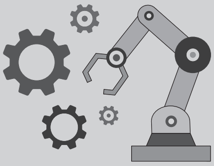
30 Years
Previous Solved Papers

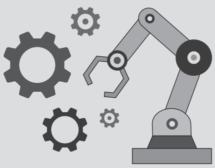
GATE 2025

Instrumentation Engineering



- Fully solved with explanations
- Analysis of previous papers
- Topicwise presentation
- Thoroughly revised & updated

MADE EASY PUBLICATIONS



Editions

1st Edition	:	2011
2nd Edition	:	2012
3rd Edition	:	2013
4th Edition	:	2014
5th Edition	:	2015
6th Edition	:	2016
7th Edition	:	2017
8th Edition	:	2018
9th Edition	:	2019
10th Edition	:	2020
11th Edition	:	2021
12th Edition	:	2022
13th Edition	:	2023
14th Edition	**:**	**2024**

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GATE - 2025

Instrumentation Engineering

Topicwise Previous GATE Solved Papers (1995-2024)

Preface

Over the period of time the GATE examination has become more challenging due to increasing number of candidates. Though every candidate has ability to succeed but competitive environment, in-depth knowledge, quality guidance and good source of study is required to achieve high level goals.

The new edition of **GATE 2025 Solved Papers : Instrumentation Engineering** has been fully revised, updated and edited. The whole book has been divided into topicwise sections.

At the beginning of each subject, analysis of previous papers are given to improve the understanding of subject.

I have true desire to serve student community by way of providing good source of study and quality guidance. I hope this book will be proved an important tool to succeed in GATE examination. Any suggestions from the readers for the improvement of this book are most welcome.

B. Singh (Ex. IES)
Chairman and Managing Director
MADE EASY Group

GATE-2025

Instrumentation Engineering

CONTENTS

Electrical Circuits & Electrical Machines

UNIT

II

CONTENTS

Electrical Circuits & Electrical Machines

Syllabus

Voltage and current sources : independent, dependent, ideal and practical; v-i relationships of resistor, inductor, mutual inductance and capacitor; transient analysis of RLC circuits with dc excitation.

Kirchhoff's laws, mesh and nodal analysis, superposition, Thevenin, Norton, maximum power transfer and reciprocity theorems.

Peak-, average- and rms values of ac quantities; apparent-, active- and reactive powers; phasor analysis, impedance and admittance; series and parallel resonance, locus diagrams, realization of basic filters with R, L and C elements. transient analysis of RLC circuits with ac excitation.

One-port and two-port networks, driving point impedance and admittance, open-, and short circuit parameters.

Single phase transformer : equivalent circuit, phasor diagram, open circuit and short circuit tests, regulation and efficiency; Three phase induction motors: principle of operation, types, performance, torque-speed characteristics, no-load and blocked rotor tests, equivalent circuit, starting and speed control; Types of losses and efficiency calculations of electric machines.

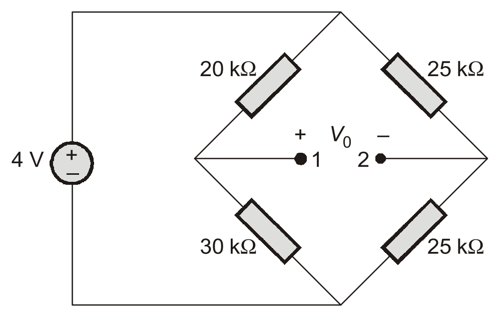
Analysis of Previous GATE Papers

Exam Year	1 Mark Ques.	2 Marks Ques.	Total Marks
1995	–	–	–
1996	–	–	–
1997	–	–	–
1998	1	–	**1**
1999	–	–	–
2000	–	–	–
2001	–	–	–
2002	–	1	**2**
2003	–	1	**2**
2004	–	–	–
2005	–	2	**4**
2006	1	4	**9**
2007	2	4	**10**
2008	2	7	**16**
2009	–	2	**4**

Exam Year	1 Mark Ques.	2 Marks Ques.	Total Marks
2010	2	2	**6**
2011	2	2	**6**
2012	4	6	**16**
2013	3	5	**13**
2014	3	4	**11**
2015	3	4	**11**
2016	3	3	**9**
2017	3	4	**11**
2018	3	4	**11**
2019	5	2	**9**
2020	2	3	**8**
2021	1	5	**11**
2022	2	4	**10**
2023	2	5	**12**
2024	3	4	**11**

1 Network Laws and Network Theorems

1.1 The output resistance across the terminals 1 and 2 of the DC bridge in figure is



(a) 12.5 kΩ (b) 24.5 kΩ
(c) 25.0 kΩ (d) 100 kΩ

[2003 : 2 M]

1.2 The root-mean-square value of a voltage waveform consisting of a superimposition of 2 V dc and a 4 V peak-to-peak square wave is

(a) 2 V (b) $\sqrt{6}$ V
(c) $\sqrt{8}$ V (d) $\sqrt{12}$ V

[2006 : 1 M]

1.3 A metal wire has a uniform cross-section A, length l, and resistance R between its two end points. It is uniformly stretched so that its length becomes αl. The new resistance is

(a) αR (b) $\alpha^2 R$
(c) $\sqrt{\alpha} R$ (d) $e^{\alpha} R$

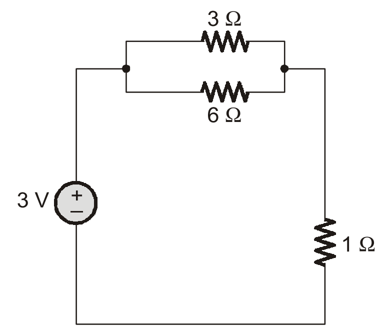
[2006 : 2 M]

1.4 In full sunlight, a solar cell has a short circuit current of 75 mA and a current of 70 mA for a terminal voltage of 0.6 V with a given load. The Thevenin resistance of the solar cell is

(a) 8 Ω (b) 8.6 Ω
(c) 120 Ω (d) 240 Ω

[2007 : 1 M]

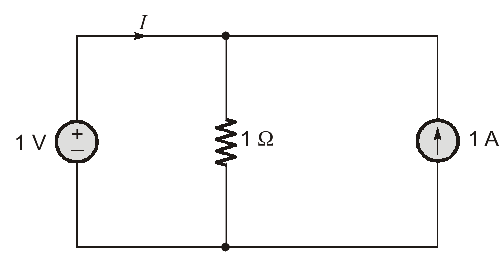
1.5 The power supplied by the dc voltage source in the circuit shown below is



(a) 0 W (b) 1.0 W
(c) 2.5 W (d) 3.0 W

[2008 : 1 M]

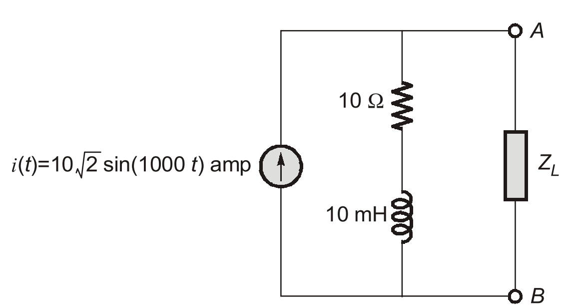
1.6 The current I supplied by the dc voltage source in the circuit shown below is



(a) 0 A (b) 0.5 A
(c) 1 A (d) 2 A

[2008 : 1 M]

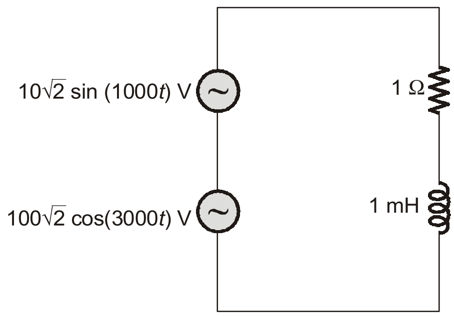
1.7 In the circuit shown below the maximum power that can be transferred to the load Z_L is



