* parameters of the following two-port network are



(a) $\begin{bmatrix} 3.5+j2 & 20.5 \\ 20.5 & 3.5-j2 \end{bmatrix}$

(b) $\begin{bmatrix} 3.5+j2 & 0.5 \\ 0.5 & 3.5-j2 \end{bmatrix}$

(c) $\begin{bmatrix} 10 & 2+j0 \\ 2+j0 & 10 \end{bmatrix}$

(d) $\begin{bmatrix} 7+j4 & 0.5 \\ 30.5 & 7-j4 \end{bmatrix}$

[EC-2015 : 2 Marks]

Q.29 Consider a two-port network with the transmission matrix:

$$T = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

If the network is reciprocal, then

(a) $T^{-1} = T$

(b) $T^2 = T$

(c) Determinant $(T) = 0$

(d) Determinant $(T) = 1$

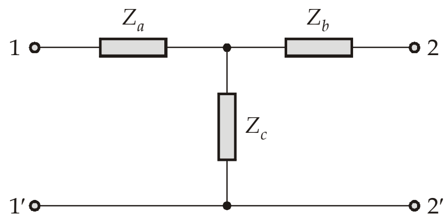
[EC-2016 : 1 Mark]

Q.30 The Z-parameter matrix for the two-port network shown is

$$\begin{bmatrix} 2j\omega & j\omega \\ j\omega & 3+2j\omega \end{bmatrix}$$

where the entries are in Ω.

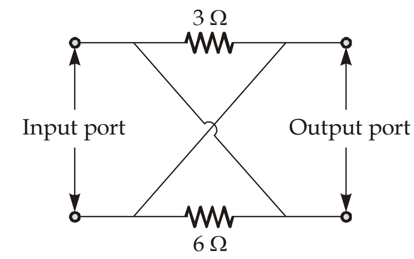
Suppose, $Z_b(j\omega) = R_b + j\omega$



Then the value of R_b (in Ω) equals ______ .

[EC-2016 : 1 Mark]

Q.31 The Z-parameter matrix $\begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$ for the two-port network shown is



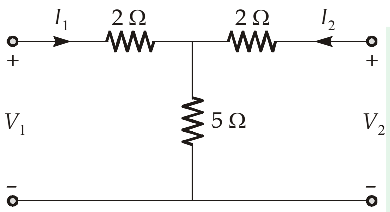
(a) $\begin{bmatrix} 2 & -2 \\ -2 & 2 \end{bmatrix}$ (b) $\begin{bmatrix} 2 & 2 \\ 2 & 2 \end{bmatrix}$

(c) $\begin{bmatrix} 9 & -3 \\ 6 & 9 \end{bmatrix}$ (d) $\begin{bmatrix} 9 & 3 \\ 6 & 9 \end{bmatrix}$

[EC-2016 : 2 Marks]

Q.32 The *ABCD* matrix for a two-port network is defined by

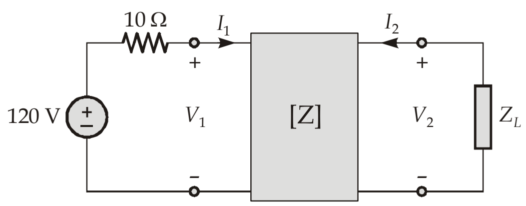
$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$



The parameter *B* for the given two-port network (in Ω, correct to two decimal places) is ____ .

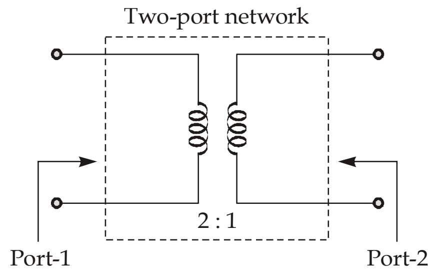
[EC-2018 : 1 Mark]

Q.33 In the given circuit, the two-port network has the impedance matrix $[Z] = \begin{bmatrix} 40 & 60 \\ 60 & 120 \end{bmatrix}$. The value of Z_L for which maximum power is transferred to the load is ______ Ω.



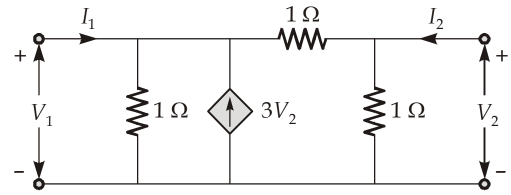
[EC-2020 : 1 Mark]

Q.34 For a two-port network consisting of an ideal lossless transformer, the parameter S_{21} (rounded off to two decimal places) for a reference impedance of 10 Ω, is ______ .



[EC-2020 : 2 Marks]

Q.35 Consider the two-port network shown in the figure.



The admittance parameters, in Siemens are

(a) $y_{11} = 1, y_{12} = -2, y_{21} = -1, y_{22} = 3$

(b) $y_{11} = 2, y_{12} = -4, y_{21} = -4, y_{22} = 2$

(c) $y_{11} = 2, y_{12} = -4, y_{21} = -4, y_{22} = 3$

(d) $y_{11} = 2, y_{12} = -4, y_{21} = -1, y_{22} = 2$

[EC-2021 : 2 Marks]

Q.36 A linear two-port network is shown in Fig. (a). An ideal DC voltage source of 10 V is connected across Port-1. A variable resistance *R* is connected across Port-2. As *R* is varied, the measured voltage and current at Port-2 is shown in Fig. (b) as a V_2 versus $-I_2$ plot. Note that for $V_2 = 5$ V, $I_2 = 0$ mA and for $V_2 = 4$ V, $I_2 = -4$ mA. When the variable resistance *R* at Port-2 is replaced by the load shown in Fig. (c), the current I_2 is ______ mA (Rounded off to one decimal places).

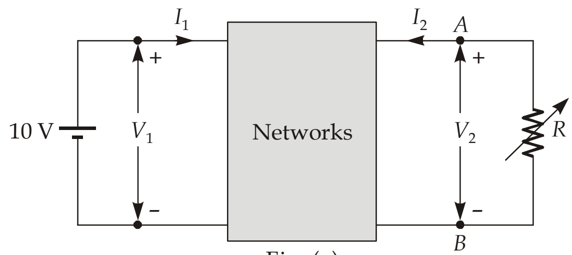


Fig. (a)

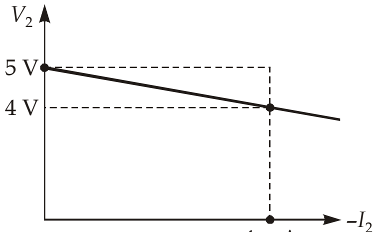


Fig. (b)

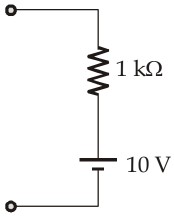


Fig. (c)

[EC-2022]

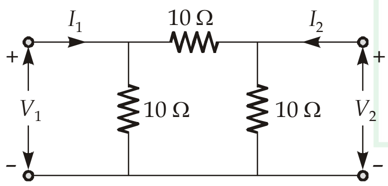
ELECTRICAL ENGINEERING
(GATE Previous Years Solved Papers)

Q.1 If a two-port network is reciprocal, then we have, with the usual notation, the following relationship

(a) $h_{12} = h_{21}$ (b) $h_{12} = -h_{21}$
(c) $h_{11} = h_{22}$ (d) $h_{11}h_{22} - h_{12}h_{21} = 1$

[EE-1994 : 1 Mark]

Q.2 For the two-port network shown in figure, the admittance matrix is ________ .



[EE-1997 : 2 Marks]

Q.3 A two-port device is defined by the following pair of equations:

$i_1 = 2V_1 + V_2$ and $i_2 = V_1 + V_2$

Its impedance parameters $\begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$ are given by

(a) $\begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix}$ (b) $\begin{bmatrix} 1 & -1 \\ -1 & 2 \end{bmatrix}$

(c) $\begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix}$ (d) $\begin{bmatrix} 2 & -1 \\ -1 & 1 \end{bmatrix}$

[EE-2000 : 2 Marks]

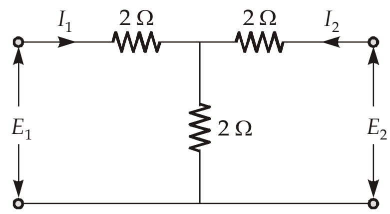
Q.4 A passive two-port network is in steady-state. Compared to its input, the steady-state output can never offer

(a) higher voltage (b) lower impedance
(c) greater power (d) better regulation

[EE-2001 : 1 Mark]

Q.5 A two-port network, shown in figure, is described by the following equations:

$I_1 = Y_{11}E_1 + Y_{12}E_2$
$I_2 = Y_{21}E_1 + Y_{22}E_2$



The admittance parameters, Y_{11}, Y_{12}, Y_{21} and Y_{22} for the network shown are

(a) 0.5 ℧, 1 ℧, 2 ℧ and 1 ℧ respectively.

(b) $\frac{1}{3}$ ℧, $-\frac{1}{6}$ ℧, $\frac{1}{3}$ ℧ and $\frac{1}{3}$ ℧ respectively.

(c) 0.5 ℧, 0.5 ℧, 1.5 ℧ and 2 ℧ respectively.

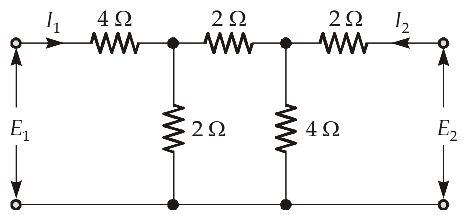
(d) $-\frac{2}{5}$ ℧, $-\frac{3}{7}$ ℧, $\frac{3}{7}$ ℧ and $\frac{2}{5}$ ℧ respectively.

[EE-2000 : 2 Marks]

Q.6 The h-parameters for a two-port network are defined by

$$\begin{bmatrix} E_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ E_2 \end{bmatrix}$$

For the two-port networks shown in figure, the value of h_{12} is given by



(a) 0.125 (b) 0.167
(c) 0.625 (d) 0.25

[EE-2003 : 2 Marks]

Q.7 The Z-matrix of a two-port network is given by

$$Z = \begin{bmatrix} 0.9 & 0.2 \\ 0.2 & 0.6 \end{bmatrix}.$$

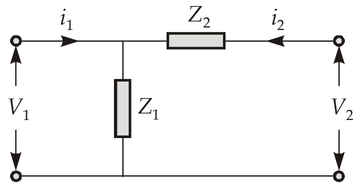
The element Y_{22} of the corresponding Y matrix of the same network is given by

(a) 1.2 (b) 0.4

(c) –0.4 (d) 1.8

[EE-2004 : 2 Marks]

Q.8 For the two-port network shown in the figure the Z-matrix is given by



(a) $\begin{bmatrix} Z_1 & Z_1+Z_2 \\ Z_1+Z_2 & Z_2 \end{bmatrix}$

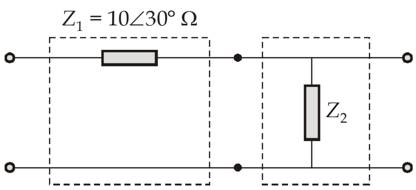
(b) $\begin{bmatrix} Z_1 & Z_1 \\ Z_1+Z_2 & Z_2 \end{bmatrix}$

(c) $\begin{bmatrix} Z_1 & Z_2 \\ Z_1 & Z_1+Z_2 \end{bmatrix}$

(d) $\begin{bmatrix} Z_1 & Z_1 \\ Z_1 & Z_1+Z_2 \end{bmatrix}$

[EE-2005 : 1 Mark]

Q.9 Two networks are connected in cascade as shown in the figure. With the usual notations the equivalent A, B, C and D constants are obtained. Given that, $C = 0.025\angle 45°$, the value of Z_2 is



(a) $10\angle 30°\ \Omega$ (b) $40\angle -450°\ \Omega$

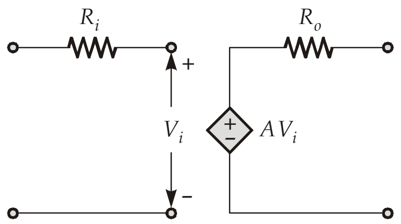
(c) $1\ \Omega$ (d) $0\ \Omega$

[EE-2005 : 2 Marks]

Q.10 The parameters of the circuit shown in the figure are:

$$R_i = 1\ \text{M}\Omega,\ R_o = 10\ \Omega,\ A = 10^6\ \text{V/V}$$

If $V_i = 1\ \mu\text{V}$, the output voltage, input impedance and output impedance respectively are

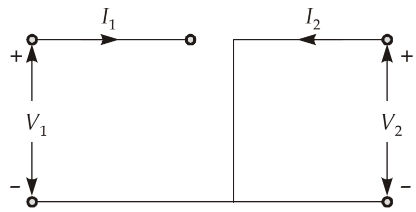


(a) 1 V, ∞, 10 Ω (b) 1 V, 0, 10 Ω

(c) 1 V, 0, ∞ (d) 10 V, ∞, 10 Ω

[EE-2006 : 2 Marks]

Q.11 The parameter type and the matrix representation of the relevant two-port parameters that describe the circuit shown are:



(a) z-parameters, $\begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$

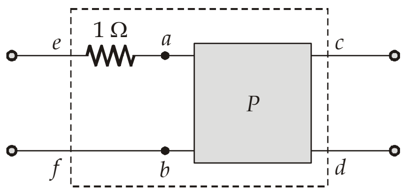
(b) h-parameters, $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

(c) g-parameters, $\begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$

(d) z-parameters, $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

[EE-2006 : 2 Marks]

Q.12 The two-port network 'P' shown in the figure has port 1 and 2 denoted by terminals (a, b) and (c, d), respectively. It has an impedance matrix Z with parameters denoted by Z_{ij}. A 1 Ω resistor is connected in series with the network at port 1 as shown in the figure. The impedance matrix of the modified two-port network (shown as a dashed box) is



(a) $\begin{pmatrix} Z_{11}+1 & Z_{12}+1 \\ Z_{21} & Z_{22}+1 \end{pmatrix}$

(b) $\begin{pmatrix} Z_{11}+1 & Z_{12} \\ Z_{21} & Z_{22}+1 \end{pmatrix}$

(c) $\begin{pmatrix} Z_{11}+1 & Z_{12} \\ Z_{21} & Z_{22} \end{pmatrix}$

(d) $\begin{pmatrix} Z_{11}+1 & Z_{12} \\ Z_{21}+1 & Z_{22} \end{pmatrix}$ **[EE-2010 : 2 Marks]**

Common Data for Questions (13 and 14):

With 10 V dc connected at port 'A' in the linear non-reciprocal two-port network shown below, the following were observed:

(i) 1 Ω connected at port 'B' draws a current of 3 A.

(ii) 2.5 Ω connected at port 'B' draws a current of 2 A.

Q.13 For the same network with 6 V dc connected at port 'A', 1 Ω connected at port 'B' draws 7/3 A. If 8 V dc is connected to port 'A', the open-circuit voltage at port 'B' is

(a) 6 V (b) 7 V
(c) 8 V (d) 9 V

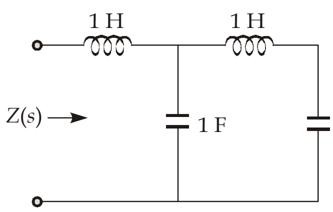
[EE-2012 : 2 Marks]

Q.14 With 10 V dc connected at port 'A', the current drawn by 7 Ω connected at port 'B' is

(a) $\frac{3}{7}$ A (b) $\frac{5}{7}$ A
(c) 1 A (d) $\frac{9}{7}$ A

[EE-2012 : 2 Marks]

Q.15 The driving point impedance $Z(s)$ for the circuit shown below is



(a) $\frac{s^4+3s^2+1}{s^3+2s}$ (b) $\frac{s^4+2s^2+4}{s^2+2}$

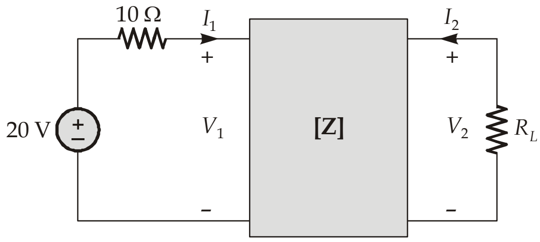
(c) $\frac{s^2+1}{s^4+s^2+1}$ (d) $\frac{s^3+1}{s^4+s^2+1}$

[EE-2014 : 1 Mark]

Q.16 The Z-parameter of the two-port network shown in the figure are:

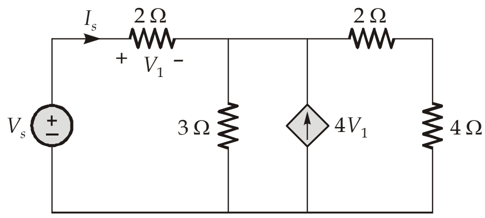
$Z_{11} = 40\ \Omega$, $Z_{12} = 60\ \Omega$, $Z_{21} = 80\ \Omega$ and $Z_{22} = 100\ \Omega$

The average power delivered to $R_L = 20\ \Omega$, in Watts, is _______ .