(a) 250 W (b) 500 W
(c) 1000 W (d) 2000 W

[2008 : 2 M]

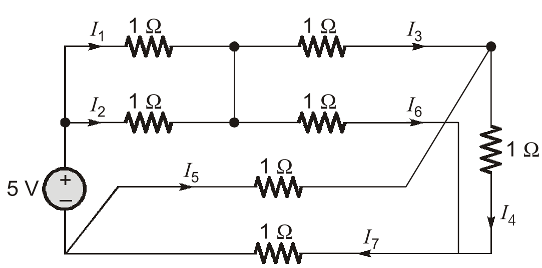
1.8 In the circuit shown below the average power consumed by the 1 Ω resistor is



(a) 50 W (b) 1050 W
(c) 5000 W (d) 10100 W

[2008 : 2 M]

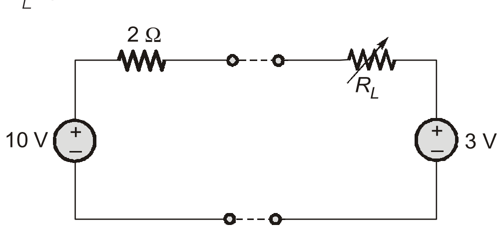
1.9 Which one of the following equations is valid for the circuit shown below?



(a) $I_3 + I_5 - I_6 + I_7 = 0$
(b) $I_3 - I_5 + I_6 + I_7 = 0$
(c) $I_3 + I_5 + I_6 + I_7 = 0$
(d) $I_3 + I_5 + I_6 - I_7 = 0$

[2008 : 2 M]

1.10 The source network S is connected to the load network L as shown by dashed lines. The power transferred from S to L would be maximum when R_L is



(a) 0 Ω (b) 0.6 Ω
(c) 0.8 Ω (d) 2 Ω

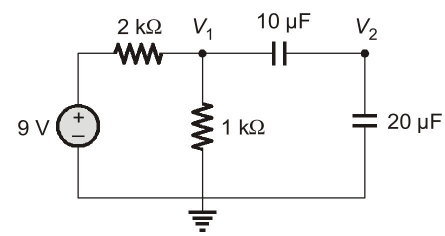
[2009 : 2 M]

1.11 The root mean squared value of $x(t) = 3 + 2\sin(t)\cos(2t)$ is

(a) $\sqrt{3}$ (b) $\sqrt{8}$
(c) $\sqrt{10}$ (d) $\sqrt{11}$

[2009 : 2 M]

1.12 In the dc circuit shown in the adjoining figure, the node voltage V_2 at steady state is



(a) 0 V (b) 1 V
(c) 2 V (d) 3 V

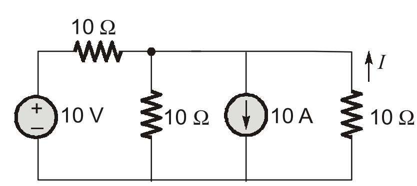
[2010 : 1 M]

1.13 A 100 W, 1 Ω resistor and a 800 W, 2 Ω resistor are connected in series. The maximum dc voltage that can be applied continuously to the series circuit without exceeding the power limit of any of the resistor is

(a) 90 V (b) 0 V
(c) 45 V (d) 40 V

[2010 : 1 M]

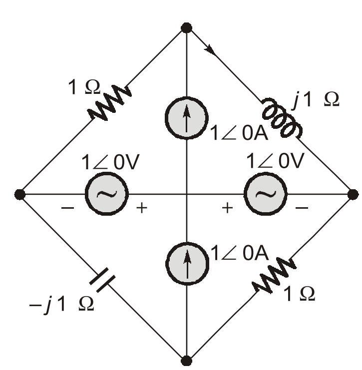
1.14 The current I shown in the circuit given below is equal to



(a) 3A (b) 3.67 A
(c) 6 A (d) 9 A

[2011 : 1 M]

1.15 In the circuit shown below, the current through the inductor is

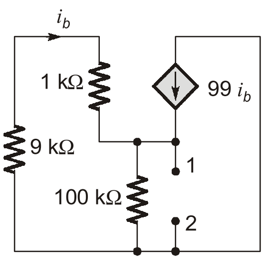


(a) $\frac{2}{1+j}A$ (b) $\frac{-1}{1+j}A$

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

[2012 : 1 M]

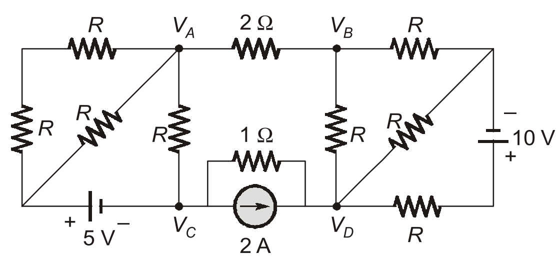
1.16 The impedance looking into nodes 1 and 2 in the given circuit is



(a) 50 Ω (b) 100 Ω
(c) 5 kΩ (d) 10.1 kΩ

[2012 : 1 M]

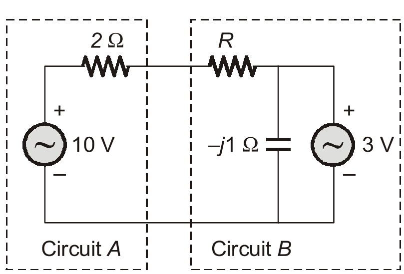
1.17 If $V_A - V_B = 6$ V, then $V_C - V_D$ is



(a) –5 V (b) 2 V
(c) 3 V (d) 6 V

[2012 : 2 M]

1.18 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

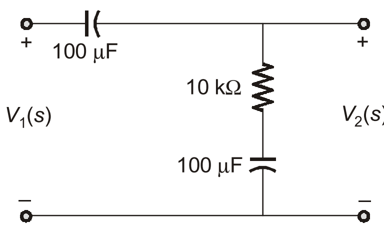
[2012 : 2 M]

1.19 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

[2013 : 1 M]

1.20 The transfer function $V_2(s)/V_1(s)$ of the circuit shown below is

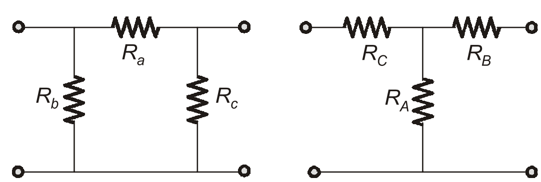


(a) $\frac{0.5s+1}{s+1}$ (b) $\frac{3s+6}{s+2}$

(c) $\frac{s+2}{s+1}$ (d) $\frac{s+1}{s+2}$

[2013 : 1 M]

1.21 Consider a delta connection of resistors and its equivalent star connection as shown. 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

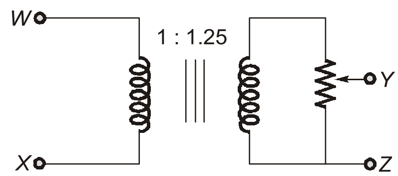


(a) k^2 (b) k

(c) $1/k$ (d) $\sqrt{k}$

[2013 : 1 M]

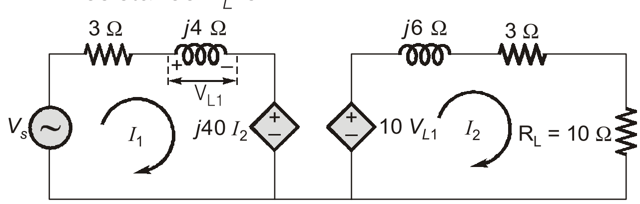
1.22 The following arrangement consists of an ideal transformer and an attenuator, which attenuates by a factor of 0.8. An ac voltage V_{WX1} = 100 V is applied across WX to get an open circuit voltage V_{YZ1} across YZ Next, an ac voltage Y_{YZ2} = 100 V is applied across YZ to get an open circuit voltage 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 $\frac{100}{100}$ (d) $\frac{80}{100}$ and $\frac{80}{100}$

[2013 : 2 M]

1.23 In the circuit shown below, if the source voltage $V_S = 100\angle 53.13°$ Volts, 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) $100\angle 60°$

[2013 : 2 M]

1.24 Time domain expressions for the voltage $v_1(t)$ and $v_2(t)$ are given as

$v_1(t) = V_m \sin(10t - 130°)$

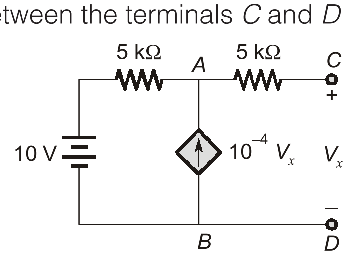
and $v_2(t) = V_m \cos(10t + 10°)$.

Which one of the following statements is TRUE?

(a) $v_1(t)$ leads $v_2(t)$ by 130°
(b) $v_1(t)$ lags $v_2(t)$ by 130°
(c) $v_1(t)$ lags $v_2(t)$ by –130°
(d) $v_1(t)$ leads $v_2(t)$ by –130°

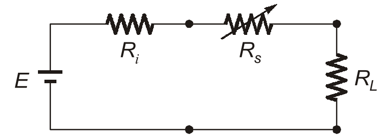
[2014 : 1 M]

1.25 The circuit shown in the figure contains a dependent current source between A and B terminals. The Thevenin's equivalent resistance in kΩ between the terminals C and D is _______.



[2014 : 2 M]

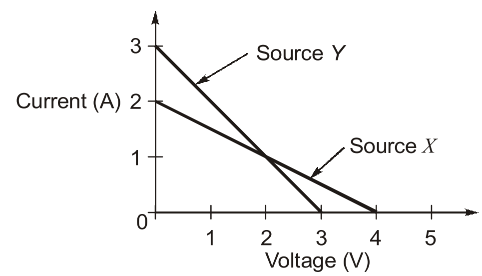
1.26 A load resistor R_L is connected to a battery of voltage E with internal resistance R_i through a resistance R_s as shown in the figure. For fixed values of R_L and R_i, the value of $R_s(\geq 0)$ for maximum power transfer to R_L is

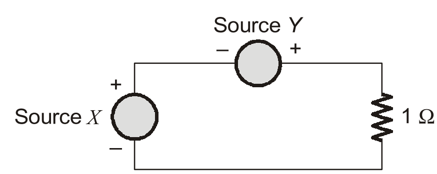


(a) 0 (b) $R_L - R_i$
(c) R_L (d) $R_L + R_i$

[2015 : 1 M]

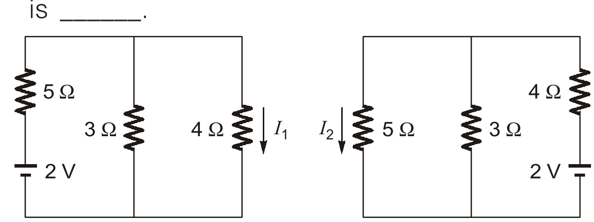
1.27 The linear I-V characteristic of 2-terminal non-ideal DC sources X and Y are shown in the figure. If the sources are connected to a 1 Ω resistor as shown, the current through the resistor in amperes is _____ A.





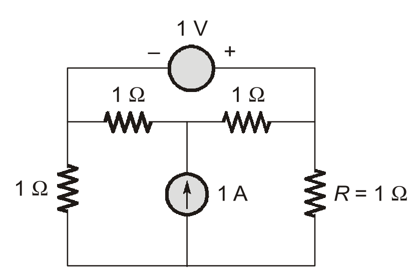
[2015 : 2 M]

1.28 Consider the circuits shown in the figure. The magnitude of the ratio of the currents, i.e. $|I_1/I_2|$, is ______.



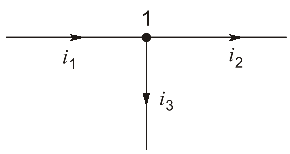
[2015 : 2 M]

1.29 The current in amperes through the resistor R in the circuit shown in the figure is ____ A.



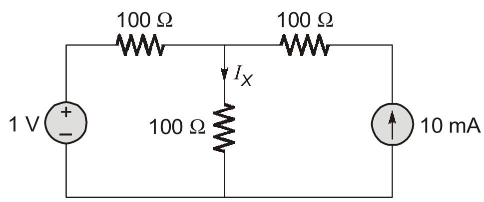
[2015 : 2 M]

1.30 Three currents i_1, i_2 and i_3 meet at a node as shown in the figure below. If i_1 = 3 cos (ωt) ampere, i_2 = 4 sin (ωt) ampere and $i_3 = I_3 \cos(\omega t + \theta)$ ampere, the value of I_3 in ampere is______.



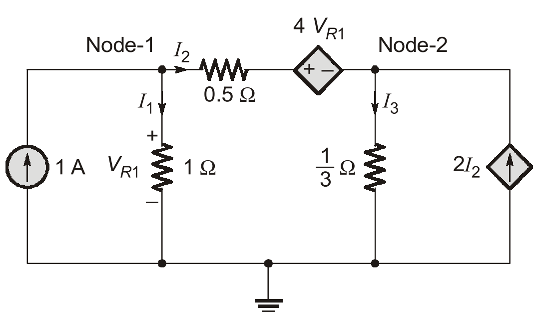
[2016 : 1 M]

1.31 The current I_X in the circuit given below in milliampere is_______.



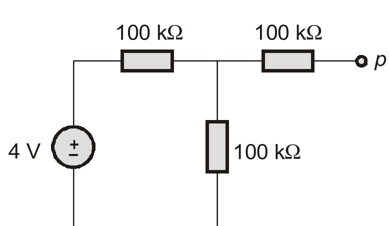
[2016 : 2 M]

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



[2017 : 1 M]

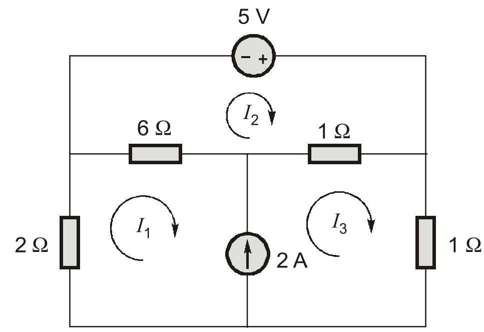
1.33 The Thevenin equivalent circuit representation across terminals p-q of the circuit shown in the figure is a



(a) 1 V source in series with 150 kΩ
(b) 1 V source in parallel with 100 kΩ
(c) 2 V source in series with 150 kΩ
(d) 2 V source in parallel with 200 kΩ

[2018 : 1 M]

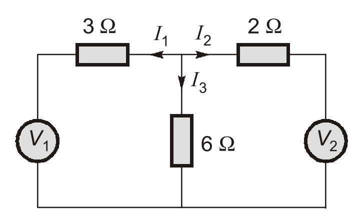
1.34 In the given circuit the mesh current I_1, I_2 and I_3 are



(a) I_1 = 1 A, I_2 = 2 A and I_3 = 3 A
(b) I_1 = 2 A, I_2 = 3 A and I_3 = 4 A
(c) I_1 = 3 A, I_2 = 4 A and I_3 = 5 A
(d) I_1 = 4 A, I_2 = 5 A and I_3 = 6 A

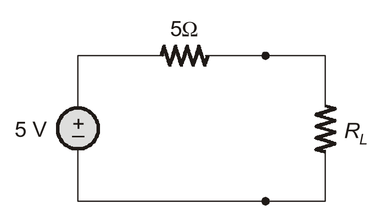
[2018 : 2 M]

1.35 In the given circuit, superposition is applied. When V_2 is set to 0 V, the current I_2 is –6 A. When V_1 is set to 0 V, the current I_1 is +6 A. Current I_3 (in A) when both sources are applied will be (up to two decimal places) ________.