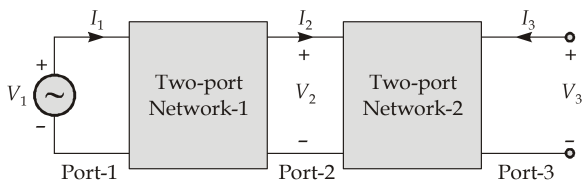
[EE-2016 : 2 Marks]

Q.17 The driving point input impedances seen from the source V_s of the circuit shown below (in Ω), is _______ .



[EE-2016 : 2 Marks]

Q.18 Two passive two-port networks are connected in cascade as shown in figure. A voltage source is connected at port 1.



Given,

$$V_1 = A_1V_2 + B_1I_2$$
$$I_1 = C_1V_2 + D_1I_2$$
$$V_2 = A_2V_3 + B_2I_3$$
$$I_2 = C_2V_3 + D_2I_3$$

$A_1, B_1, C_1, D_1, A_2, B_2, C_2$ and D_2 are in generalized circuit constants. If the Thevenin equivalent circuit at port 3 consists of a voltage source V_T and an impedance Z_T, connected in series, then

(a) $V_T = \dfrac{V_1}{A_1A_2},\ Z_T = \dfrac{A_1B_2 + B_1D_2}{A_1A_2 + B_1C_2}$

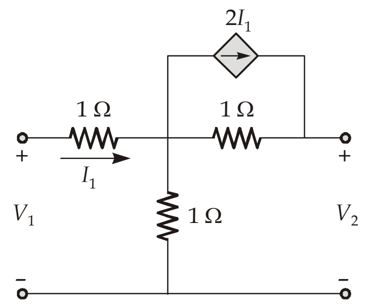
(b) $V_T = \dfrac{V_1}{A_1A_2 + B_1C_2},\ Z_T = \dfrac{A_1B_2 + B_1D_2}{A_1A_2}$

(c) $V_T = \dfrac{V_1}{A_1 + A_2},\ Z_T = \dfrac{A_1B_2 + B_1D_2}{A_1 + A_2}$

(d) $V_T = \dfrac{V_1}{A_1A_2 + B_1C_2},\ Z_T = \dfrac{A_1B_2 + B_1D_2}{A_1A_2 + B_1C_2}$

[EE-2017 : 2 Marks]

Q.19 In the two-port network shown, the h_{11} parameter (where, $h_{11} = V_1/I_i$, when $V_2 = 0$) (in Ω) is _______ (upto 2 decimal places).



[EE-2018 : 1 Mark]

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Electronics & Electrical Engineering

GATE Previous Years Solved Paper

Answers & Explanations

Answers — EC — Two-Port Network

1. (c)	**2.** (c, d)	**3.** (a)	**4.** (a)	**5.** (d)	**6.** (b, c)	**7.** (1)	**8.** (b)
9. (a)	**10.** (c)	**11.** (c)	**12.** (a)	**13.** (d)	**14.** (b)	**15.** (d)	**16.** (d)
17. (b)	**18.** (c)	**19.** (a)	**20.** (a)	**21.** (d)	**22.** (c)	**23.** (c)	**24.** (1.25)
25. (b)	**26.** (c)	**27.** (a)	**28.** (b)	**29.** (d)	**30.** (3)	**31.** (a)	**32.** (4.80)
33. (48)	**34.** (0.8)	**35.** (d)	**36.** (4)				

Answers — EC — Two-Port Network

1. (c)

$$[Y] = [Y]_A + [Y]_B$$

2. (c, d)

The poles lying on the imaginary axis must be simple. A pole may lie at origin.

3. (a)

For reciprocal network,

$$AD - BC = 1$$

4. (a)

$$Z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0} = \frac{1 \times I_2}{I_2} = 1\,\Omega$$

$$Z_{22} = \left.\frac{V_1}{I_2}\right|_{I_1=0}$$

$$Z_{22} = \frac{2I_2 \times 1I_2}{I_2} = 3\,\Omega$$

$$Z_{11} = -\frac{2I_1 \times 1}{I_1} = -2$$

$$Z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0}$$

$$Z_{21} = \frac{-6I_1 + V_1}{I_1} = \frac{-6I_1 - 2I_1}{I_1}$$

$$Z_{21} = -8$$

5. (d)

$ABCD$ parameter matrices,

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix}\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix}$$

6. (b, c)

$$y_{21} = y_{12}$$
$$h_{21} = -h_{12}$$

7. Sol.

$$AD - BC = 1$$

8. (b)

$$Y_{12} \neq Y_{21}$$

So, the given two-port network is non-reciprocal and active.

9. (a)

$$I_2 = h_{21}I_1 + h_{22}V_2$$

$$h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0}$$

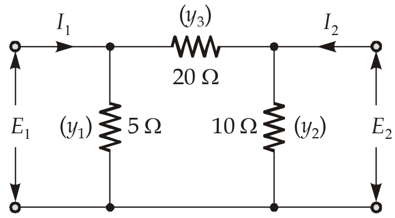
when, $V_2 = 0 = I_2R(I_1 + I_2)\,R$

$$I_2 = -\frac{I_1}{2} \Rightarrow \frac{I_2}{I_1} = -\frac{1}{2}$$

10. (c)

$$\begin{bmatrix} y_1 + y_3 & -y_3 \\ -y_3 & y_2 + y_3 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix}$$

$$y_{12} = -y_3$$



$$y_{12} = -\frac{1}{20} = -0.05\ ℧$$

11. (c)

$$V_1 = Z_{11}I_1 + Z_{12}I_2$$
$$V_2 = Z_{21}I_1 + Z_{22}I_2$$

$$Z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0}$$

Applying KVL in LHS loop,

$$E_1 - 2I_1 - 4I_1 + 10E_1 = 0$$
$$11E_1 = 6I_1$$
$$\Rightarrow \quad \frac{E_1}{I_1} = \frac{6}{11}\,\Omega$$

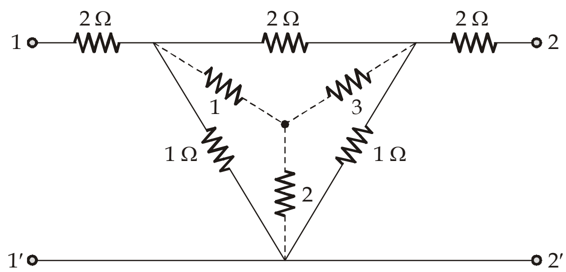
$$Z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0}$$

KVL in RHS loop,

$$E_2 - 4I_1 + 10E_1 = 0$$
$$\Rightarrow \quad E_2 - 4I_1 + 10 \times \frac{6}{11}I_1 = 0 \quad \left(E_1 = \frac{b}{11}I_1\right)$$
$$\Rightarrow \quad 11E_2 - 44I_1 + 60I_1 = 0$$
$$\frac{E_2}{I_1} = -\frac{16}{11}\,\Omega$$

12. (a)

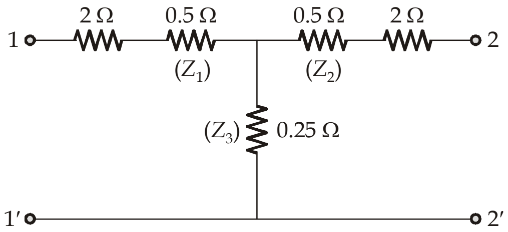
Using Δ-Y conversion,



$$R_1 = \frac{2 \times 1}{4} = \frac{2}{4} = 0.5$$

$$R_2 = \frac{1\times 1}{4} = \frac{1}{4} = 0.25$$

$$R_3 = \frac{2\times 1}{4} = 0.5$$



$$\begin{bmatrix} Z_1+Z_3 & Z_3 \\ Z_3 & Z_2+Z_3 \end{bmatrix}$$

$$Z_{11} = Z_1 + Z_3$$
$$= 2.5 + 0.25 = 2.75$$
$$Z_{12} = Z_3 = 0.25$$

13. (d)

For Lattice network, Z-parameter is given as,

$$\begin{bmatrix} \frac{Z_a+Z_b}{2} & \frac{Z_a-Z_b}{2} \\ \frac{Z_a-Z_b}{2} & \frac{Z_a+Z_b}{2} \end{bmatrix}$$

$$Z_a = 2j,\ Z_b = 2\ \Omega$$

$$\begin{bmatrix} 1+j & -1+j \\ -1+j & 1+j \end{bmatrix}$$

14. (b)

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}\begin{bmatrix} V_2 \\ I_2 \end{bmatrix}$$

$$-\frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{n}{1}$$

$$V_1 = AV_2 - BI_2$$

$$A = \left.\frac{V_1}{V_2}\right|_{I_2=0} = n$$

$$D = -\left.\frac{I_1}{I_2}\right|_{V_2=0} = \frac{V_2}{V_1} = \frac{1}{n}$$

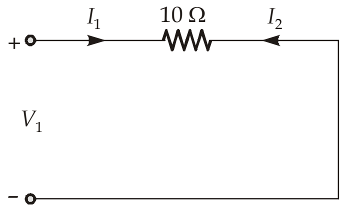
15. (d)

$$V_1 = h_{11}I_1 + h_{12}V_2$$
$$I_2 = h_{21}I_1 + h_{22}V_2$$

$$h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0},\ h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1=0}$$

$$h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0},\ h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1=0}$$

When, $V_2 = 0$



$$I_1 = -I_2$$

$$\frac{I_2}{I_1} = -1 = h_{21}$$

$$V_1 = 10I_1$$

$$\Rightarrow \quad \frac{V_1}{I_1} = 10$$

When, $I_1 = 0$

$$V_1 = V_2$$

$$\Rightarrow \quad \frac{V_1}{V_2} = h_{12} = 1$$

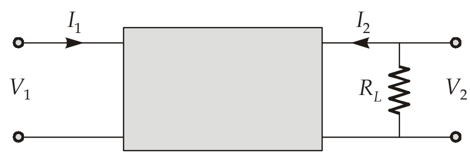
(As no drop in 10 Ω resistance)

$$V_2 = 20I_2$$

$$\Rightarrow \quad \frac{I_2}{V_2} = h_{22} = \frac{1}{20} = 0.05$$

$$\begin{bmatrix} 10 & 1 \\ -1 & 0.05 \end{bmatrix}$$

16. (d)



$$V_1 = AV_2 - BI_2$$
$$I_1 = CV_2 - DI_2$$
$$V_2 = -I_2R_L$$

$$\therefore \quad \frac{V_1}{I_1} = \frac{AV_2 - BI_2}{CV_2 - DI_2} = \frac{-A\cdot I_2R_L - BI_2}{-C\cdot I_2R_L - DI_2}$$

$$\text{Input impedance} = \frac{AR_L + B}{CR_L + D}$$

17. (b)

$$V_1 = Z_{11}I_1 + Z_{12}I_2$$
$$V_2 = Z_{21}I_1 + Z_{22}I_2$$
$$Z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0}$$
$$Z_{12} = \left.\frac{V_2}{I_1}\right|_{I_2=0}$$

When, $I_1 = 0$

$\Rightarrow$ $V_1 = 0$

$\Rightarrow$ $\frac{V_1}{I_2} = 0 = Z_{12}$

When, $I_2 = 0, V_2 = -\beta I_1 r_o$

$\Rightarrow$ $\frac{V_2}{I_1} = -\beta r_o = Z_{21}$

18. (c)

When, $I = 0$

then, $V_1 = 4.5\text{ V}$

$V_2 = 1.5\text{ V}$

$I_2 = 1\text{ A}$

$$V_1 = Z_{11}I_1 + Z_{12}I_2$$
$$V_2 = Z_{21}I_1 + Z_{22}I_2$$
$$Z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0} = \frac{4.5}{1} = 4.5$$
$$Z_{22} = \left.\frac{V_2}{I_2}\right|_{I_1=0} = \frac{1.5}{1} = 1.5$$

When, $I_2 = 0$

then, $I_1 = 4\text{ A}$

$V_1 = 6\text{ V}$

$V_2 = 6\text{ V}$

$$Z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0} = \frac{6}{4} = 1.5$$
$$Z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0} = \frac{6}{4} = 1.5$$

So, Z-parameter matrix is $\begin{bmatrix} 1.5 & 4.5 \\ 1.5 & 1.5 \end{bmatrix}$.

19. (a)

$$V_1 = h_{11}I_1 + h_{12}V_2$$
$$I_2 = h_{21}I_1 + h_{22}V_2$$
$$h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1=0} = \frac{4.5}{1.5} = 3$$
$$h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1=0} = \frac{1}{1.5} = 0.67$$
$$h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0}$$

When, $V_2 = 0, Z_{21}I_1 + Z_{22}I_2 = 0$

$\Rightarrow$ $I_2 = -\frac{Z_{21}I_1}{Z_{22}}$

$\Rightarrow$ $V_1 = Z_{11}I_1 + Z_{12}\left(-\frac{Z_{21}I_1}{Z_{22}}\right)$

$\Rightarrow$ $\frac{V_1}{I_1} = \left(Z_{11} - \frac{Z_{12}Z_{21}}{Z_{22}}\right) = h_{11}$

$\Rightarrow$ $h_{11} = 1.5 - \frac{4.5 \times 1.5}{1.5} = -3$

$\Rightarrow$ $h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0} = -\frac{Z_{21}}{Z_{22}}$

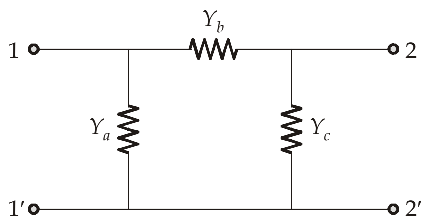
$$= -\frac{1.5}{1.5} = -1$$

So, h-parameter matrix is $\begin{bmatrix} -3 & 3 \\ -1 & 0.67 \end{bmatrix}$.

20. (a)

Short-circuit admittance parameters for a 2-port π-network are,

$$Y_{11} = Y_a + Y_b$$
$$Y_{12} = Y_{21} = -Y_b$$
$$Y_{22} = Y_b + Y_c$$



For the given network,

$$Y_a = Y_b = Y_c = \frac{1}{0.5} = 2\ \mho$$

So,
$$Y_{11} = 2 + 2 = 4\ \mho$$
$$Y_{12} = Y_{21} = -2\ \mho$$
$$Y_{22} = 2 + 2 = 4\ \mho$$

21. **(d)**

$$I_2 = Y_{21}V_1 + Y_{22}V_2$$
$$\therefore \quad I_2 = 0.01V_1 + 0.1V_2 \quad \text{...(i)}$$

From given figure,

$$V_2 = -I_2R_L = -100I_2$$
$$\therefore \quad I_2 = -\frac{V_2}{100}$$

Putting value of I_2 in equation (i),

$$-\frac{V_2}{100} = 0.01V_1 + 0.1V_2$$
$$\Rightarrow \quad -0.01V_2 - 0.1V_2 = 0.01V_1$$
$$\therefore \quad \frac{V_2}{V_1} = -\frac{0.01}{0.11}$$
$$\text{or,} \quad \frac{V_2}{V_1} = -\frac{1}{11}$$

22. **(c)**

Case-I:

$$V_{DC} = 10\text{ V}, R_L = 1\ \Omega, I = 3\text{ A}$$
$$V_{Th} = I(R_{Th} + R_L) = 3(R_{Th} + 1)$$
$$\Rightarrow \quad V_{Th} = 3R_{Th} + 3 \quad \text{...(i)}$$

Case-II:

$$R_L = 2.5\ \Omega,$$
$$I = 2\text{ A},$$
$$V_{DC} = 10\text{ V}$$
$$V_{Th} = 2(R_{Th} + 2.5)$$
$$V_{Th} = 2R_{Th} + 5 \quad \text{...(ii)}$$

From equation (i) and (ii),

$$V_{Th} = 9\text{ V and } R_{Th} = 2\ \Omega \quad \text{...(iii)}$$

Now, V_{Th} depends on independent voltage source and varies with applied voltage. R_{Th} does not depend on voltage source and is same for any applied voltage source, since voltage source is short-circuited while calculating R_{Th}.

For $V_{DC} = 6\text{ V}, R_L = 1\ \Omega, I = 7/3$

$$V_{Th} = I(R_{Th} + R_L)$$
$$V_{Th} = \frac{7}{3}(2+1) = 7\text{ V} \quad \text{...(iv)}$$

$\because$ The network is linear and non-reciprocal, it may contain dependent voltage source.

$$\therefore \quad V_{Th} = aV + b \quad \text{...(v)}$$
$$\Rightarrow \quad 9 = a10 + b \quad \text{[From equation (iii)]}$$
$$\text{and} \quad 7 = a6 + b \quad \text{[From equation (iv)]}$$

Solving, we get, $a = \frac{1}{2}$ and $b = 4$

$$\therefore \quad V_{Th} = \frac{V}{2} + 4 = \frac{8}{2} + 4 = 8\text{ V}$$

For 8 V source.

23. **(c)**

From the above solution:

When, $V_{DC} = 10\text{ V}$

$$V_{Th} = 9\text{ V}$$

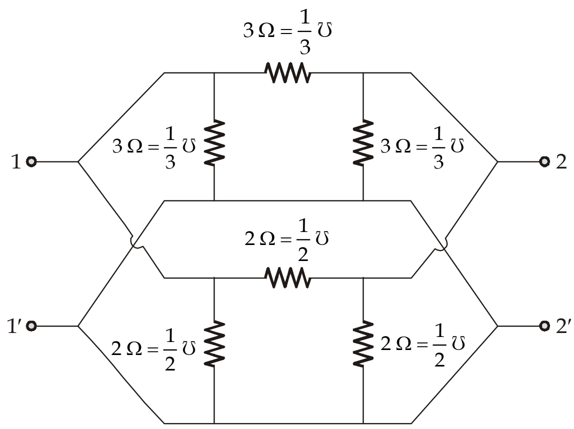
and $R_{Th} = 2\ \Omega$

When, $R_L = 7\ \Omega, I = ?$

$$V_{Th} = I(R_{Th} + R_L)$$
$$I = \frac{V_{Th}}{R_{Th} + R_L}$$
$$= \frac{9}{2+7} = 1\text{ A}$$

24. **Sol.**

When two, 2-port networks are connected in parallel then individual Y-parameters are added. Therefore, from the given network,



For network (1) Y-parameter is,

$$Y_1 = \begin{bmatrix} \frac{1}{3}+\frac{1}{3} & -\frac{1}{3} \\ -\frac{1}{3} & \frac{1}{3}+\frac{1}{3} \end{bmatrix}$$

Similarly for network (2),

$$Y_2 = \begin{bmatrix} 1 & -\frac{1}{2} \\ -\frac{1}{2} & 1 \end{bmatrix}$$

Thus, $$Y = Y_1 + Y_2 = \begin{bmatrix} \frac{5}{3} & -\frac{5}{6} \\ -\frac{5}{6} & \frac{5}{3} \end{bmatrix}$$

$\therefore$ $$I_1 = Y_{11}V_1 + Y_{12}V_2$$

$$= \frac{5}{3}Y_1 - \frac{5}{6}V_2 \quad ...(i)$$

$$I_2 = Y_{21}V_1 + Y_{22}V_2$$

$$= -\frac{5}{6}V_1 + \frac{5}{3}V_2 \quad ...(ii)$$

Also, $$h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1=0}$$

From equation (i), we get,

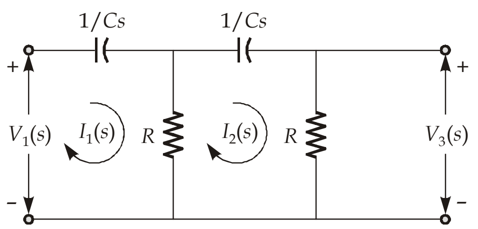
$$V_1 = \frac{1}{2}V_2 \quad ...(iii)$$

and from equation (ii) and (iii), we get

$$h_{22} = \frac{I_2}{V_2} = \frac{15}{12} = 1.25$$

25. (b)

The cascaded network is,



Applying mesh analysis to determine the current $I_2(s)$.

We get,

$$\left(R + \frac{1}{Cs}\right)I_1(s) = RI_2(s) = V_1(s) \quad ...(i)$$

$$\left(R + \frac{1}{Cs}\right)I_2(s) - RI_2(s) = 0 \quad ...(ii)$$

Also, $$V_3(s) = I_2(s) \times R \quad ...(iii)$$

From equation (i) and (ii), we get

$$= \left(R + \frac{1}{Cs}\right) \times \left(1 + \frac{1}{RCs}\right)I_2(s) - RI_2(s) = V_1(s)$$

$$= \left(\frac{RCs+1}{Cs}\right)\left(\frac{RCs+1}{RCs}\right)I_2(s) - RI_2(s) = V_1(s)$$

or, $$I_2(s) = \frac{RC^2s^2V_1(s)}{(1+RCs)^2 - R^2C^2s^2} \quad ...(iv)$$

Using equation (iii) and (iv), we get

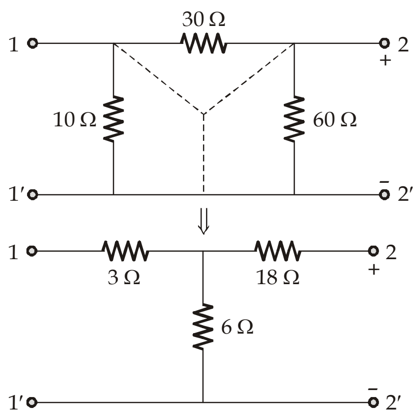
$$\frac{V_3(s)}{V_1(s)} = \frac{s^2R^2C^2}{1+3RCs+s^2R^2C^2} \quad ...(v)$$

$\because$ $R = 10\text{ k}\Omega$, $C = 100\ \mu\text{F}$ and $RC = 1$

$$\frac{V_3(s)}{V_1(s)} = \frac{s^2}{1+3s+s^2}$$

26. (c)

Converting Π-network to Y-network, we get,

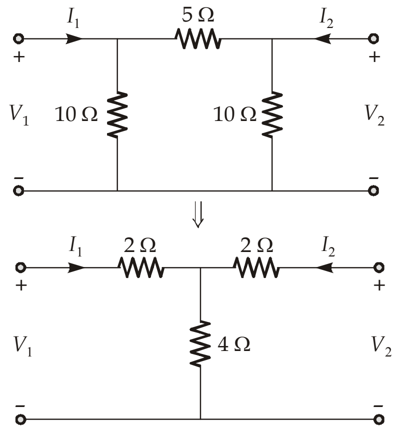


$\therefore$ Z-parameter,

$$Z_{11} = 3\ \Omega + 6\ \Omega = 9\ \Omega$$
$$Z_{12} = Z_{21} = 6\ \Omega$$
$$Z_{22} = 18\ \Omega + 6\ \Omega = 24\ \Omega$$

$$[Z] = \begin{bmatrix} 9 & 6 \\ 6 & 24 \end{bmatrix}$$

27. (a)

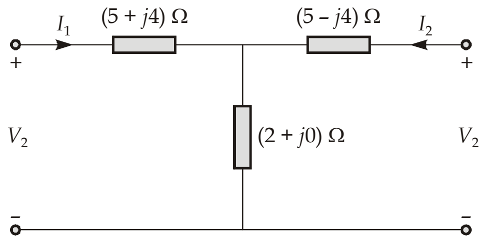


$$V_1 = 6I_1 + 4I_2$$
$$V_2 = 4I_1 + 6I_2$$
$$[Z] = \begin{bmatrix} 6 & 4 \\ 4 & 6 \end{bmatrix}$$
$$Y = \frac{1}{20}\begin{bmatrix} 6 & -4 \\ -4 & 6 \end{bmatrix} = \begin{bmatrix} 0.3 & -0.2 \\ -0.2 & 0.3 \end{bmatrix}$$

Ignoring negative sign:

$$[Y] = \begin{bmatrix} 0.3 & 0.2 \\ 0.2 & 0.3 \end{bmatrix}$$

28. (b)



$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}\begin{bmatrix} V_2 \\ I_2 \end{bmatrix}$$

When, $I_2 = 0$

$$V_1 = (5 + j4 + 2)\, I_1$$
$$V_2 = 2I_1$$
$$A = \left.\frac{V_1}{V_2}\right|_{I_2=0} = \frac{7+j4}{2} = 3.5 + j2$$
$$C = \left.\frac{I_1}{V_2}\right|_{I_2=0} = \frac{1}{2} = 0.5$$

From here only (b) option matches.

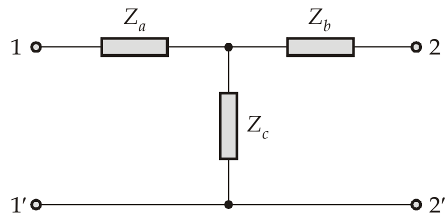
29. (d)

For reciprocal network, $AD - BC = 1$,

$$|T| = 1$$

30. Sol.

For T-network,



$$Z_{11} = Z_a + Z_c$$
$$Z_{22} = Z_b + Z_c$$

and $Z_{12} = Z_{21} = Z_c$

Given, $[Z] = \begin{bmatrix} 2j\omega & j\omega \\ j\omega & 3+2j\omega \end{bmatrix}$

Therefore, $Z_{12} = j2$

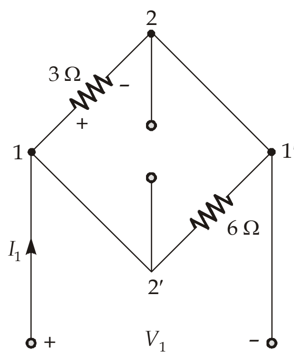
and $Z_{22} = 3 + 2j\omega = 3 + j\omega + j\omega$

$$= Z_b + Z_c = R_b + j\omega + Z_c$$

$\therefore$ $R_b = 3\ \Omega$

31. (a)

Redrawing the circuit,



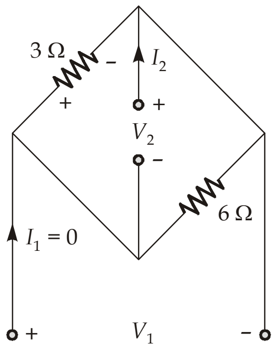
$$Z_{11} = \frac{V_1}{I_1} = 3\,||\,6 = 2\ \Omega$$
$$V_2 = -3 \times I_{3\,\Omega}$$
$$= -3 \times I_1 \times \frac{6}{9} = -2I_1$$

$\therefore$ $Z_{21} = \dfrac{V_2}{I_1} = -2$

Now, $Z_{22} = \left.\dfrac{V_2}{I_1}\right|_{I_1=0} = 3\,||\,6 = 2\ \Omega$

$$V_1 = -6 \times I_{6\,\Omega} = -6 \times I_2 \times \frac{3}{9} = -2$$

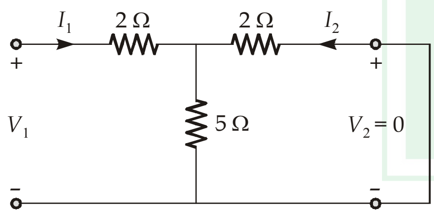
$$\therefore \quad [Z] = \begin{bmatrix} 2 & -2 \\ -2 & 2 \end{bmatrix}$$



32. Sol.

$$B = -\frac{V_1}{I_2}\bigg|_{V_2=0}$$

When, $V_2 = 0$ (i.e., when port-2 is short-circuited)



$$I_1 = \frac{V_1}{2\,\Omega + (5\,\Omega \,||\, 2\,\Omega)} = \frac{7\,V_1}{24\,\Omega}$$

$$I_2 = -I_1 \times \frac{5\,\Omega}{5\,\Omega + 2\,\Omega} = \frac{-5\,V_1}{24\,\Omega}$$

So, $$B = -\frac{V_1}{I_2} = \frac{24}{5}\,\Omega = 4.80\,\Omega$$

33. Sol.

From maximum power transfer theorem,

$$Z_L = Z_{Th}$$

$$Z_{Th} = Z_{22} - \frac{Z_{12} \times Z_{21}}{R_s + Z_{11}}$$

For given data,

$$Z_{Th} = 120 - \frac{60 \times 60}{10 + 40} = 48\,\Omega$$

$$Z_L = 48\,\Omega$$

34. Sol.

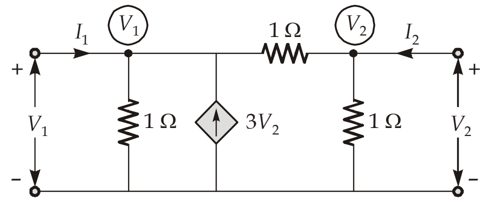
For ideal transformer on $n : 1$, the scattering matrix is,

$$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \begin{bmatrix} \frac{n^2-1}{n^2+1} & \frac{2n}{n^2+1} \\ \frac{2n}{n^2+1} & \left(\frac{1-n^2}{1+n^2}\right) \end{bmatrix}$$

$$S_{21} = \frac{2n}{n^2+1} = \frac{2(2)}{2^2+1} = \frac{4}{5} = 0.8$$

35. (d)

Consider the two-port network,



For Y-parameters:

$$I_1 = y_{11}V_1 + y_{12}V_2$$
$$I_2 = y_{21}V_1 + y_{22}V_2$$

By KCL at (V_1)

$$I_1 + 3V_2 = \frac{V_1}{1} + \frac{V_1 - V_2}{1}$$

$$I_1 = 2V_1 - 4V_2 \quad \text{...(1)}$$

By KCL at (V_2), $$I_2 = \frac{V_2}{1} + \frac{V_2 - V_1}{1}$$

$$I_2 = -V_1 + 2V_2 \quad \text{...(2)}$$

From equation (1) and (2),

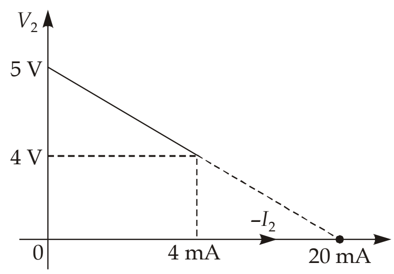
$$I_1 = 2V_1 - 4V_2$$
$$I_2 = -V_1 + 2V_2$$

$$\begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} = \begin{bmatrix} 2 & -4 \\ -1 & 2 \end{bmatrix}$$

36. (4)

For $I_2 = 0$: $\quad V_2 = V_{OC} = 5\text{ V}$

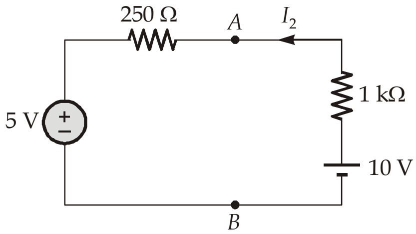
For Thevenin's resistance R_{Th},



For $-I_2 = 20$ mA,

$$V_2 = 0$$
$$I_{SC} = -I_2$$
$$I_{SC} = 20\text{ mA}$$
$$R_{Th} = \frac{V_{OC}}{I_{SC}} = \frac{5}{20}\times 10^3 = 250\ \Omega$$

Network is replaced by Thevenin's equivalent,



$$I_2 = \frac{10-5}{1.25\times 10^3}$$
$$= \frac{5}{1.25}\times 10^{-3}\text{ A} = 4\text{ mA}$$

❐❐❐❐

Answers EE Two Port Networks

1. (b)	**3.** (b)	**4.** (c)	**5.** (b)	**6.** (d)	**7.** (d)	**8.** (d)	**9.** (b)
10. (a)	**11.** (c)	**12.** (c)	**13.** (b)	**14.** (c)	**15.** (a)	**16.** (35.55)	**17.** (20)
18. (d)	**19.** (0.5)						

Solutions EE Two Port Networks

1. (b)

For reciprocity,

$$h_{12} = -h_{21}$$

For symmetry,

$$\begin{vmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{vmatrix} = 1$$

2. Sol.

Using KCL,

$$I_1 = \frac{V_1}{10} + \frac{V_1 - V_2}{10} = \frac{1}{5}V_1 - \frac{1}{10}V_2$$

Again using KCL,

$$I_2 = \frac{V_2}{10} + \frac{V_2 - V_1}{10} = -\frac{1}{10}V_1 + \frac{1}{5}V_2$$

Hence, $$[y] = \begin{bmatrix} 0.2 & -0.1 \\ -0.1 & 0.2 \end{bmatrix}$$

3. (b)

$$[y] = \begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix}$$
$$[z] = [y]^{-1}$$
$$= \frac{1}{2-1}\begin{bmatrix} 1 & -1 \\ -1 & 2 \end{bmatrix} = \begin{bmatrix} 1 & -1 \\ -1 & 2 \end{bmatrix}$$

4. (c)

For a passive two-port network, output power can never be greater than input power.