[2018 : 2 M]

1.36 In the circuit shown below, maximum power is transferred to the load resistance R_L, when R_L = ___________Ω.



[2019 : 1 M]

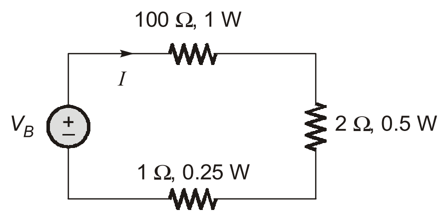
1.37 Consider a circuit comprising only resistors with constant resistance and ideal independent DC voltage sources. If all the resistances are scaled down by a factor 10, and all source voltages are scaled up by a factor 10, the power dissipated in the circuit scales up by a factor of________.

[2019 : 1 M]

1.38 Three 400 Ω resistors are connected in delta and powered by a 400 V (rms), 50 Hz, balanced, symmetrical *R-Y-B* sequence, three-phase three-wire mains. The rms value of the line current (in amperes, rounded off to one decimal place) is _____.

[2020 : 1 M]

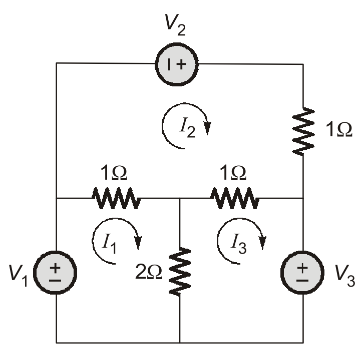
1.39 In the circuit shown below, the safe maximum value for the current I is _____.



(a) 0.5 A (b) 0.1 A
(c) 1.0 A (d) 0.05 A

[2020 : 1 M]

1.40 I_1, I_2 and I_3 in the figure below are mesh currents. The correct set of mesh equations for these currents, in matrix form, is _____.



(a) $\begin{bmatrix} 1 & -1 & -2 \\ -1 & 2 & -1 \\ -2 & -1 & 3 \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$

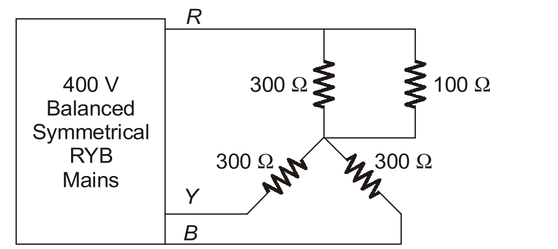
(b) $\begin{bmatrix} -3 & -1 & -2 \\ -1 & 3 & -1 \\ -2 & -1 & 3 \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ -V_3 \end{bmatrix}$

(c) $\begin{bmatrix} 3 & -1 & -2 \\ -1 & 3 & -1 \\ -2 & -1 & 3 \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ -V_3 \end{bmatrix}$

(d) $\begin{bmatrix} 3 & -1 & -2 \\ -1 & 3 & -1 \\ -2 & -1 & -3 \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$

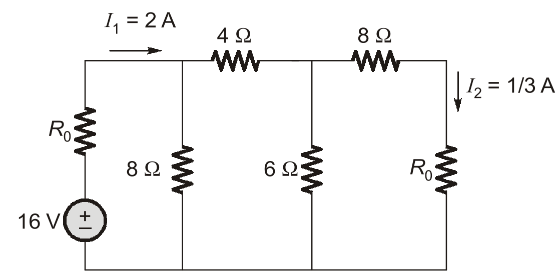
[2020 : 2 M]

1.41 In the circuit shown, the rms value of the voltage across the 100 Ω, resistor (in volts) _____.

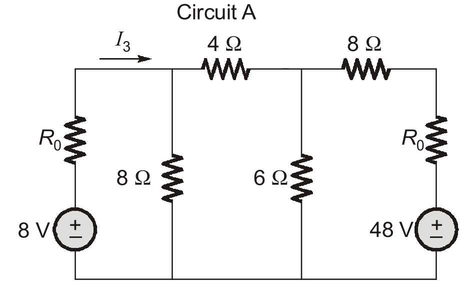


[2020 : 2 M]

1.42 Given Circuit *A* with currents I_1 and I_2 as shown, the current I_3 in Circuit B (in amperes), is ________(round off to one decimal place)



Circuit A



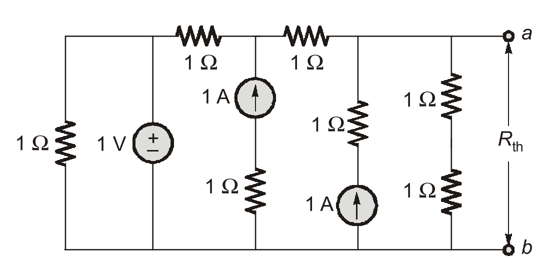
Circuit B

[2022 : 2 M]

1.43 A 1 kHz sine-wave generator having an internal resistance of 50 Ω generates an open-circuit voltage of 10 $V_{p\text{-}p}$. When a capacitor is connected across the output terminals, the voltage drops to 8 $V_{p\text{-}p}$. The capacitance of the capacitor (in microfarads) is _______ (round off to two decimal places)

[2022 : 2 M]

1.44 In the circuit given, the Thevenin equivalent resistance R_{th} across the terminals '*a*' and '*b*' is ________ Ω (rounded off to one decimal place).



[2023 : 1 M]

1.45 The voltage applied and the current drawn by a circuit are

$v(t) = 95 + 200\cos(120\pi t) + 90\cos(360\pi t - 60°)$V

$i(t) = 4\cos(120\pi t - 60°) + 1.5\cos(240\pi t - 75°)$A

The average power absorbed by the circuit is ________W (rounded off to nearest integer).

[2024 : 1 M]

1.46 The current $i(t)$ drawn by a circuit is given as

$i(t) = 4 + 30\cos(t) - 20\sin(t) + 15\cos(3t) - 10\sin(3t)$ A

The root-mean-square value of $i(t)$ is ________ A (rounded off to one decimal place).

[2024 : 1 M]

Answers Network Laws & Network Theorems

1.1 (b)	1.2 (c)	1.3 (b)	1.4 (c)	1.5 (d)	1.6 (a)	1.7 (b)
1.8 (b)	1.9 (d)	1.10 (c)	1.11 (c)	1.12 (b)	1.13 (c)	1.14 (a)
1.15 (c)	1.16 (a)	1.17 (a)	1.18 (a)	1.19 (c)	1.20 (d)	1.21 (b)
1.22 (b)	1.23 (c)	1.24 (a)	1.25 (20)	1.26 (a)	1.27 (1.75)	1.28 (1)
1.29 (1)	1.30 (5)	1.31 (10)	1.32 (2)	1.33 (c)	1.34 (a)	1.35 (1)
1.36 (5)	1.37 (1000)	1.38 (1.7)	1.39 (b)	1.40 (c)	1.41 (115.47)	1.42 (0.0)
1.43 (2.39)	1.44 (1)	1.45 (200)	1.46 (28.78)			

Explanations Network Laws & Network Theorems

1.1 (b)

We can find the Thevenin resistance between terminals 1 and 2, by short circuiting the battery of 4 V.

$$R_{12} = 30||20 + 25||25$$

$$= \frac{30\times20}{30+20} + \frac{25\times25}{25+25} = \frac{600}{50} + \frac{625}{50}$$

$$= 12 + 12.5 = 24.5\text{ k}\Omega$$

1.2 (c)

Given function,

$$y(t) = \begin{cases} 2+a & ; \quad 0 < t < \frac{T}{2} \\ 2-a & ; \quad \frac{T}{2} < t < T \end{cases}$$

here T is the period of square wave and a is peak value of square wave.

Given, $a = 2$

$$\therefore \quad y(t) = \begin{cases} 4 & ; \quad 0 < t < \frac{T}{2} \\ 0 & ; \quad \frac{T}{2} < t < T \end{cases}$$

RMS value of any periodic function $y(t)$

$$= \sqrt{\frac{1}{T}\int_0^T y^2(t)\,dt}$$

$$\therefore \quad y_{rms} = \sqrt{\frac{1}{T}\left[\int_0^{T/2}(4)^2dt + \int_{T/2}^{T}(0)^2\,dt\right]}$$

$$= \sqrt{\frac{1}{T}\cdot16\cdot\frac{T}{2}} = \sqrt{8}\text{ V}$$

1.3 (b)

We know, $R = \rho\frac{l}{A}$

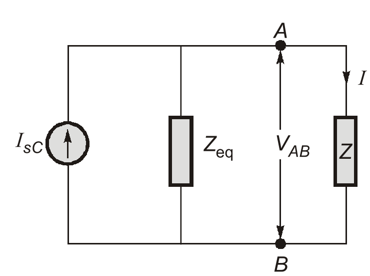
as ρ is the property of the material, so it will be constant for same material.