5. (b)

Using KVL,

$$E_1 = 2I_1 + 2(I_1 + I_2)$$

Again using KVL,

$$E_2 = 2I_2 + 2(I_1 + I_2)$$

$$\Rightarrow \quad [z] = \begin{bmatrix} 4 & 2 \\ 2 & 4 \end{bmatrix}$$

$$[y] = [z]^{-1}$$

$$= \frac{1}{(4\times4)-(2\times2)}\cdot\begin{bmatrix}4 & -2\\ -2 & 4\end{bmatrix}$$

$$\begin{bmatrix}Y_{11} & Y_{12}\\ Y_{21} & Y_{22}\end{bmatrix} = \begin{bmatrix}1/3 & -1/6\\ -1/6 & 1/3\end{bmatrix}$$

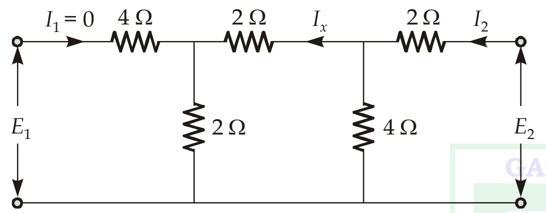
6. (d)

$$h_{12} = \left.\frac{E_1}{E_2}\right|_{I_1=0}$$

or h_{12} is ratio of E_1 to E_2 for the input open-circuited condition.

Two method are provided to solve the problem.

Assuming, $I_1 = 0$



$$I_2 = \frac{E_2}{2+(2+4)||4} = \frac{E_2}{4}$$

$$I_x = \frac{I_2}{(2+2)+4}\times 4$$

$$= \frac{I_2}{2} = \frac{1}{2}\left(\frac{E_2}{4}\right) = \frac{E_2}{8}$$

$$E_1 = 2I_x = 2\left(\frac{E_2}{8}\right) = \frac{E_2}{4}$$

$$\Rightarrow \quad \frac{E_1}{E_2} = 0.25$$

7. (d)

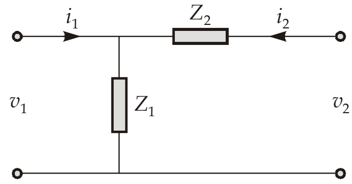
$$[z] = \begin{bmatrix}0.9 & 0.2\\ 0.2 & 0.6\end{bmatrix}$$

$$[y] = [z]^{-1} = \frac{\begin{bmatrix}0.6 & -0.2\\ -0.2 & 0.9\end{bmatrix}}{[0.9\times0.6-0.04]}$$

$$= \begin{bmatrix}1.2 & -0.4\\ -0.4 & 1.8\end{bmatrix}$$

$$y_{22} = 1.8$$

8. (d)



$$v_1 = (i_1 + i_2)\, z_1$$

$$= z_1 i_1 + z_1 i_2 \qquad \text{...(i)}$$

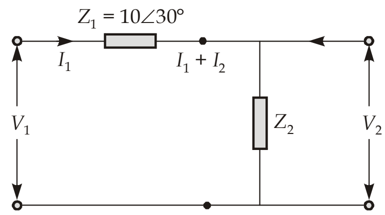
$$v_2 = z_2 i_1 + z_1(i_1 + i_2)$$

$$= z_1 i_1 + (z_1 + z_2)\, i_2 \qquad \text{...(ii)}$$

From equation (i) and (ii),

$$z\text{-matrix} = \begin{bmatrix}z_1 & z_1\\ z_1 & z_1+z_2\end{bmatrix}$$

9. (b)



$$V_1 = AV_2 + BI_2$$

$$I_1 = CV_2 + DI_2$$

$$V_2 = Z_2(I_1 + I_2) \qquad \text{...(i)}$$

$$C = \left.\frac{I_1}{V_2}\right|_{I_2=0}$$

Putting, $I_2 = 0$ in equation (i),

$$V_2 = Z_2 I_1$$

$$\Rightarrow \quad Z_2 = \left.\frac{V_2}{I_1}\right|_{I_2=0} = \frac{1}{C} = \frac{1}{0.025\angle45°}$$

$$Z_2 = 40\angle{-45°}\ \Omega$$

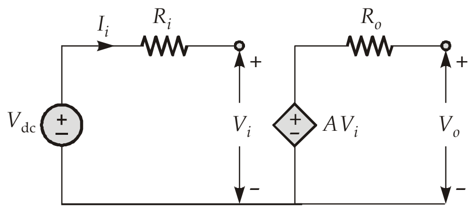
10. (a)

Output voltage $= V_0 = AV_i$

$V_0 = 10^6 \times 1 \times 10^{-6} = 1$ V

[Given: $A = 10^6$ V/V, $V_i = 1\ \mu$V)

To calculate input impedance, V_{dc} source is connected at input port,



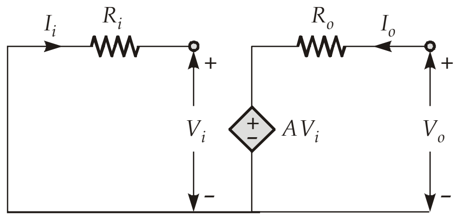
Input impedance,

$$Z_i = \frac{V_{dc}}{I_i}$$

as loop is not closed, $I_i = 0$

So, $$Z_i = \frac{V_{dc}}{0} \to \infty$$

To calculate output impedance, V_{dc} source is connected at output port,



Output impedance,

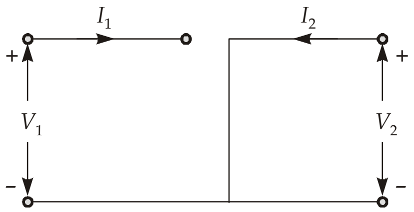
$$Z_0 = \frac{V_0}{I_0} = \frac{I_0 R_0 + AV_i}{I_0}$$

As, $$V_i = 0$$

$$Z_0 = \frac{I_0 R_0 + A \times 0}{I_0} = R_0 = 10\ \Omega$$

11. (c)

$$I_1 = g_{11}V_1 + g_{12}I_2$$
$$V_2 = g_{21}V_1 + g_{22}I_2$$



Since port-1 is open-circuit,

$$I_1 = 0$$

Port-2 is short-circuit,

$$V_2 = 0$$

$$g_{11} = \left.\frac{I_1}{V_1}\right|_{I_2=0} = \frac{0}{V_1} = 0$$

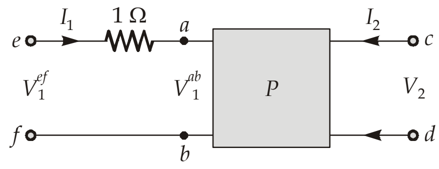
$$g_{12} = \left.\frac{I_1}{I_2}\right|_{V_1=0} = \frac{0}{I_2} = 0$$

$$g_{21} = \left.\frac{V_2}{V_1}\right|_{I_2=0} = \frac{0}{V_1} = 0$$

$$g_{22} = \left.\frac{V_2}{I_1}\right|_{V_1=0} = \frac{0}{I_2} = 0$$

So, g-parameters $= \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$

12. (c)



$$V_1^{ab} = Z_{11}I_1 + Z_{12}I_2 \quad ...(i)$$

$$V_2 = Z_{21}I_1 + Z_{22}I_2 \quad ...(ii)$$

As 1 Ω resistor is connection in series with the network at port-1.

V_2 does not get affected,

$$V_1^{ef} = V_1^{ab} + I_1 \times 1$$
$$= Z_{11}I_1 + Z_{12}I_2 + I_1$$
$$= (Z_{11} + 1)\, I_1 + Z_{12}I_2$$

Modified Z-parameter

$$= \begin{bmatrix} Z_{11}+1 & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

13. (b)

(i) $V_1 = 10\text{ V}; \quad V_2 = 3\text{ V}$

$I_2 = -3\text{ A}; \quad V_1 = AV_2 - BI_2$

$10 = 3A + 3B \quad ...(i)$

(ii) $V_2 = 5\text{ V}$

$I_2 = -2\ A$

$10 = 5\,A + 2\,B \quad ...(ii)$

$$A = \frac{10}{9} \quad ...(iii)$$

$$B = \frac{20}{9} \quad ...(iv)$$

Given, $V_1 = 8\text{ V}$

$(V_2)_{OC} = ?$

$I_2 = 0$

$V_1 = AV_2 - BI_2$

$8 = A(V_2)_{OC} - 0$

$$(V_2)_{OC} = \frac{8}{A} = \frac{8}{10/9} = 7.2\text{ V}$$

14. (c)

Given, $V_1 = 10\text{ V}, \quad V_2 = (-7I_2)$

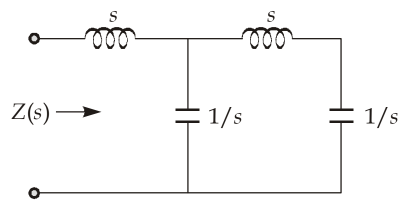
$$V_1 = AV_2 - BI_2$$

$$10 = -7I_2A - BI_2 = -\frac{70}{9}I_2 - \frac{20}{9}I_2$$

$$I_2 = -1\text{ A}$$

(–ve) sign signifies that current is drawn.

15. (a)



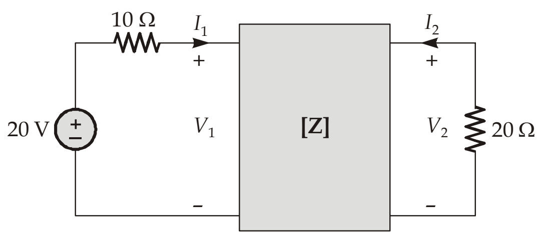
Driving point impedance, $Z(s)$ is

$$Z(s) = s + \left(\frac{\left(s+\frac{1}{s}\right)\times\frac{1}{s}}{s+\frac{1}{s}+\frac{1}{s}}\right) = s + \left(\frac{s^2+1}{s^2}\right)\times\frac{s}{(s^2+2)}$$

$$= s + \frac{s^2+1}{s(s^2+2)} = \frac{s^2(s^2+2)+s^2+1}{s^3+2s}$$

or, $$Z(s) = \frac{s^4+3s^2+1}{s^3+2s}$$

16. Sol.



Given, $Z_{11} = 40\ \Omega,\ Z_{12} = 60\ \Omega$

$Z_{21} = 80\ \Omega,\ Z_{22} = 100\ \Omega$

From the figure,

$$V_2 = -20I_2 \quad \text{...(i)}$$

and $$V_1 = 40I_1 + 60I_2 \quad \text{...(ii)}$$

$$V_2 = 80I_1 + 100I_2 \quad \text{...(iii)}$$

From equation (i) and (iu), we get

so, $$-20I_2 = 80I_1 + 100I_2$$

$\Rightarrow$ $$I_2 = -\frac{2}{3}I_1 \quad \text{...(iv)}$$

Using equation (ii) and (iv), we get

so, $$V_1 = 40I_1 + 60I_2$$

$$= 40I_1 + 60\left(\frac{-2}{3}I_1\right)$$

$$V_1 = 0$$

From the figure,

$$20 = 10I_1 + V_1$$

Since, $V_1 = 0$

So, $I_1 = 2\text{ A}$

So, $$I_2 = -\frac{4}{3}\text{ A}$$

Power dissipated in

$$P_{R_L} = I_2^2R_L = \left(\frac{4}{3}\right)^2\times 20$$

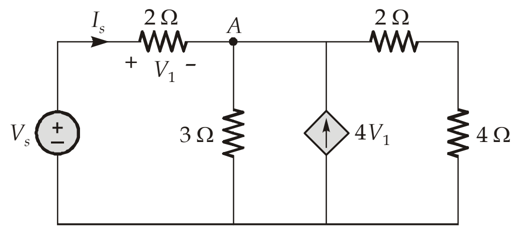
$$= \frac{16}{9}\times 20 = 35.55\text{ W}$$

17. Sol.

To find impedance seen by V_s,

$$Z_s = \frac{V_s}{I_s}$$

$$V_1 = 2I_s$$



Applying KCL at node A,

$$I_s + 4V_1 = \frac{V_A}{3} + \frac{V_A}{6}$$

$$V_A = V_s - V_1$$

and $V_1 = 2I_s$

So, $$I_s + 8I_s = \frac{V_s - 2I_s}{3} + \frac{V_s - 2I_s}{6}$$

$\Rightarrow$ $$54I_s = 2V_s - 4I_s + V_s - 2I_s$$

$\Rightarrow$ $$3V_s = 60I_s$$

$$\frac{V_s}{I_s} = 20\ \Omega$$

18. (d)

For two port networks we can write,

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix}\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix}$$

or, $A = A_1A_2 + B_1C_2$ ...(i)

$B = A_1B_2 + B_1D_2$ ...(ii)

or, $V_1 = AV_2 - BI_2$ ...(iii)

To get, $V_T(I_2 = 0)$, from equation (iii),

$$V_2 = V_T = \frac{V_1}{A} = \frac{V_1}{A_1A_2 + B_1C_2}$$

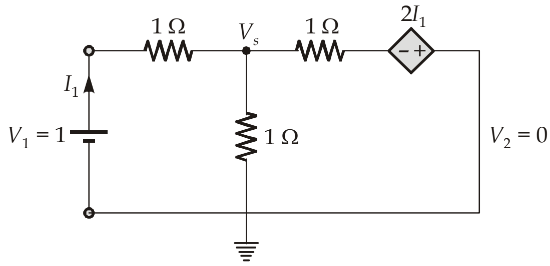
To get, $Z_T(V_T = 0)$, from equation (iii),

$$V_1 = AV_2 - BI_2$$

$$0 = AV_2 - BI_2$$

$$Z_T = \frac{V_2}{I_2} = \frac{B}{A} = \frac{A_1B_2 + B_1D_2}{A_1A_2 + B_1C_2}$$

19. Sol.



By KCL,

$$\frac{V_a - 1}{1} + \frac{V_a}{1} + \frac{V_a + 2I_1}{1} = 0$$

$$3V_a + 2I_1 = 1 \quad \text{...(i)}$$

$$I_1 = \frac{1 - V_a}{1} \quad \text{...(ii)}$$

Substitute equation (ii) in equation (i),

$$V_a = -1$$

$$I_1 = \frac{1 - V_a}{1} = \frac{1-(-1)}{1} = 2$$

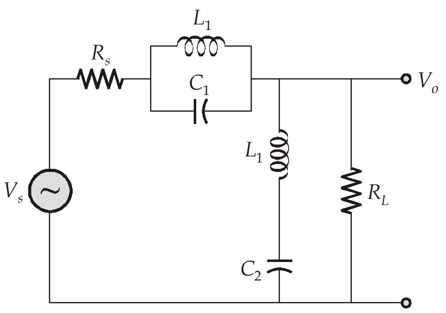
$$h_{11} = \frac{V_1}{I_1} = \frac{1}{2} = 0.5\,\Omega$$

❐❐❐❐

6 Network Functions

ELECTRONICS ENGINEERING
(GATE Previous Years Solved Papers)

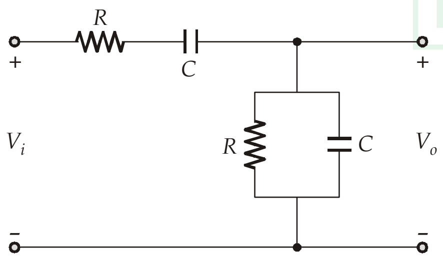
Q.1 The circuit of the figure represents a



(a) low pass filter (b) high pass filter
(c) band pass filter (d) band reject filter

[EC-2001 : 1 Mark]

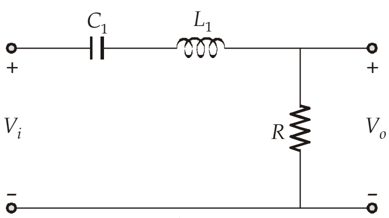
Q.2 The RC circuit shown in the figure is



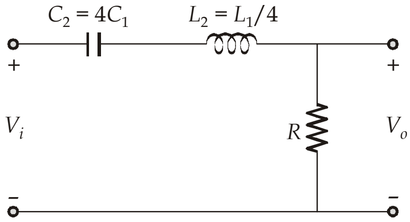
(a) a low-pass filter
(b) a high-pass filter
(c) a band-pass filter
(d) a band-reject filter

[EC-2007 : 1 Mark]

Q.3 Two series resonant filters are as shown in the figure. Let the 3 dB bandwidth of filter 1 be B_1 and that of filter 2 be B_2. The value of B_1/B_2 is



Filter-1



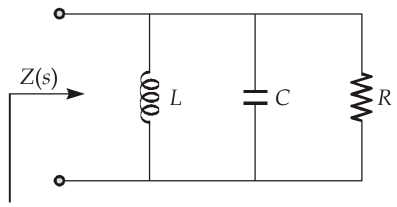
Filter-2

(a) 4 (b) 1
(c) $\frac{1}{2}$ (d) $\frac{1}{4}$

[EC-2007 : 2 Marks]