For constant volume

$$R = kl^2$$

$$\therefore \quad R' = k(\alpha l)^2 = \alpha^2\cdot(kl)^2 = \alpha^2R$$

1.4 (c)



Let the given load is Z.

Then the current,

$$I = \frac{Z_{eq.}}{Z+Z_{eq}}\times I_{SC} \qquad ...(i)$$

Given, $I = 70$ mA, $I_{SC} = 75$ mA, $V_{AB} = 0.6$ V

From equation (i),

$$70 = \frac{Z_{eq.}}{Z + Z_{eq}} \times 75$$

$$\Rightarrow \quad \frac{75}{70} = 1 + \frac{Z}{Z_{eq.}}$$

$$\Rightarrow \quad \boxed{Z_{eq} = 14 \times Z}$$

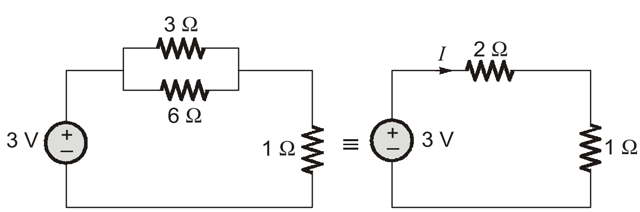
and $\quad V_{AB} = Z \times I$

$$0.6 = Z \times 70 \times 10^{-3}$$

$$\Rightarrow \quad Z = \frac{600}{70}$$

$$\therefore \quad Z_{eq} = 14 \times \frac{600}{70} = 120\ \Omega$$

1.5 (d)



Current I in the circuit

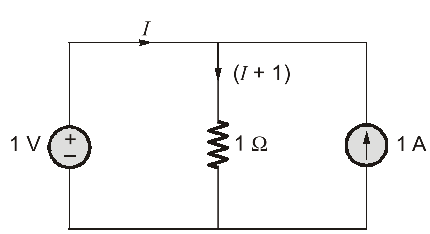
$$I = \frac{3}{2+1} = 1\text{ A}$$

$\because$ Power supplied by the d.c. voltage source = Power absorbed by the load.

$\therefore$ Power supplied $= I^2 \cdot R_{eq}$

$$= I^2 \times 3 = 3.0\text{ W}$$

1.6 (a)



By applying KVL in 1st loop

$$1 = I + 1$$

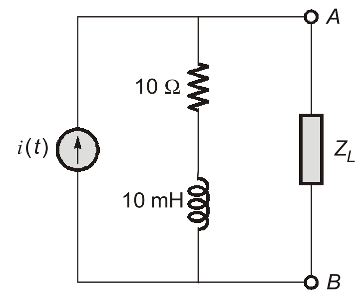
$$I = 0\text{ A}$$

1.7 (b)

$$i(t) = 10\sqrt{2}\sin(1000t)\,A$$

$$\omega = 1000$$

$$\therefore \quad j\omega L = j10^3 \times 10 \times 10^{-3} = j10\ \Omega$$



Thevenin resistance across AB

$$Z_{Th} = (10 + j10)$$

For maximum power transfer

Load impedance $= Z_{Th}^*$

$$\Rightarrow \quad Z_L = (10 - j10)$$

r.m.s value of source current

$$I_{rms} = \frac{10\sqrt{2}}{\sqrt{2}} = 10\text{ A}$$

$\therefore$ Current in branch AB (or load current)

$$I_L = \frac{Z_{Th}}{Z_{Th} + Z_L} \times I_{rms}$$

$$= \frac{(10 + j10)}{(10 + j10 + 10 - j10)} \times 10$$

$$I_L = \frac{10 + j10}{20} \times 10 = (5 + j5)$$

$$I_L = 5\sqrt{2}\angle 45°\text{A}$$

Only resistive part of load impedance is responsible for power loss.

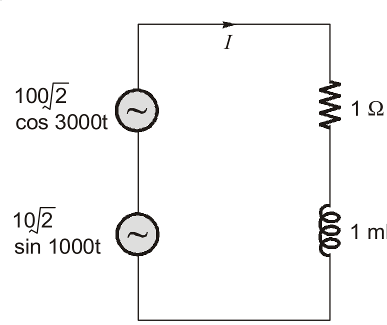
$\therefore$ Power transferred to load

$$= |I_L|^2 \cdot \text{Real part of } Z_L$$

$$= (5\sqrt{2})^2 \times 10 = 50 \times 10$$

$$= 500\text{ W}$$

1.8 (b)



Current,

$$I = \frac{100\sqrt{2}\cos 3000t}{1 + j\omega_1 L} + \frac{10\sqrt{2}\sin 1000t}{1 + j\omega_2 L}$$

$$I = \frac{100\sqrt{2}\cos 3000t}{1 + j\times 3000\times 10^{-3}} + \frac{10\sqrt{2}\sin 1000t}{1 + j\times 1000\times 10^{-3}}$$

$$= \frac{100\sqrt{2}\cos 3000t}{1 + j3} + \frac{10\sqrt{2}\sin 1000t}{1 + j1}$$

$$= \frac{100\sqrt{2}\cos 3000t}{\sqrt{10}\,\angle\phi_1} + \frac{10\sin(1000t)\times\sqrt{2}}{\sqrt{2}\,\angle\phi_1}$$

where,

$$\phi_1 = \tan^{-1}(3) \text{ and } \phi_2 = \tan^{-1}(1)$$

So, $I = \frac{100\sqrt{2}}{\sqrt{10}}\cos(3000t - \phi_1) + \frac{10\sin(1000t)\times\sqrt{2}}{\sqrt{2}\,\angle\phi_2}$

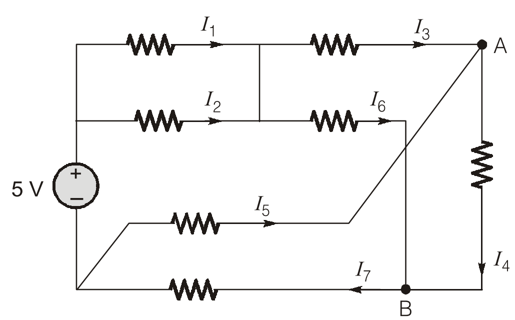
$\Rightarrow$ So, RMS of I is

$$I_{rms} = \sqrt{\frac{1}{2}\left[\frac{10000\times 2}{10} + 100\right]} = \sqrt{1050}$$

So, power dissipated is

$$P = I_{rms}^2 \times R = 1050 \times 1 = 1050 \text{ Watt}$$

1.9 (d)



By applying KCL at node A,

$$I_3 + I_5 = I_4 \quad \text{...(i)}$$

and at node B,

$$I_4 + I_6 = I_7$$

$$\Rightarrow \quad I_4 = I_7 - I_6 \quad \text{...(ii)}$$

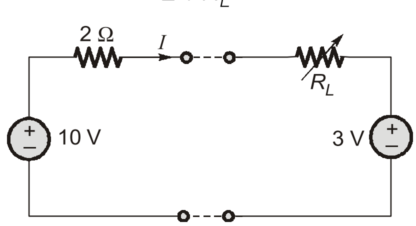
From equation (i) and (ii)

$$I_3 + I_5 = I_7 - I_6$$

$$I_3 + I_5 + I_6 - I_7 = 0$$

1.10 (c)

$$\text{Current, } I = \frac{7}{2 + R_L}$$



Power transferred to load,

$$= \left(\frac{7}{2+R_L}\right)^2 R_L + 3\times\frac{7}{2+R_L}$$

$$= \frac{49R_L}{(2+R_L)^2} + \frac{21}{(2+R_L)}$$

$$= \frac{49R_L + 21R_L + 42}{(2+R_L)^2}$$

$$= \frac{70R_L + 42}{(2+R_L)^2} = \frac{14(5R_L + 3)}{(2+R_L)^2}$$

For maximum power transfer

$$\frac{dP}{dR_L} = 0$$

$\Rightarrow (R_L + 2)^2 \times 5 - (5R_L + 3) \times 2(R_L + 2) = 0$

$\Rightarrow 5R^2_L + 20R_L + 20 - 2(5R^2_L + 13R_L + 6) = 0$

$\Rightarrow \quad -5R^2_L - 6R_L + 8 = 0$

$\Rightarrow \quad 5R^2_L + 6R_L - 8 = 0$

$\Rightarrow \quad R_L = 0.8 \text{ and } -2$

Hence, $\quad R_L = 0.8\ \Omega$

1.11 (c)

$$x(t) = 3 + 2\sin t\cdot\cos 2t$$
$$= 3 + \sin 3t - \sin t$$

If $\quad y(t) = a_0 + (a_1\cos\omega t + a_2\cos 2\omega t + ...) + (b_1\sin\omega t + b_2\sin 2\omega t + ...)$

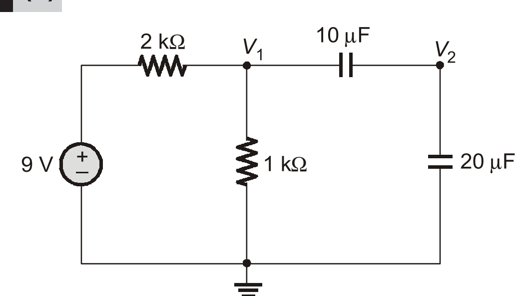
then,

$$y_{rms} = \sqrt{a_0^2 + \frac{1}{2}(a_1^2 + a_2^2 + ...) + \frac{1}{2}(b_1^2 + b_2^2 + ...)}$$

$\therefore$ Rms value of $x(t) = \sqrt{(3)^2 + \frac{1}{2}(1 + (-1)^2)}$

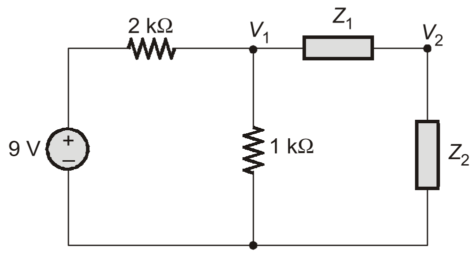
$$= \sqrt{9 + \frac{1}{2}(2)} = \sqrt{10}$$

1.12 (b)



By applying voltage divider rule.
The voltage,

$$V_1 = \frac{1}{1+2}\times 9\text{ V} = 3\text{ V}$$



$$Z_1 = \frac{1}{j\omega \times 10 \times 10^{-6}}$$

and $$Z_2 = \frac{1}{j\omega \times 20 \times 10^{-6}}$$

$\Rightarrow$ $$Z_1 = 2\,Z_2$$

Again by applying voltage divider rule,

$$V_2 = \frac{Z_2}{Z_1 + Z_2} \times 3\text{V}$$

$$= \frac{Z_2}{2Z_2 + Z_2} \times 3\text{V} = 1\text{ V}$$

1.13 **(c)**

Resistor 1 : 100 Ω, 1 W

Resistor 2 : 800 Ω, 2 W

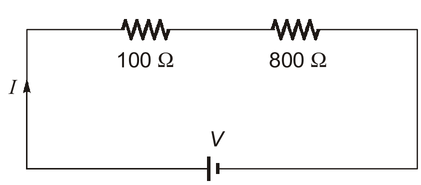
maximum current that resistor can withstand

$$I_1 = \sqrt{\frac{1}{100}} = \frac{1}{10}\text{A}$$

Similarly,

$$I_2 = \sqrt{\frac{2}{800}} = \frac{1}{20}\text{A}$$

if these two resistors are connected in series.

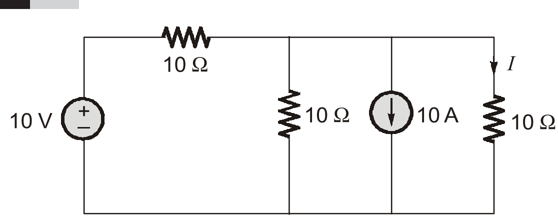


Then maximum value of $I = \dfrac{1}{20}$

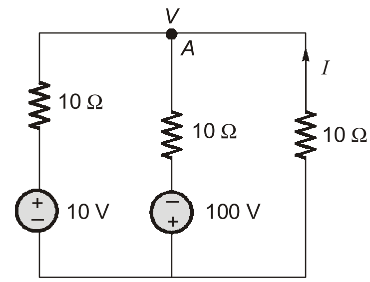
$\therefore$ $$V = I(100 + 800)$$

$$= \frac{1}{20}(900) = 45\text{ volt}$$

1.14 **(a)**



By source transformation,



Let V is the voltage at node A.

By applying KCL at node A

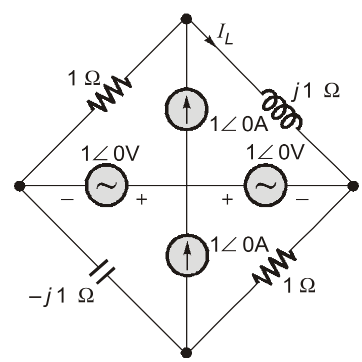
$$\frac{V-10}{10} + \frac{V+100}{10} + \frac{V}{10} = 0$$

$$3\text{ V} + 90 = 0$$

$$V = -30\text{ V} \quad \text{and} \quad V = -I \times 10$$

$$\therefore \quad -30 = -I \times 10 \quad \Rightarrow I = 3\text{ A}$$

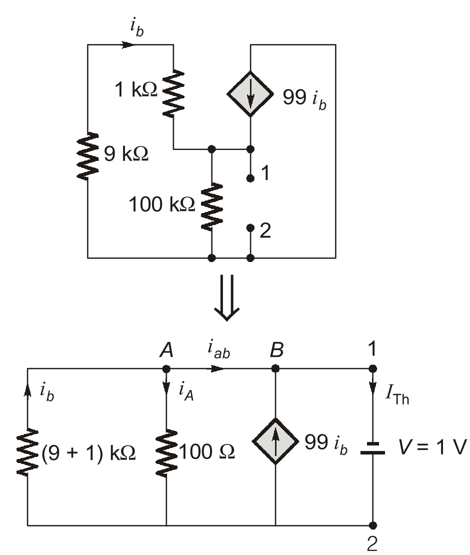
1.15 **(c)**



By applying current division rule in upper part of the circuit.

$$I_L = \frac{1}{1+j} \times 1\angle 0 = \frac{1}{1+j}$$

1.16 **(a)**



To find Thevenin impedance across node 1 and 2. Connect a 1 V source and find the current through voltage source.