Q.4 The driving point impedance of the following network, is given by

$$Z(s) = \frac{0.2s}{s^2 + 0.1s + 2}$$

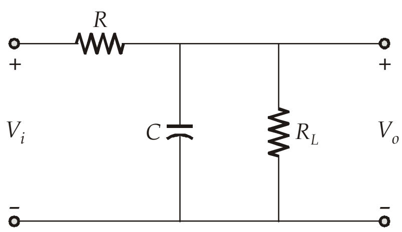


The component values are
(a) $L = 5$ H, $R = 0.5\ \Omega$, $C = 0.1$ F
(b) $L = 0.1$ H, $R = 0.5\ \Omega$, $C = 5$ F
(c) $L = 5$ H, $R = 2\ \Omega$, $C = 0.1$ F
(d) $L = 0.1$ H, $R = 2\ \Omega$, $C = 5$ F

[EC-2008 : 2 Marks]

Q.5 If the transfer function of the following network is,

$$\frac{V_o(s)}{V_i(s)} = \frac{1}{2 + sCR}$$



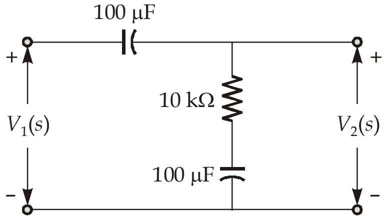
The value of the load resistance R_L is

(a) $R/4$ (b) $R/2$

(c) R (d) $2R$

[EC-2009 : 1 Mark]

Q.6 The transfer function $V_2(s)/V_1(s)$ of the circuit shown below is



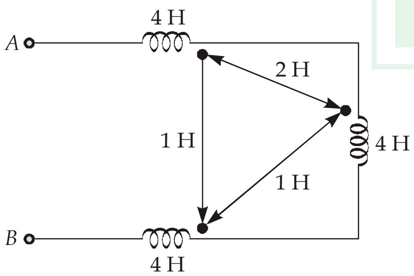
(a) $\frac{0.5s+1}{s+1}$ (b) $\frac{3s+6}{s+2}$

(c) $\frac{s+2}{s+1}$ (d) $\frac{s+1}{s+2}$

[EC-2013 : 1 Mark]

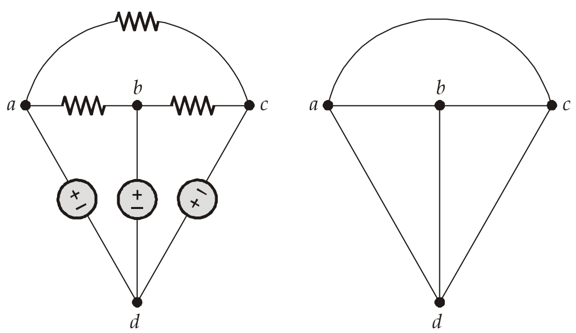
ELECTRICAL ENGINEERING
(GATE Previous Years Solved Papers)

Q.1 The equivalent inductances seen at terminals A-B in figure is ______ H.



[EE-1992 : 2 Marks]

Q.2 Figure shows a dc resistive network and its graph is drawn a side. A 'proper tree' chosen for analysis the network will not contain the edges:



(a) *ab, bc, ad* (b) *ab, bc, ca*

(c) *ab, bd, cd* (d) *ac, bd, ad*

[EE-1994 : 1 Mark]

Q.3 Two identical coils of negligible resistance when connected in series across a 200 V, 50 Hz source draws a current of 10 A. When the terminals of one of the coils are reversed, then current drawn is 8 A. The coefficient of coupling between the two coils is _______ .

[EE-1997 : 2 Marks]

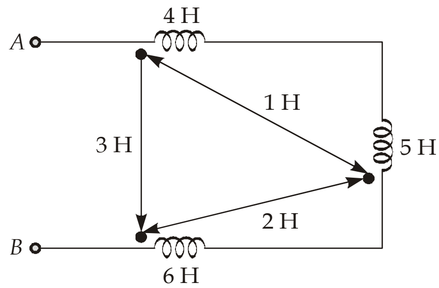
Q.4 A major advantage of active filter is that they can be realized without using

(a) op-amps (b) inductors

(c) resistors (d) capacitors

[EE-1997 : 1 Mark]

Q.5 The effective inductance of the circuit across the terminals A, B in the figure shown below is

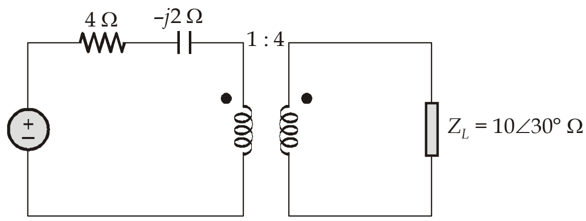


(a) 9 H (b) 21 H

(c) 11 H (d) 6 H

[EE-1998 : 2 Marks]

Q.6 The impedance seen by the source in the circuit in figure is given by



(a) $(0.54 + j0.313)\ \Omega$ (b) $(4 - j2)\ \Omega$

(c) $(4.54 - j1.693)\ \Omega$ (d) $(4 + j2)\ \Omega$

[EE-2000 : 2 Marks]

Q.7 Given two coupled inductors L_1 and L_2, their mutual inductance 'M' satisfies

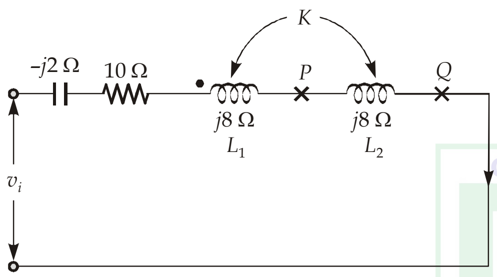
(a) $M = \sqrt{L_1^2 + L_2^2}$ (b) $M > \frac{(L_1 + L_2)}{2}$

(c) $M > \sqrt{L_1 L_2}$ (d) $M \le \sqrt{L_1 L_2}$

[EE-2000 : 1 Mark]

Q.8 In the circuit shown in figure it is found that the input ac voltage (V_i) and current 'i' are in phase.

The coupling coefficient is $K = \frac{M}{\sqrt{L_1 L_2}}$, where M is the mutual inductance between the two coils. The value of 'K' and the dot polarity of the coil P-Q are



(a) $K = 0.25$ and dot at P
(b) $K = 0.5$ and dot at P
(c) $K = 0.25$ and dot at Q
(b) $K = 0.5$ and dot at Q

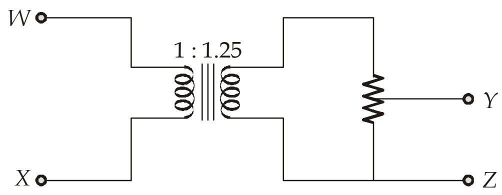
[EE-2002 : 2 Marks]

Q.9 A first order, low pass filter is given with $R = 50\ \Omega$ and $C = 5\ \mu F$. What is the frequency at which the gain of the voltage transfer function of the filter is 0.25?

(a) 4.92 kHz (b) 0.49 kHz
(c) 2.46 kHz (d) 24.6 kHz

[EE-2002 : 2 Marks]

Q.10 The following arrangement consists of an ideal transformer and an attenuator which attenuates by a factor of 0.8. An a.c. voltage $V_{WX1} = 100$ V is applied across WX to get an open-circuit voltage V_{YZ1} across YZ. Next, an a.c. voltage $V_{YZ2} = 100$ V is applied across YZ to get an open-circuit voltage V_{WX2} across WX. Then V_{YZ1}/V_{WX1}, V_{WX2}/V_{YZ2} are respectively.



(a) $\frac{125}{100}$ and $\frac{80}{100}$ (b) $\frac{100}{100}$ and $\frac{80}{100}$

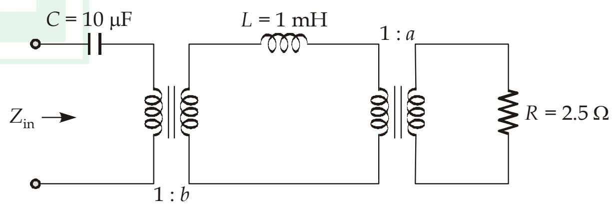
(c) $\frac{100}{100}$ and $\frac{100}{100}$ (b) $\frac{80}{100}$ and $\frac{80}{100}$

[EE-2013 : 2 Marks]

Q.11 Two identical coupled inductors are connected in series. The measured inductances for the two possible series connections are 380 μH and 240 μH. Their mutual inductance in μH is ________ .

[EE-2014 : 1 Mark]

Q.12 Find the transformer ratios a and b such that the impedance (Z_{in}) is resistive and equals 2.5 Ω when the network is excited with a since wave voltage of angular frequency of 5000 rad/sec.



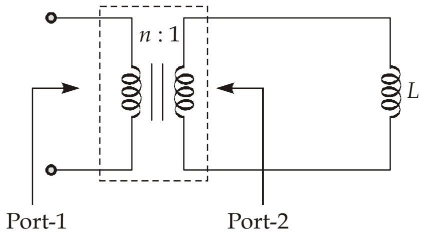
(a) $a = 0.5, b = 2.0$ (b) $a = 2.0, b = 0.5$
(c) $a = 1.0, b = 1.0$ (d) $a = 4.0, b = 0.5$

[EE-2015 : 1 Mark]

Q.13 Two identical coils each having inductance L are placed together on the same core. If an overall inductance of aL is obtained by interconnecting these two coils, the minimum value of a is ________ .

[EE-2015 : 2 Marks]

Q.14 If an ideal transformer has an inductive load element at port 2 as shown in the figure below, the equivalent inductance at port 1 is

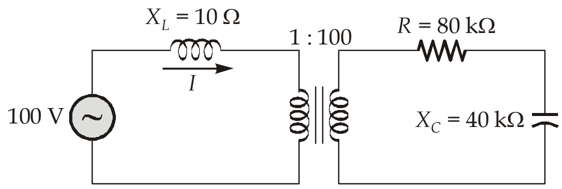


(a) nL (b) n^2L

(c) $\frac{n}{L}$ (d) $\frac{n^2}{L}$

[EE-2016 : 1 Mark]

Q.15 The following figure shows the connection of an ideal transformer with primary to secondary turns ratio of 1 : 100. The applied primary voltage is 100 V(rms), 50 Hz, AC. The rms value of the current I, in ampere, is ______ .



[EE-2016 : 1 Mark]

Electronics & Electrical Engineering

GATE Previous Years Solved Paper

Answers & Explanations

Answers EC Network Functions

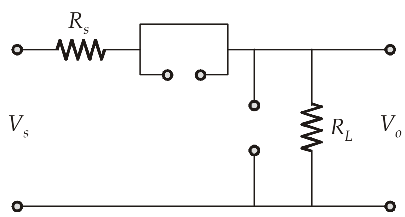
1. (d) 2. (c) 3. (d) 4. (d) 5. (c) 6. (d)

Solutions EC Network Functions

1. (d)

Analyzing the circuit for ω = 0 and ω = ∞.

At ω = 0 ;

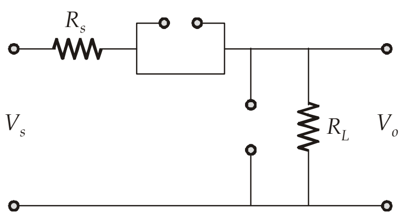


$$\omega = 0, \text{Ind} = \omega L = 0 \text{ (SC)}$$

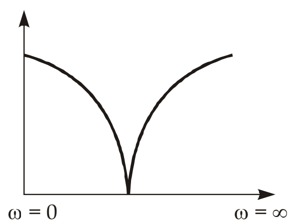
$$\text{cap} = \frac{1}{\omega C} = \infty \text{ (OC)}$$

$$\frac{V_o}{V_s} = \frac{R_L}{R_L + R_s} \text{ (finite value)}$$

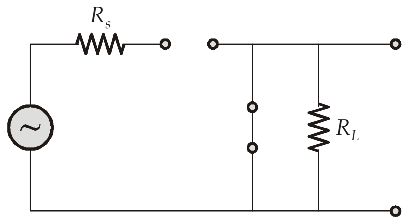
At ω = ∞ ;



$$\frac{V_o}{V_s} = \frac{R_L}{R_L + R_s} \text{ (finite value)}$$



At $\omega = \frac{1}{\sqrt{LC}}$;

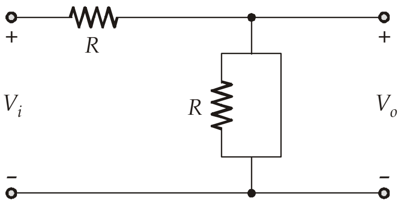


$$v_o = 0$$

2. (c)

At $\omega \to \infty$, capacitor $\to$ short-circuited

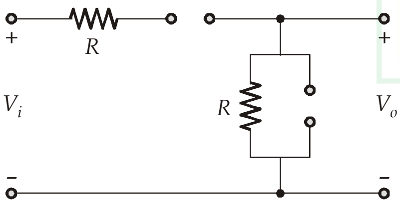
Circuit looks like,



$$\frac{V_o}{V_i} = 0$$

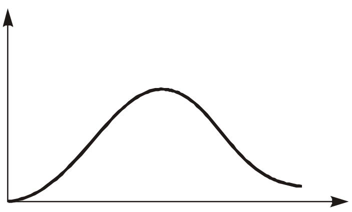
At $\omega \to 0$, capacitor $\to$ open-circuited

Circuit looks like,



$$\frac{V_o}{V_i} = 0$$

So frequency response of the circuit will be



So the circuit is bandpass filter.

3. (d)

Bandwidth of series RLC circuit is R/L

Bandwidth of filter 1;

$$B_1 = \frac{R}{L_1}$$

Bandwidth of filter 2;

$$B_2 = \frac{R}{L_2} = \frac{R}{L_1/4} = \frac{4R}{L_1}$$

So, $$\frac{B_1}{B_2} = \frac{1}{4}$$

4. (d)

$$Z(s) = \frac{0.2s}{s^2 + 0.1s + 2}$$

$$Y(s) = \frac{s^2 + 0.1s + 2}{0.2s} = \frac{s}{0.2} + \frac{1}{2} + \frac{2}{0.2s}$$

$$= 5s + 0.5 + \frac{10}{s}$$

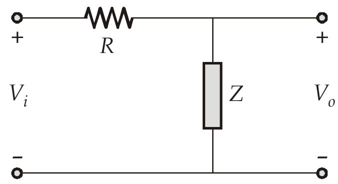
Comparing with

$$Y(s) = Cs + \frac{1}{R} + \frac{1}{Ls}$$

$$C = 5\,\text{F},\ R = \frac{1}{0.5} = 2\,\Omega$$

$$L = \frac{1}{10} = 0.1\,\text{H}$$

5. (c)



$$Z = \frac{R_L}{1 + sR_LC}$$

$$H(s) = \frac{Z}{Z+R} = \frac{R_L}{(R_L + R) + sRR_LC}$$

If, $$R = R_L$$

$$H(s) = \frac{1}{2 + sRC}$$

6. (d)

$$\frac{V_2(s)}{V_1(s)} = \frac{10\times10^3 + \frac{1}{100\times10^{-6}s}}{10\times10^3 + \frac{1}{100\times10^{-6}s} + \frac{1}{100\times10^{-6}s}}$$

$$\frac{V_2(s)}{V_1(s)} = \frac{s\times10^4 + 10^4}{s\times10^4 + 10^4 + 10^4} = \frac{10^4(1+s)}{10^4(s+2)}$$

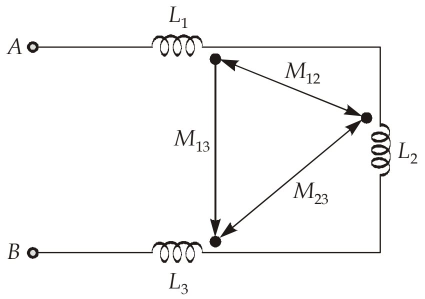
$$\frac{V_2(s)}{V_1(s)} = \frac{s+1}{s+2}$$

Answers EE Network Functions

1. (8)	2. (b)	3. (1/9)	4. (b)	5. (c)	6. (c)	7. (d)	8. (c)
9. (c)	10. (b)	11. (35)	12. (b)	13. (0)	14. (b)	15. (10)	

Solutions EE Network Functions

1. Sol.



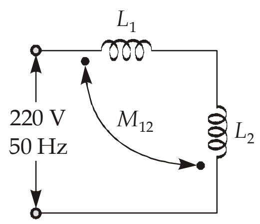
$$L = L_1 + L_2 + L_3 - 2M_{12} + 2M_{23} - 2M_{13}$$
$$= 4 + 4 + 4 - (2 \times 2) + (2 \times 1) - (2 \times 1)$$
$$= 8 \text{ H}$$

2. (b)

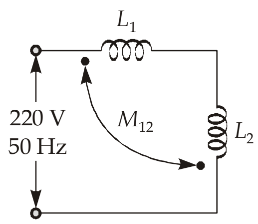
Tree must not contain any closed loop.
Hence option (b) is correct.