Then, $Z_{Th} = \frac{1}{I_{Th}}$

By applying KCL at node B and A

$$i_{AB} + 99i_b = I_{Th}$$
$$i_b = i_A + i_{AB}$$
$$\Rightarrow \quad i_b - i_A + 99i_b = I_{Th}$$
$$\Rightarrow \quad 100\, i_b - i_A = I_{Th} \qquad \text{...(i)}$$

By applying KVL in outer loop

$$10 \times 10^3\, i_b = 1$$
$$i_b = 10^{-4}\ \text{A}$$

and $10 \times 10^3\, i_b = -100\, i_A$

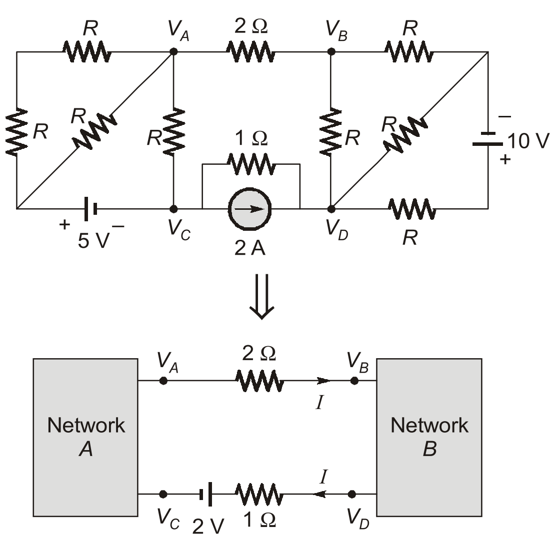
$$\Rightarrow \quad i_A = -100\, i_b$$

∴ From equation (i)

$$100\, i_b + 100\, i_b = I_{Th}$$
$$\Rightarrow \quad i_{Th} = 200\, i_b$$
$$= 200 \times 10^{-4} = 0.02$$

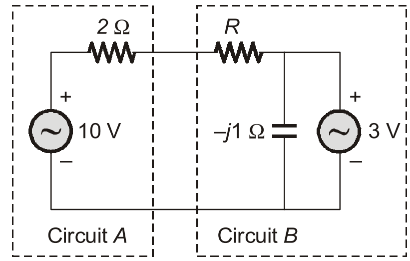
$$\therefore \quad Z_{Th} = \frac{1}{I_{Th}} = \frac{1}{0.02} = 50\ \Omega$$

1.17 (a)

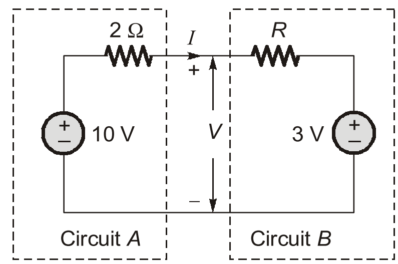


$$V_A - V_B = 2I$$
$$\Rightarrow \quad 2I = 6$$
$$\Rightarrow \quad I = 3\text{A}$$
$$V_c + 2 + 1 \times I = V_D$$
$$V_C - V_D = -2 - 3$$
$$= -5\ \text{V}$$

1.18 (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 $\frac{dP}{dR} = 0$

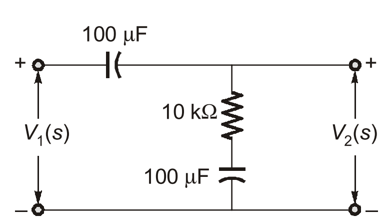
$$(R+2)^2 (10) - (10R+6) \times 2(R+2) = 0$$
$$5R^2 + 20R + 20 = 10R^2 + 26R + 12$$
$$5R^2 + 6R = 8$$
$$\Rightarrow \quad R = 0.8\ \Omega$$

1.19 (c)

For pure resistive load to extract the maximum power

$$R_L = \sqrt{R_s^2 + X_s^2} = \sqrt{4^2 + 3^2}$$
$$R_L = 5\ \Omega$$

1.20 (d)



$$\frac{V_2(s)}{V_1(s)} = \frac{R + \frac{1}{Cs}}{\frac{1}{Cs} + R + \frac{1}{Cs}} = \frac{1+RCs}{2+RCs}$$

$$= \frac{1+10\times10^3\times100\times10^{-6}s}{2+10\times10^3\times100\times10^{-6}s} = \frac{1+s}{2+s}$$

1.21 (b)

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

$$R'_a = kR_a$$

$$R'_b = kR_b$$

$$R'_c = kR_c$$

$$R'_A = \frac{kR_b \cdot kR_c}{kR_a + kR_b + kR_c} = \frac{k^2 R_b R_c}{k(R_A + R_b + R_c)}$$

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

$$R'_A = kR_A$$

1.22 (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,

$$V_{wx_2} = \frac{100}{1.25} = 80 \text{ V}$$

$$\Rightarrow \quad \frac{Y_{YZ_1}}{Y_{wx_1}} = \frac{100}{100}, \quad \frac{V_{wx_2}}{V_{YZ_2}} = \frac{80}{100}$$

1.23 (c)

To find V_{Th}, open circuit the load voltage R_L then

$$I_2 = 0$$

$$j40\, I_2 = 0$$

$$V_{L_1} = \frac{V_s \cdot (j4)}{3+j4} = \frac{100\angle 53.13^\circ}{5\angle 53.13^\circ} \times 4\angle 90^\circ$$

$$V_{L_1} = 80\angle 90^\circ$$

$$V_{Th} = 10V_{L_1} + I_2 j6 + I_2 5$$

$$V_{Th} = 10 \times 80\angle 90^\circ + 0 \times j6 + 0 \times 5$$

$$V_{Th} = 800\angle 90^\circ + 0 + 0$$

$$V_{Th} = 800\angle 90^\circ$$

1.24 (a)

$$v_1(t) = V_m \sin(10t - 130^\circ)$$

$$= V_m \cos(10t - 130^\circ - 90^\circ)$$

$$= V_m \cos(10t - 220^\circ)$$

$$= V_m \cos(10t - 220^\circ + 360^\circ)$$

$$= V_m \cos(10t + 140^\circ)$$

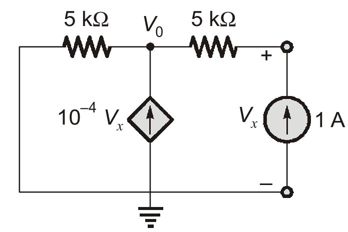
$$v_2(t) = V_m \cos(10t + 10^\circ)$$

∴ Clearly $v_1(t)$ is leading $v_2(t)$ by 140° – 10°

$$= 130^\circ$$

1.25 (20)

Thevenin equivalent circuit is made by connecting 1 A current source at the output and short circuiting the battery.



At node, V_0

$$\frac{V_o}{5000} = 10^{-4}\ V_x + 1 \qquad \text{...(i)}$$

Also, $\quad V_x = 5000 + V_0 \qquad$ ...(ii)

Putting equation (ii) in (i), we get

$$\frac{V_x - 5000}{5000} = 10^{-4}\ V_x + 1$$

$$\therefore \quad \frac{2\,V_x}{10000} = \frac{V_x}{10000} + 2$$

$$\therefore \quad V_x = 20000$$

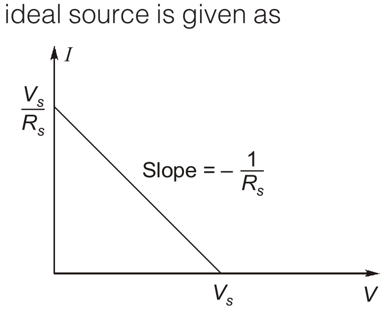
$$R_{Th} = \frac{V_x}{1\,A} = \frac{20000}{1} = 20\text{ k}\Omega$$

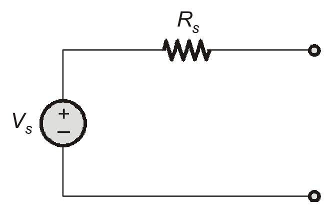
1.26 (a)

- For the above network maximum power transfer theorem can not be applied since load resistor is constant and other resistance is variable.
- In the above network power dissipation in the R_L is maximum for minimum value of R_s so that current in the R_L will be maximum hence $R_s = 0$.