3. Sol.

Case-I



Case-II



$$|I_1| = \frac{V}{\omega(L_1 + L_2 - 2M_{12})}$$

$$|I_2| = \frac{V}{\omega(L_1 + L_2 + 2M_{12})}$$

From above expressions, it is clear that,

$$|I_1| > |I_2|$$

$\therefore$ Taking, $|I_1| = 10$ A

and $|I_2| = 8$ A

and putting, $V = 220$ V

and $L_1 = L_2 = L$

we have, $$10 = \frac{200}{\omega(2L - 2M_{12})} \quad ...(i)$$

$$8 = \frac{200}{\omega(2L + 2M_{12})} \quad ...(ii)$$

On solving equation (i) and equation (ii),

we get, $M_{12} = \frac{1}{9}L$

Which can be written as,

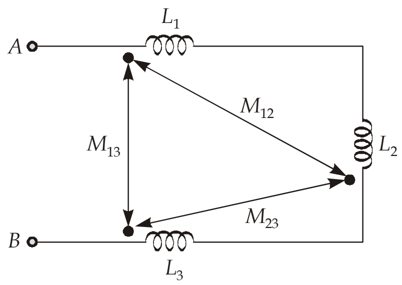
$$M_{12} = \frac{1}{9}\sqrt{L \cdot L} = \frac{1}{9}\sqrt{L \cdot L}$$

Hence, coefficient of coupling $= \frac{1}{9}$.

4. (b)

Inductive coils are bulky in nature.

5. (c)



$$L = L_1 + L_2 + L_3 - 2M_{12} + 2M_{23} - 2M_{13}$$
$$= 4 + 5 + 6 - (2 \times 1) + (2 \times 2) - (2 \times 3)$$
$$= 11 \text{ H}$$

6. (c)

$$Z = (4 - j2) + \left(\frac{1}{4}\right)^2 \times 10\angle 30°$$
$$= (4.54 - j1.69)\ \Omega$$

7. (d)

$$M = K\sqrt{L_1 L_2}$$

Where, K = coefficient of coupling

$\because \quad 0 < K < 1$

$\therefore \quad M \le \sqrt{L_1 L_2}$

8. (c)

Input ac voltage and current will be in phase only at resonance condition.

i.e., $\quad X_C = X_L$

$$|-j12| = \left|j8 + j8 + 2k\sqrt{(j8)\times(j8)}\right|$$

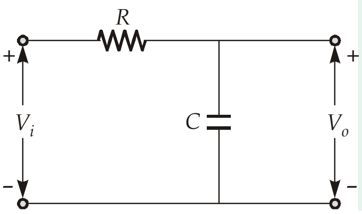
$$12 = 8 + 8 + 16\,k$$

$$\Rightarrow \quad k = -\frac{4}{16} = -\frac{1}{4} = -0.25$$

Hence coupling will be opposite.

$\therefore$ Dot will be at Q.

9. (c)



$$\text{T.F.} = \frac{V_o}{V_i} = \frac{1/j\omega C}{R + \frac{1}{j\omega C}} = \frac{1}{1 + j\omega CR}$$

$$\therefore \quad |\text{Gain}| = \frac{1}{\sqrt{1 + (\omega CR)^2}}$$

$$0.25 = \frac{1}{\sqrt{1 + (\omega \times 5 \times 10^{-6} \times 50)^2}}$$

On solving,

$$\omega = 15.49 \times 10^3 \text{ rad/sec.}$$

$$\Rightarrow \quad f = \frac{15.49}{2\pi} = 2.46 \text{ kHz}$$

10. (b)

$$V_{YZ1} = 100 \times 1.25 \times 0.8$$
$$= 100 \text{ V}$$

In second case when 100 V is applied at YZ terminals, this whole 100 V will appear across the secondary winding.

Hence, $\quad V_{WX_2} = \frac{100}{1.25} = 80 \text{ V}$

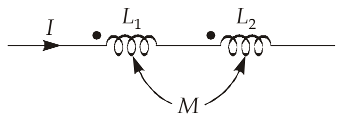
$$\Rightarrow \quad \frac{V_{YZ_1}}{V_{WX_1}} = \frac{100}{100}$$

$$\frac{V_{YZ_2}}{V_{WX_2}} = \frac{80}{100}$$

11. Sol.

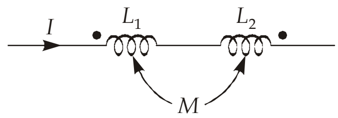
The two possible series connection are shown below:

Let the mutual inductance be M



(i) Additive connection,

$$L_{eq.} = L_1 + L_2 + 2M = 380 \ \mu\text{H}$$



(ii) Subtractive connection,

$$L_{eq.} = L_1 + L_2 - 2M = 240 \ \mu\text{H}$$

Thus, $\quad L_1 + L_2 + 2M = 380 \ \mu\text{H} \quad$ ...(i)

and $\quad L_1 + L_2 - 2M = 240 \ \mu\text{H} \quad$ ...(ii)

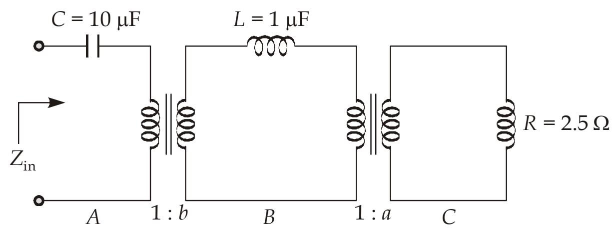
Solving equations (i) and (ii), we get,

$$4M = 10 \ \mu\text{H} \ \text{ or } \ M = 35 \ \mu\text{H}$$

$\therefore \quad$ Mutual inductance,

$$M = 35 \ \mu\text{H}$$

12. (b)



$$(R_{eq})_B = \frac{2.5}{a^2}$$

$$(2_{eq})_B = \left[\frac{2.5}{a^2} + j\omega(1 \times 10^{-3})\right]$$

$$(2_{eq})_A = \left[\frac{2.5}{a^2} + j\omega(1 \times 10^{-3})\right] \Big/ b^2$$

$$Z_{in} = \frac{2.5}{a^2b^2} + \frac{j\omega(10^{-3})}{b^2} + \frac{1}{j\omega(10 \times 10^{-5})}$$

$$Z_{in} = \frac{2.5}{a^2b^2} + j\left[\frac{5\times10^3\times10^{-3}}{b^2} - \frac{1}{5\times10^3\times10\times10^{-6}}\right] \quad ...(i)$$

From problem,

$$Z_{in} = 2.5 \quad ...(ii)$$

From equation (i) and (ii),

$$a^2b^2 = 1 \quad ...(ii)$$

$$\frac{5}{b^2} - \frac{1}{5\times10^{-2}} = 0$$

$\Rightarrow$ $5 \times 5 \times 10^{-2} = b^2$

$\Rightarrow$ $b = 0.5$ and $a = 2$

13. Sol.

Case-I:

$$L_{eff.} = L_1 + L_2 = 2L,\ a = 2$$

Case-II:

$$L_{eff.} = \frac{L_1L_2}{L_1+L_2} = \frac{L^2}{2L} = \frac{L}{2},\ a = 0.5$$

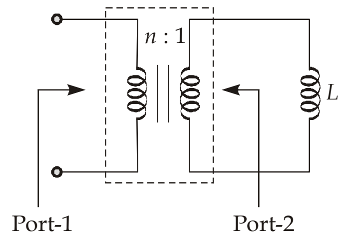
Case-III:

If both are differentially coupled then,

$$L_{eff.} = 0$$

Minimum value = 0

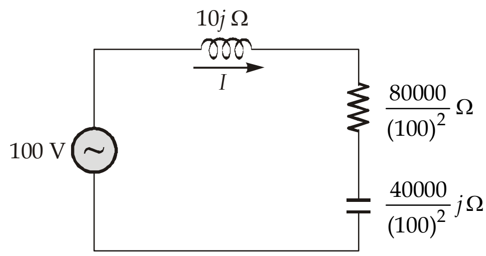
14. (b)



At port 1 i.e., high voltage side impedance will be high and current will be low, So n^2L.

15. Sol.

The above circuit can be drawn by transferring secondary circuit to primary side.



$$I = \frac{100\text{ V}}{(8+10j-4j)\,\Omega} = \frac{100\text{ V}}{(8+6j)\,\Omega}$$

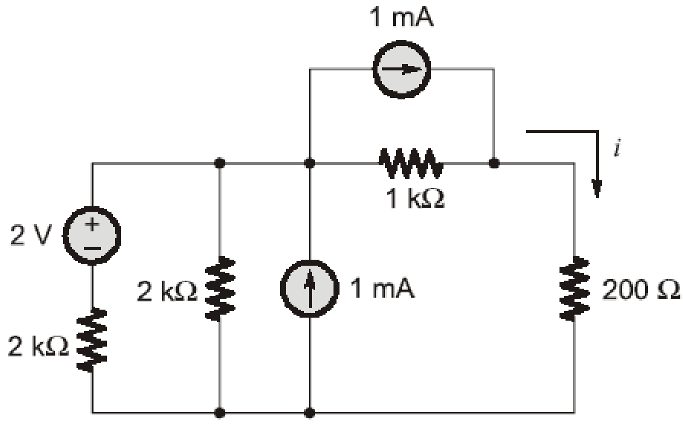
So the rms value of I will be 10 A.

❑❑❑❑

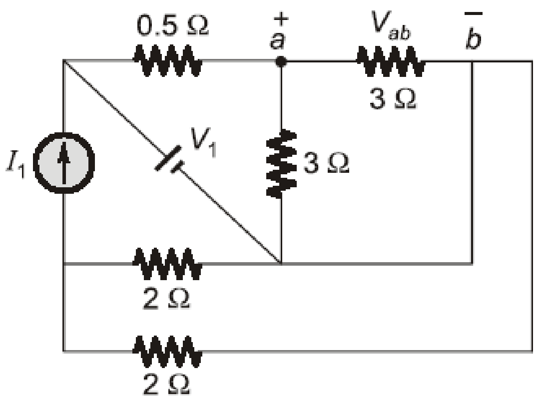
Questions from GATE 2023/2024 -EC /EE Papers

1. Basics of Network Analysis

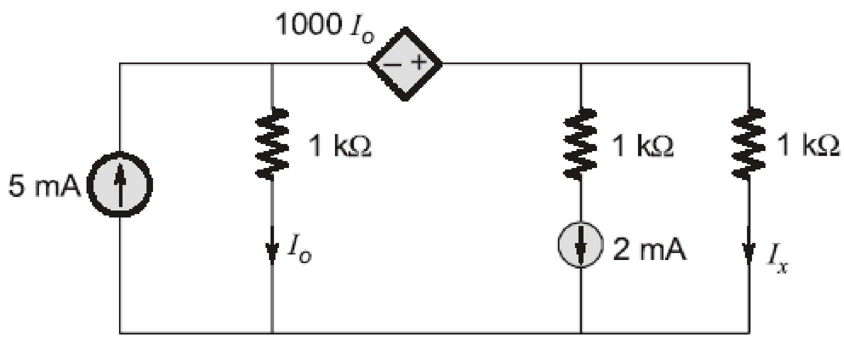
Q1. In the circuit shown below, the current flowing through the 200Ω resistor is…….(Rounded off to 3 decimal points) **(GATE EC 2023)**



Q2. In the diagram shown below, the Voltage V_1 = 8v and I_1 = 8A, The value of voltage V_{AB} is…….(Rounded to 1 decimal point) **(GATE EE 2023)**

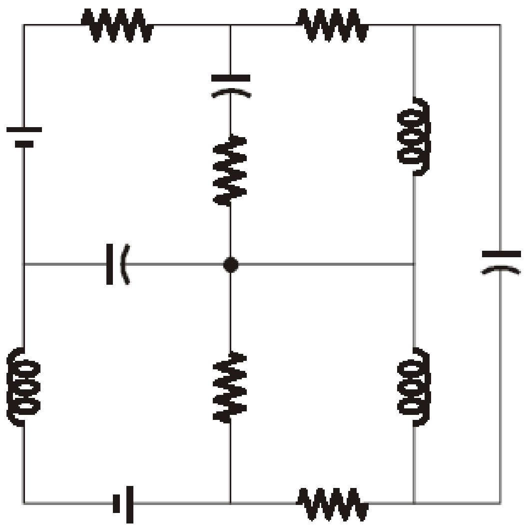


Q3. In the given circuit, the current I_x(in mA) is_________.**(GATE EC 2024)**



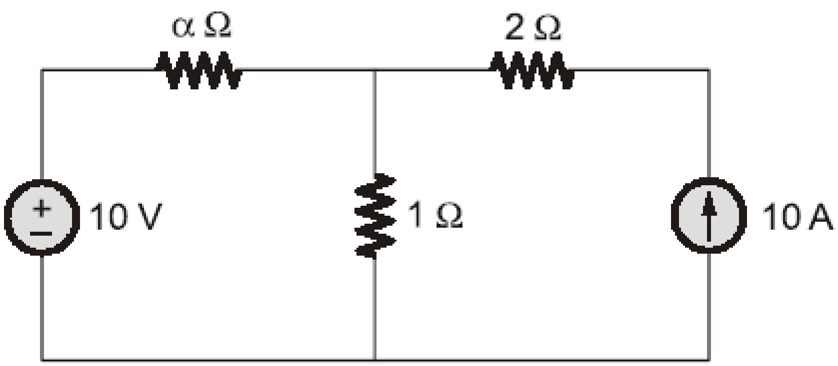
Q4. The number of junctions in the circuit is **(GATE EE 2024)**

A) 8 B) 6 C) 7 D) 9



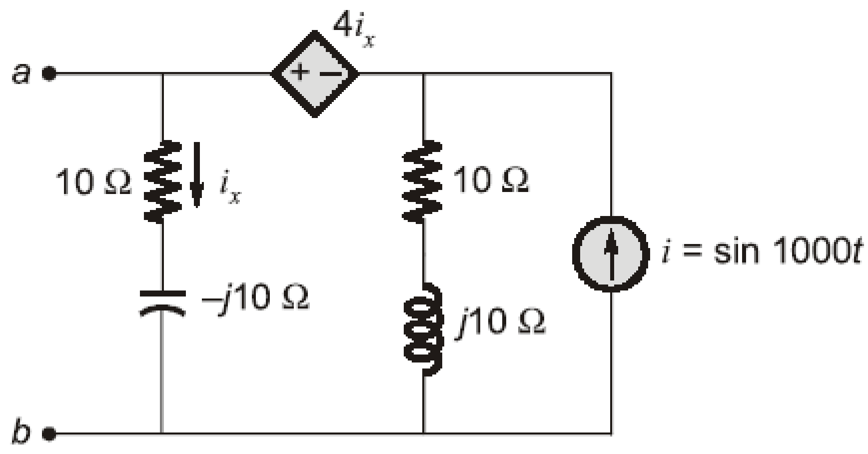
Q5. The power delivered by the 10V voltage source is ….**(GATE EE 2024)**

A) 100 w B) 0 C) Depends on α D) 50w



2. Sinusoidal Steady State Analysis

Q6. For the circuit shown, if i = sin(1000t), the instantaneous value of the Thevenin's equivalent voltage (in Volts) across the terminals a-b at time t = 5 ms is ____ (Round off to 2 decimal places). **(GATE EE 2023)**



Q7. A series RLC circuit has a quality factor Q of 1000 at a center frequency of 10^6 rad/s. The possible values of R, L and C are

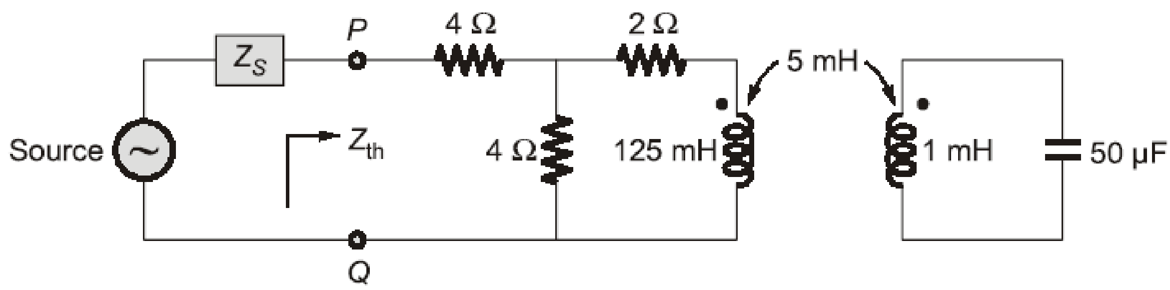
(A) R = 1 Ω, L = 1 μH and C = 1 μF

(B) R = 0.1 Ω, L = 1 μH and C = 1 μF

(C) R = 0.01 Ω, L = 1 μH and C = 1 μF

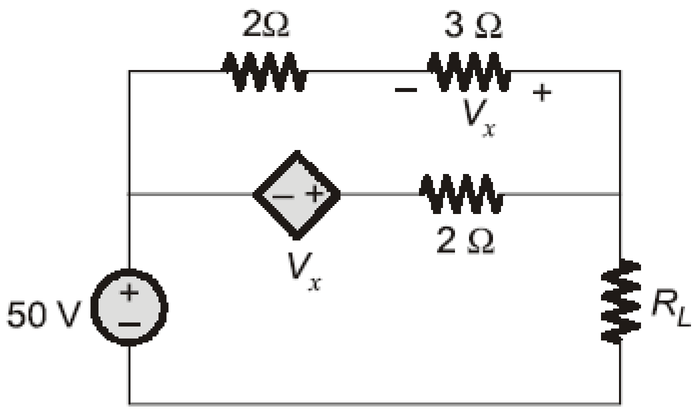
(D) R = 0.001 Ω, L = 1 μH and C = 1 μF

Q8. For the circuit shown in the figure, the source frequency is 5000 rad/sec. The mutual inductance between the magnetically coupled inductors is 5 mH with their self inductances being 125 mH and 1 mH. The Thevenin's impedance. Z_{Th}, between the terminals P and Q in Q is ___ (rounded off to 2 decimal places) . **(GATE EE 2024)**



3.Network Theorems

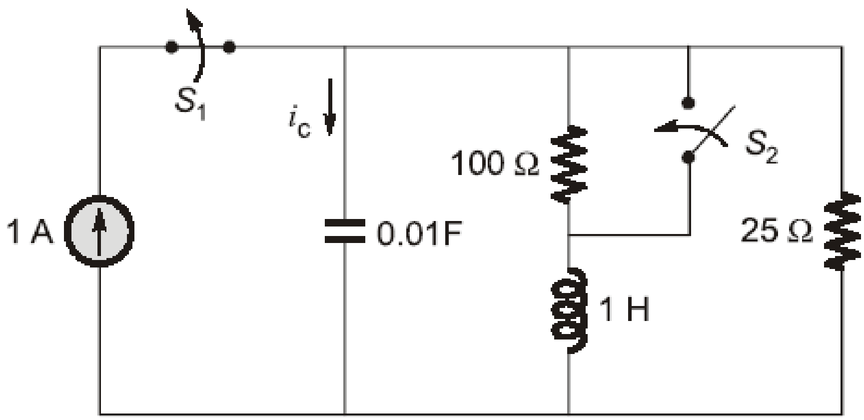
Q9. In the network shown below, What is the value of R_L in Ohms for which the power delivered to it is maximum ? **(GATE EC 2024)**



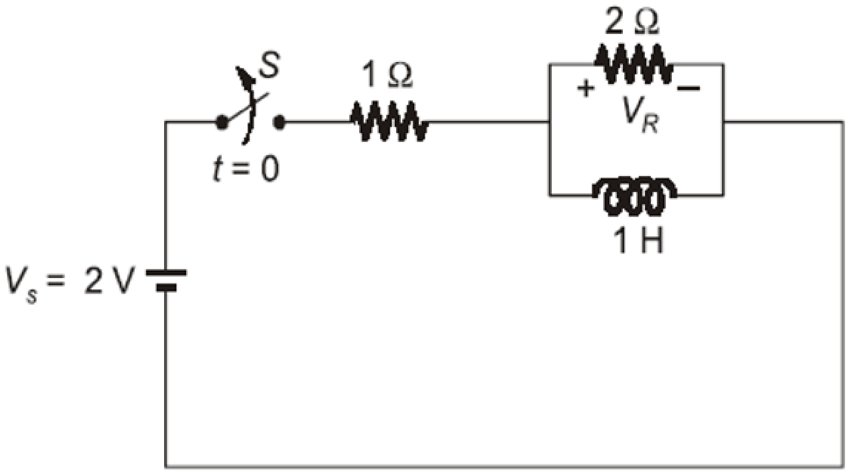
4.Transient Analysis

Q10. The switch S1 was closed and S2 was open for a long time. At t = 0, switch S1 is opened and S2 is closed, simultaneously. The value of $i_c(0+)$, in amperes, is...... **(GATE EC 2023)**

A) 1 B) -1 C) 0.2 D) 0.8



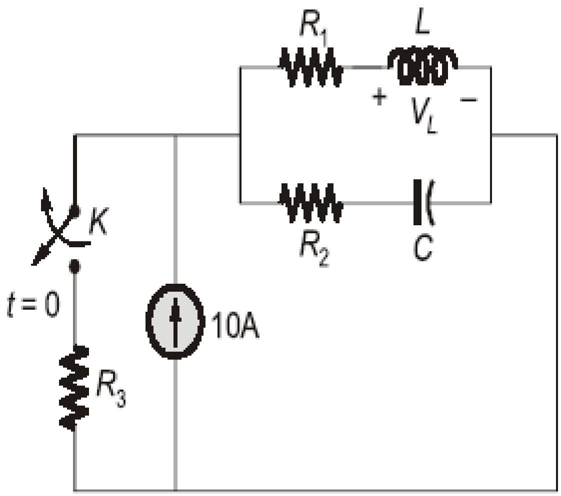
Q11. In the circuit shown below, switch S was closed for a long time. If the switch is opened at t = 0, the maximum magnitude of the voltage V_R, in volts, is ____ (rounded off to the nearest integer). **(GATE EC 2023)**



Q12. The value of parameters of the circuit shown in the figure are:

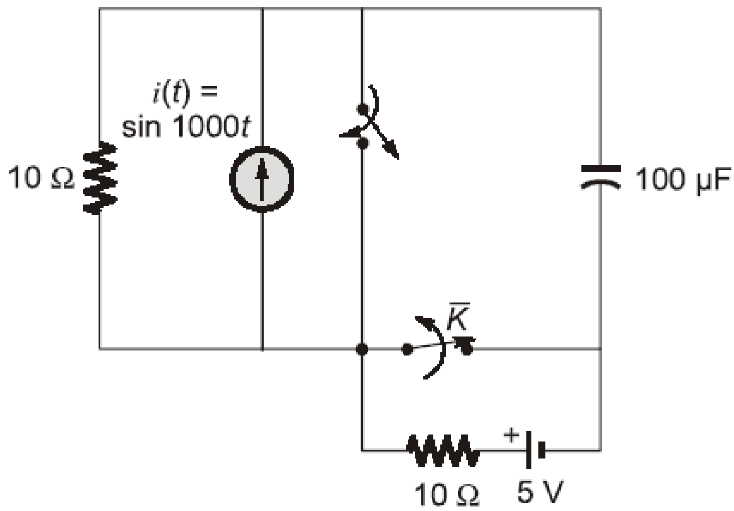
R1 = R2 = 2 ohms, R3 = 3 ohms, L = 10mH, C = 100uF

For time t < 0 the circuit is at steady state with the switch 'K' in closed condition. If the switch is opened at t = 0 the value of the voltage across the inductor V_L at t =0+ in Volts is ___________(Round off to 1 decimal place). **(GATE EE 2023)**

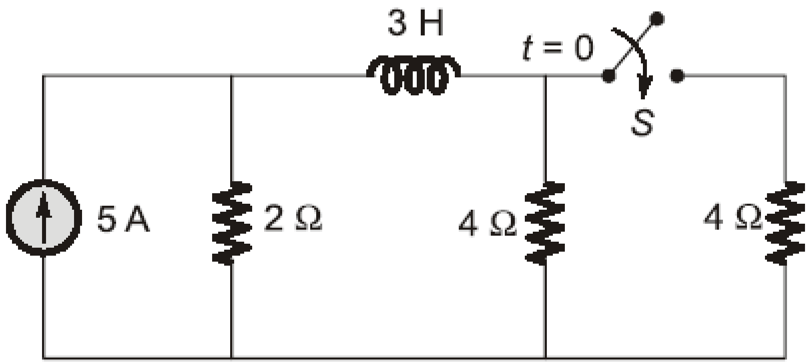


Q13. The circuit shown in the figure is initially in the steady state with the switch Kin open

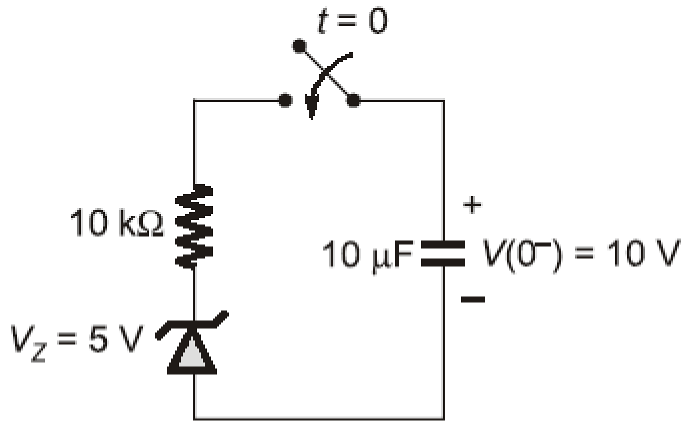
condition and R_ in closed condition. The switch K is closed and R_ is opened simultaneously at the instant t = t1 , where t1 > 0. The minimum value of t1 in milliseconds, such that there is no transient in the voltage across the 100 μF capacitor, is ____ _ (Round off to 2 decimal places). **(GATE EE 2023)**



Q14. In the circuit given below, the switch S was kept open for a sufficiently long time and is closed at time t=0. The time constant (in seconds) of the circuit for t > 0 is _________ **(GATE EC 2024)**

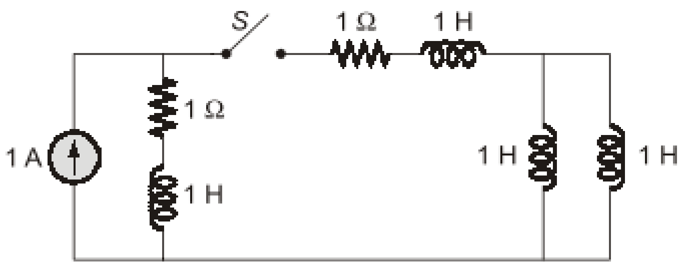


Q15. As shown in the circuit, the initial voltage across the capacitor is 10 V, with the switch being open. The switch is then closed at t = 0 The total energy dissipated in the ideal Zener diode (V_z = 5V) after the switch is closed (in mJ, rounded off to three decimal places) is_____. **(GATE EC 2024)**



Q16. The circuit shown in the figure with the switch S open, is in steady state. After the switch S is closed, the time constant of the circuit is (Sec)

(GATE EE 2024)



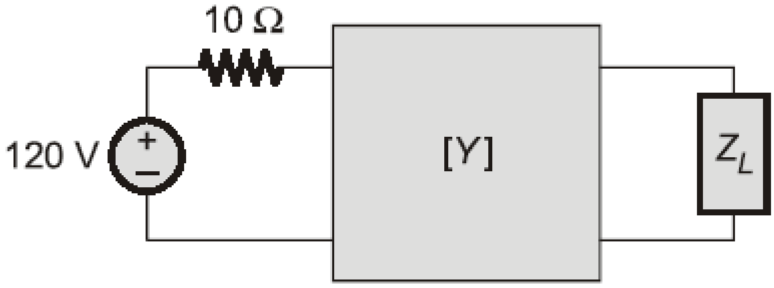
A) 1.5 B) 1.25 C) 0 D) 1

5.Two Port Networks

Q17. For the two port network shown below, the [Y]-parameters is given as

$$Y = \frac{1}{100}\begin{bmatrix} 2 & -1 \\ -1 & \frac{4}{3} \end{bmatrix}$$

The value of load impedance Z_L , in ohms, for maximum power transfer will be __ (rounded off to the nearest integer). **(GATE EC 2023)**

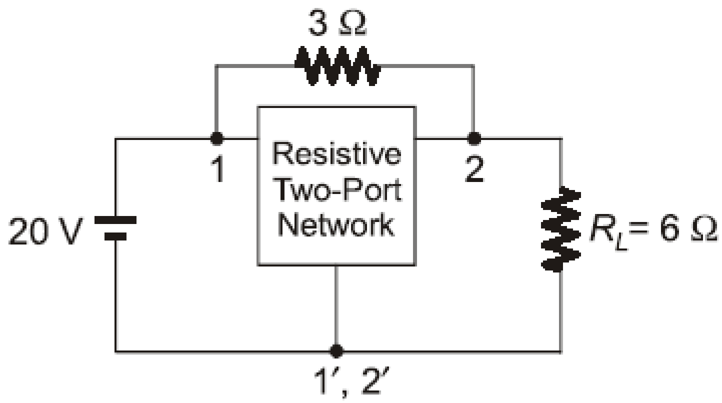


Q18. The admittance parameters of the passive resistive two-port network shown in the figure, Y_{11} = 5S, Y_{22} = 1S, Y_{12} = Y_{21} = -2.5S

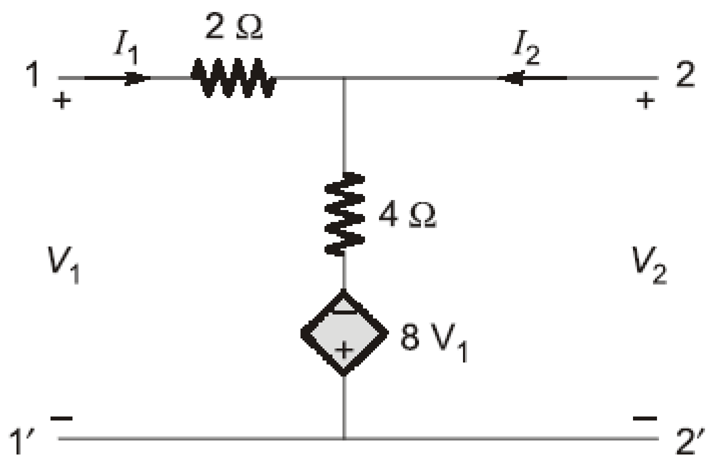
The power delivered to the load resistor R_L in Watt is ____

(Round off to 2 decimal places).

(GATE EE 2023)



Q19. For the two port network shown, the value of the Y_{21} parameter (in siemens) is ____________. **(GATE EC 2024)**

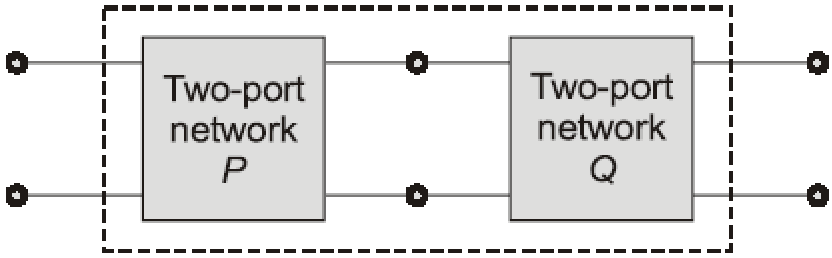


Q20. Two passive two-port network P and Q are connected as shown in the figure. The impedance matrix of network P is $Z_P = \begin{bmatrix} 40 & 60 \\ 80 & 100 \end{bmatrix} \Omega$

The admittance matrix of network Q is Y_Q =. $\begin{bmatrix} 5 & -2.5 \\ -2.5 & 1 \end{bmatrix} 1/\Omega$

Let the ABCD matrix of the two-port network R in the figure be $\begin{bmatrix} \alpha & \beta \\ \gamma & \partial \end{bmatrix} \Omega$

The value of β in Ω is ___ . (rounded off to 2 decimal places) **(GATE EE 2024)**



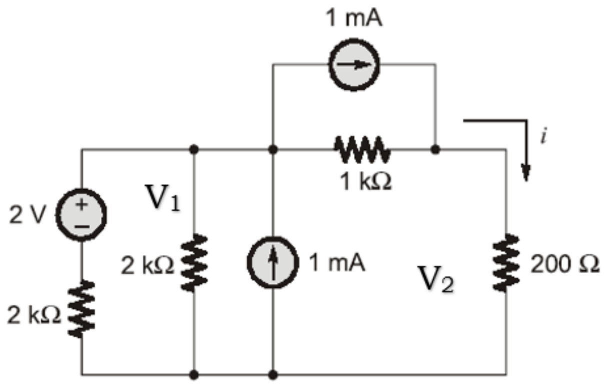
Two-port network *R*

KEY - Questions GATE 2023/2024 -EC / EE

Q1 1.36	**Q2** 6V	**Q3** 2mA	**Q4** (B)	**Q5** (B)
Q6 -12V	**Q7** (D)	**Q8** 5.33	**Q9** 2.5	**Q10** (B)
Q11 4V	**Q12** 8V	**Q13** 1.57	**Q14** 0.75	**Q15** 2.5
Q16 (B)	**Q17** 80 Ω	**Q18** 238W	**Q19** 1.5	**Q20** 19.8

Solutions – Questions GATE 2023 / 2024 – EC / EE

Q1. Let the Voltage at 2V source connected node be V_1 and across 200Ω be V_2,



$$\frac{V_1-2}{2K} + \frac{V_1}{2K} + 1mA + \frac{V_1-V_2}{1K} = 1mA.....\text{Eqn } 1$$

$$1mA + \frac{V_1-V_2}{1K} = \frac{V_2}{200} ....\text{Eqn } 2$$

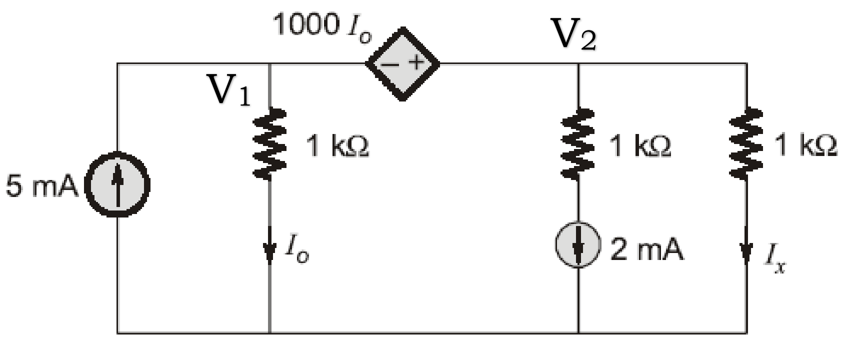
Solving these equations gives, V_2 = 0.27 Volts, V_1 = 0.63Volts

Finally I = 1.36 mA

Q2. The voltage V_1 is parallel to 0.5Ω series (3Ω parallel 3Ω)

$$Vab = \frac{1.5}{2} \text{x} 8 = 6V$$

Q3.