1.27 (1.75)

The transfer characteristics curve and circuit of a non ideal source is given as

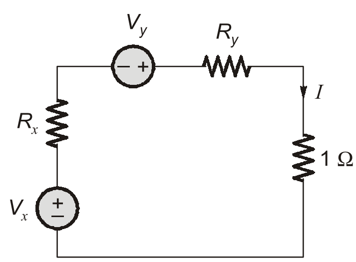




Comparing is with the given graph

X: $V_x = 4$ V, $R_x = 2\ \Omega$

Y: $V_Y = 3$ V, $R_x = 1\ \Omega$



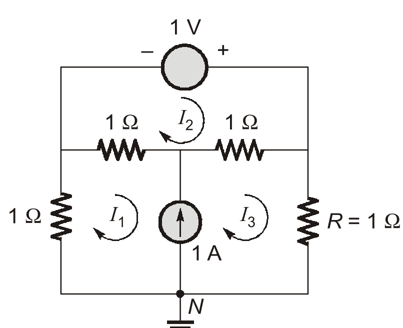
$$\therefore \qquad I = \frac{4+3}{2+1+1} = 1.75 \text{ A}$$

1.28 (1)

By Reciprocity theorem, $I_1 = I_2$

So, $\left|\frac{I_1}{I_2}\right| = 1$

1.29 (1)



Mesh, 1 and 3 form a supermesh

$$2I_1 - I_2 + 2I_3 - I_2 = 0$$

$$2I_1 - 2I_2 + 2I_3 = 0 \qquad \text{...(i)}$$

at point N applying KCL, we get

$$I_1 - I_3 = -1 \qquad \text{...(ii)}$$

In mesh 2

$$-1 + 2I_2 - I_3 - I_1 = 0$$

$$-I_1 + 2I_2 - I_3 = 1 \qquad \text{...(iii)}$$

Solving equations (i), (ii) and (iii)

Current through R, i.e. $I_3 = 1$ A

Also, since the direction of current is not specified in the question so, it could also be –1 A.

1.30 (5)

Apply KCL at NODE - 1

$$i_1 = i_2 + i_3$$

$$i_3 = i_1 - i_2$$

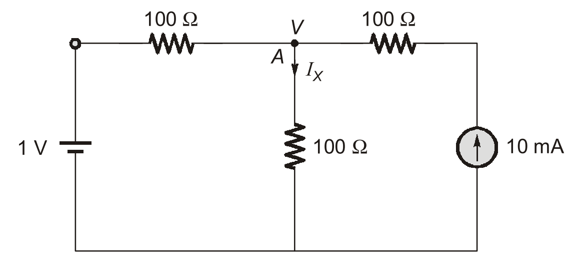
$$= 3\cos\omega t - 4\sin\omega t$$

$$= \sqrt{3^2 + 4^2}\cos(\omega t + \phi)$$

$$= 5\cos(\omega t + \phi)$$

$$\therefore \qquad I_3 = 5 \text{ Amp.}$$

1.31 (10)



Applying Node equation at Node A

$$\frac{V-1}{100} + \frac{V}{100} = 10 \times 10^{-3}$$

$$2V - 1 = 1$$

$$V = 1$$

$$I_x = \frac{V}{100} = \frac{1}{100} = 10 \text{ mA}$$

1.32 (2)

By KCL at node 2

$$2I_2 = \frac{V_2}{1/3} + \frac{V_2 + 4V_{R_1} - V_1}{0.5} \qquad \text{... (i)}$$

$$V_{R1} = -1 \qquad \text{... (ii)}$$

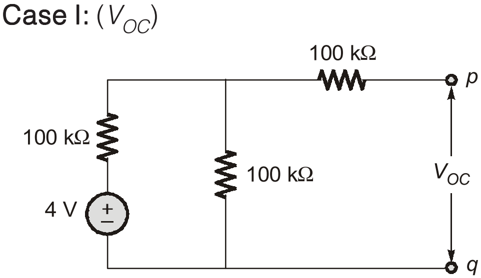
and $$I_2 = \frac{V_1 - 4V_{R_1} - V_2}{0.5} \qquad \text{... (iii)}$$

Sub equation (ii) and (iii) in equation (i),

$$V_2 = 2 \text{ V}$$

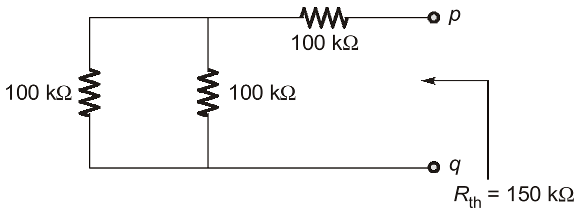
1.33 (c)

Case I: (V_{OC})



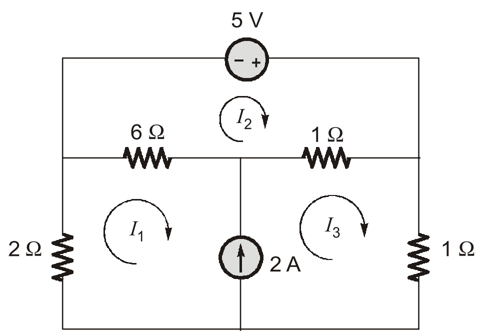
$$V_{OC} = 4 \times \frac{100}{100+100} = 2 \text{ V}$$

Case II: (R_{Th})



$$R_{Th} = 150 \text{ k}\Omega$$

1.34 (a)



$$8I_1 - 6I_2 + 2I_3 - I_2 = 0 \quad \text{... (i)}$$

$$I_3 - I_1 = 2 \text{ A} \quad \text{... (ii)}$$

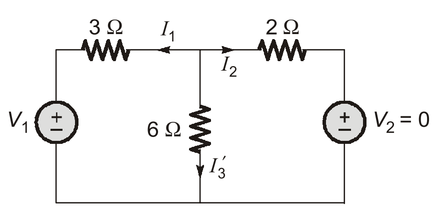
$$-6I_1 + 7I_2 - I_3 = 5 \quad \text{... (iii)}$$

By solving above equations,

I_1 = 1 A, I_2 = 2 A and I_3 = 3 A

1.35 1 (0.95 to 1.05)

Case I:

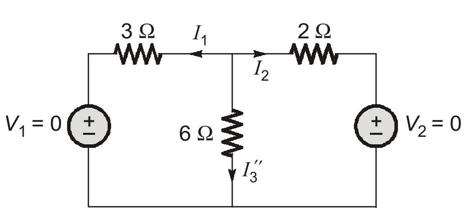


$$I_2 = -6 \text{ A}$$

Apply current division and KCL we get

$$I_3' = -2 \text{ A}$$

Case II:



$$I_1 = 6 \text{ A}$$

Apply current division we get

$$I_3'' = 3 \text{ A}$$

$$I_3 = I_3' + I_3'' = -2 \text{ A} + 3 \text{ A} = 1 \text{ A}$$

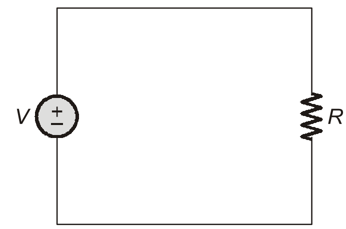
1.36 (5)

According to maximum power transfer theorem, the maximum power will be transferred to the load when,

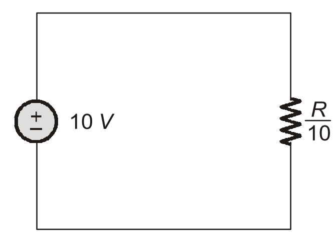
$$R_L = R_S$$

$$\therefore \quad R_L = 5 \ \Omega$$

1.37 (1000)



$$P = \frac{V^2}{R}$$

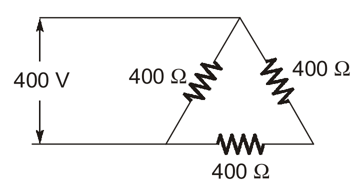


$$P' = \frac{(10V)^2}{R/10} = 1000\frac{V^2}{R}$$

$$\therefore \quad P' = 1000P$$

∴ Power dissipated scales up by a factor of 1000.

1.38 (1.7)



$$I_{Ph} = \frac{V_{Ph}}{R_{Ph}} = \frac{400}{400} = 1\text{A}$$

$$I_{Line} = \sqrt{3}\, I_{Ph} = \sqrt{3} \times 1 = 1.732 \text{ A}$$

1.39 (b)

Maximum current for 100 Ω, 1 W;

$$I = \sqrt{\frac{P}{R}} = 0.1 \text{ A}$$

Maximum current for 2 Ω, 0.5 W;

$$I = \sqrt{\frac{0.5}{2}} = 0.5 \text{ A}$$