Consider the two unknown node voltages as V_1 and V_2,

$$\frac{V_1}{10^3} + \frac{V_2}{10^3} + 2\times10^{-3} = 5\times10^{-3}$$

$$V_1 + V_2 = 3 \quad \text{-Eqn 1}$$

At Node with V_1 voltage, $I_0 = \frac{V_1}{10^3}$

$$V_2 - V_1 = 1000 I_0 = V_1$$

$$V_2 = 2V_1 \quad \text{-Eqn 2}$$

This gives, $V_2 = 2$ V and $I_x = 2$ mA

Q4. A junction forms with a connection of at least three elements

Q5. Apply Super position theorem,

The current in the voltage source branch due to current source is

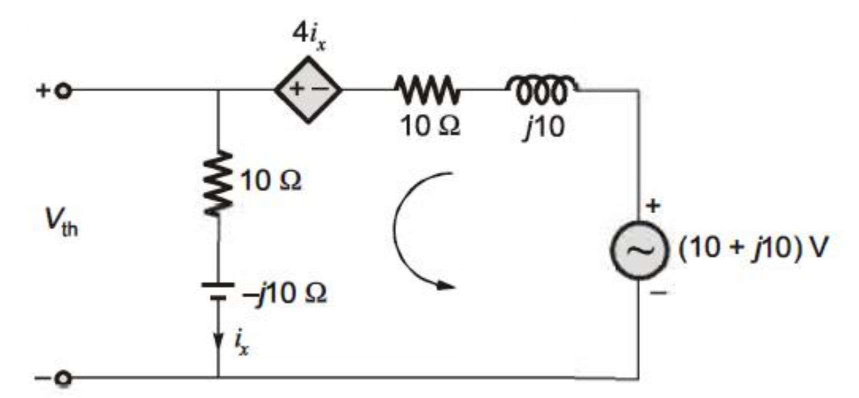
$$10 \text{ X } 1/\ (1 + \alpha)$$

The current in the voltage source without the current source is

$$10 \text{ X } 1/\ (1 + \alpha)$$

Both the directions being opposite, net current is zero.

Q6.



Applying source transformation at the current source,

Vth = (10 – j10) Ix

In the inner loop, apply KVL,

0 + j10 = (10 + j10) Ix – 4Ix + (10 - j10)Ix

Ix = (10 + j10)/16 and Vth = 12.5 V

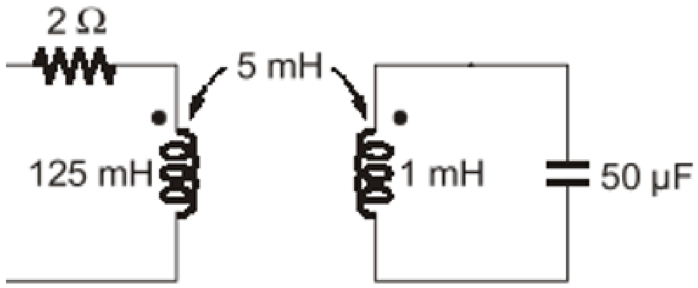
Vth in phasor form = 12.5 sin(1000t)

Vth at 5ms = -12V

Q7. $Q = \omega L/R$ $\omega = 1/\sqrt{(LC)}$

Q8. Impedance at the input of primary of coupled inductance

$$= jX_{L1} + \frac{(\omega m)^2}{jX_{L2}+Z_L}$$



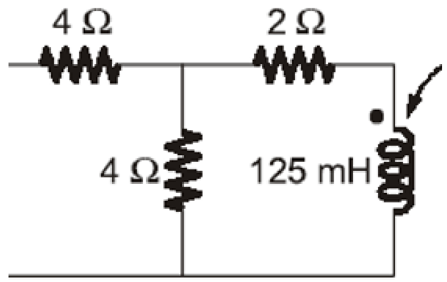
jX_{L1} = j 5000 x 125 mH = j625 Ω

jX_{L2} = j 5000 x 1 mH = j5 Ω

$Z_L = -jX_C$ = j 1/ 5000 x 50 uF = - j4 Ω

Substituting for $jX_{L1} + \frac{(\omega m)^2}{jX_{L2}+Z_L}$, This value is 0

The circuit is purely resistive with Zth = 4 + 4//2 = 5.33Ω

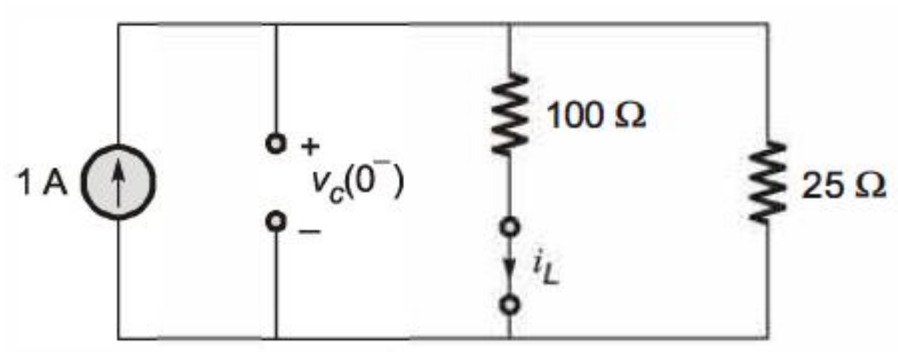


Q9. The Vx dependent source can be replaced with a 3ohm resistor as the parallel circuit has similar elements of 2Ω and Vx voltage,

The voltage source being short circuit,

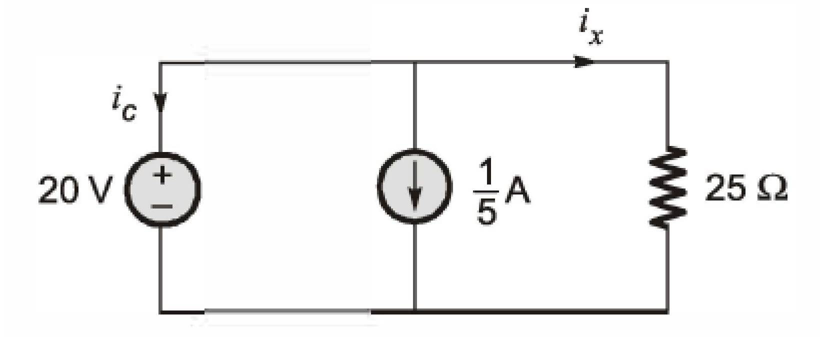
Req = Rth = 5//5 = 2.5 Ω

Q10. The circuit conditions before transients and switching is,



I_L = 0.2A and Vc = 20V

The circuit conditions just after transients and switching is,



Ix

= 20/25 = 0.8A, I_L = 0.2 A

Capacitor current is outward and discharging = -1 A

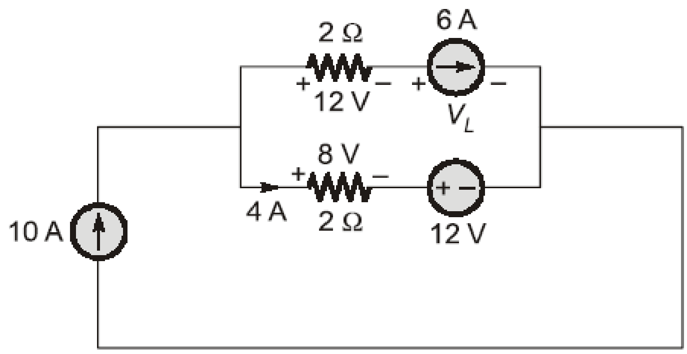
Q11. The inductor current at t=0+ is 2A

With 1Ω open circuit, current in 2Ω is 2A and V_R = 4V

Q12. As the inductor is replaces with short circuit and capacitor with open circuit, the initial condition after switching are obtained as

I_L at t = 0+ is 6A

V_C at t = 0+ is 12V



The current through the inductor being 6A, capacitor current is 4A,

$$2 \times 6 + V_L = 2 \times 4 + 12,$$

$$V_L = 8V$$

Q13. The circuit is being switched from a AC voltage to DC voltage.

If the value of AC voltage at the switching instance is equal to DC voltage, there will not be transient,

Reactance of the capacitor = -j/(1000 x 100uF) = -j10

AC voltage across capacitor = $\sin(1000t) \cdot \frac{10}{10-j10} \cdot -j10$

$= \sin(1000t)\,(5-j5) = 7.07 \sin(1000t - 45^0)$

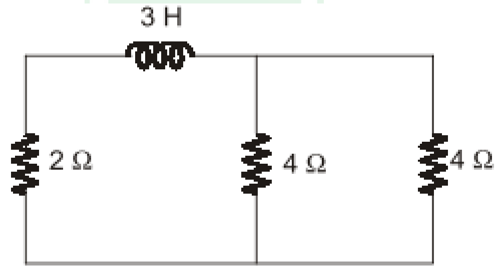
This voltage should be equal to 5 volts for zero transients,

$7.07 \sin(1000t - 45^0) = 5$,   This gives t = 1.57 milli-seconds

Q14.

Time constant = L/R,   R = 2+ 4//4 = 4ohms

L/R = 3/4 = 0.75 seconds



The equivalent circuit with current source open is show above.

Q15.

Capacitor starts discharging through 10 K resistor and zener diode Zener diode remains on till V_c becomes 5 V.

$$V(t) = 5 - (5 - 10)e^{-t_1/RC}$$

$$I(t) = C\, dV/dt = C \times 5e^{-t_1/RC} \frac{1}{RC} = 0.5\, e^{-t_1/RC}$$

Total energy dissipated in zener diode is,

$$W = \int_0^{\propto} V_z \times I(t)dt = \int_0^{\propto} 5 \times 0.5\, e^{-t_1/RC}\, dt = 0.25 \text{ mJ}$$

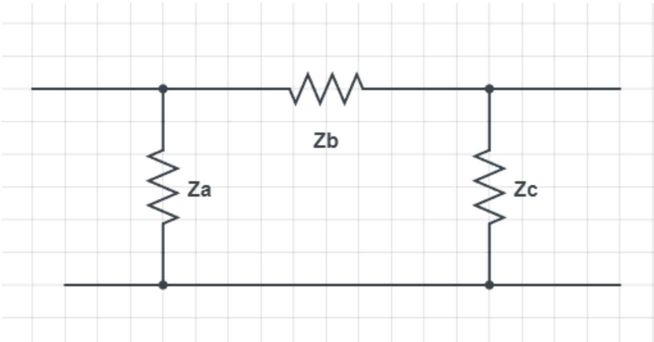
Q16.

$$L_{eq} = 1+1+(1\,||\,1) = 2.5 \text{ H}$$

$$R_{eq} = 2\ \Omega$$

$$\text{Time constant, } \tau = \frac{L_{eq}}{R_{eq}} = \frac{2.5}{2} = 1.25$$

Q17. Using the Y parameters to model the network into a Pi network



$$Y = \frac{1}{100}\begin{bmatrix} 2 & -1 \\ -1 & \frac{4}{3} \end{bmatrix}$$

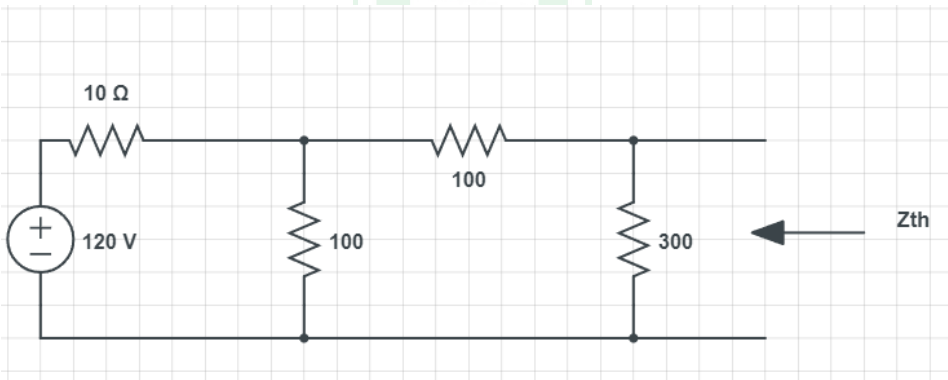
With output short circuit, input impedance = Za//Zb

With output short circuit, input admittance Y_{11} = Ya + Yb

Similarly, Y_{22} = Yb + Yc, $Y_{21} = Y_{12}$ = -Yb

This gives, Za = 100Ω, Zb = 100Ω and Zc = 300Ω

The Thevenin equivalent resistance as seen from load is,



Zth = 300 //(100 + (100//10)) = 300 // (109.1) = 80Ω

Q18. Y parameters for 3Ω resistor in series as a 2 port networks

$$Y = \begin{bmatrix} \frac{1}{3} & -\frac{1}{3} \\ -\frac{1}{3} & \frac{1}{3} \end{bmatrix}$$

$$\text{Y of the unknown 2 port network} = \begin{bmatrix} 5 & -2.5 \\ -2.5 & 1 \end{bmatrix}$$

$$\text{Y total of the combination is sum of both} = \begin{bmatrix} \frac{16}{3} & -\frac{8.5}{3} \\ -\frac{8.5}{3} & \frac{4}{3} \end{bmatrix}$$

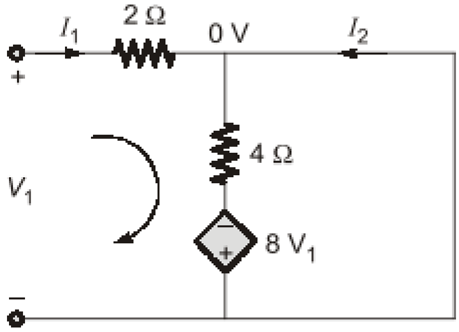
Overall Y parameters give, $I_2 = \frac{-8.5}{3} V_1 + \frac{4}{3} V_2$

With $V_2 = -I_2 R_L$ and $V_1 = 20V$

$$I_2 = \frac{-8.5}{3} \times 20 + \frac{4}{3} -I_2 6,$$

This gives $I_2 = 6.3A$, Power to load = 6.3 x 6.3 x 6= 238Watts

Q19.



$$V_1 = 2I_1 + 4(I_1 + I_2) - 8V_1 = 0$$

$$\text{But } I_1 = \frac{V_1}{2}$$

$$6V_1 = 4I_2$$
$$Y_{21} = 1.5 \text{ S}$$

Q20. Converting both the network parameters into Z parameters

For the P network, from it's Z parameters

$$\begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} = \begin{bmatrix} 0.5 & -10 \\ \frac{1}{80} & \frac{5}{4} \end{bmatrix}$$

For the Q network, from it's Y parameters

$$\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} = \begin{bmatrix} 0.4 & 0.4 \\ -0.5 & 2 \end{bmatrix}$$

The overall Transmission parameters are

$$T = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} * \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix}$$

The parameter $\beta = 0.5 \times 0.4 + (-10) \times 2 = -19.8\ \Omega$