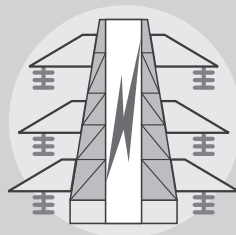


**30** *Years*  
Previous Solved Papers

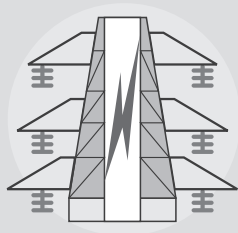
# GATE 2024

## Electrical Engineering



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





**MADE EASY Publications Pvt. Ltd.**

**Corporate Office:** 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016 | **Ph. :** 9021300500

**Email :** infomep@madeeasy.in | **Web :** www.madeeasypublications.org

**GATE - 2024**

**Electrical Engineering**

Topicwise Previous GATE Solved Papers (1994-2023)

## *Editions*

1 <sup>st</sup> Edition	: 2008
2 <sup>nd</sup> Edition	: 2009
3 <sup>rd</sup> Edition	: 2010
4 <sup>th</sup> Edition	: 2011
5 <sup>th</sup> Edition	: 2012
6 <sup>th</sup> Edition	: 2013
7 <sup>th</sup> Edition	: 2014
8 <sup>th</sup> Edition	: 2015
9 <sup>th</sup> Edition	: 2016
10 <sup>th</sup> Edition	: 2017
11 <sup>th</sup> Edition	: 2018
12 <sup>th</sup> Edition	: 2019
13 <sup>th</sup> Edition	: 2020
14 <sup>th</sup> Edition	: 2021
15 <sup>th</sup> Edition	: 2022

**16<sup>th</sup> Edition : 2023**

© Copyright, by **MADE EASY Publications Pvt. Ltd.**

All rights are reserved. No part of this publication may be reproduced, stored in or introduced into a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photo-copying, recording or otherwise), without the prior written permission of the above mentioned publisher of this book.

---

**MADE EASY Publications Pvt. Ltd.** has taken due care in collecting the data and providing the solutions, before publishing this book. In spite of this, if any inaccuracy or printing error occurs then **MADE EASY Publications Pvt. Ltd.** owes no responsibility. We will be grateful if you could point out any such error. Your suggestions will be appreciated.

# 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.



**B. Singh** (Ex. IES)

The new edition of **GATE 2024 Solved Papers : Electrical 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-2024

---

## Electrical Engineering

### CONTENTS

1.	Electric Circuits .....	1 - 78
2.	Signals and Systems .....	79 - 127
3.	Electrical Machines .....	128 - 213
4.	Power Systems .....	214 - 300
5.	Control Systems .....	301 - 365
6.	Electrical & Electronic Measurements .....	366 - 407
7.	Analog Electronics .....	408 - 459
8.	Digital Electronics .....	460 - 491
9.	Power Electronics .....	492 - 557
10.	Electromagnetic Theory .....	558 - 582
11.	Engineering Mathematics .....	583 - 637
12.	General Ability .....	638 - 674

# Electric Circuits

## UNIT I

### CONTENTS

1. Basics 3
2. Steady State AC Analysis 19
3. Resonance and Locus Diagrams 26
4. Network Theorems 36
5. Transients and Steady State Response 47
6. Two Port Network and Network Functions 62
7. Magnetically Coupled Circuits,  
Network Topology/Graph Theory & Filters 70
8. Three-Phase Circuits 76

# Electric Circuits

## Syllabus

**Network Elements:** Ideal Voltage and Current Sources, Dependent Sources, R, L, C, M Elements;

**Network Solution Methods:** KCL, KVL, Node and Mesh analysis;

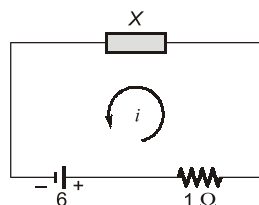
**Network Theorems:** Thevenin's, Norton's, Superposition and Maximum Power Transfer theorem; Transient response of DC and AC networks, sinusoidal steady-state analysis, resonance, two port networks, balanced three phase circuits, star-delta transformation, complex power and power factor in AC circuits.

### Analysis of Previous GATE Papers

Exam Year	1 Mark Ques.	2 Marks Ques.	5 Marks Ques.	Total Marks
1994	4	2	—	8
1995	2	—	—	2
1996	3	1	—	5
1997	4	6	2	26
1998	3	2	3	28
1999	4	5	2	24
2000	1	3	1	12
2001	5	1	1	12
2002	1	7	3	30
2003	3	6	—	15
2004	1	7	—	15
2005	4	7	—	18
2006	2	6	—	14
2007	—	7	—	14
2008	2	6	—	14
2009	2	6	—	14
2010	—	3	4	11
2011	—	3	5	13

Exam Year	1 Mark Ques.	2 Marks Ques.	Total Marks
2012	5	6	17
2013	2	3	8
2014 Set-1	2	2	6
2014 Set-2	3	2	7
2014 Set-3	3	3	9
2015 Set-1	4	3	10
2015 Set-2	3	3	9
2016 Set-1	4	5	14
2016 Set-2	5	4	13
2017 Set-1	2	3	8
2017 Set-2	2	2	6
2018	3	4	11
2019	1	3	7
2020	2	2	6
2021	4	5	14
2022	5	1	7
2023	2	4	10

- 1.1** 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 amp in the direction shown and absorbs a power  $P_x$ . It is possible that  $X$  can absorb the same power  $P_x$  for another current  $i$ . Then the value of this current is



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

[1996 : 1 M]

- 1.2** A practical current source is usually represented by

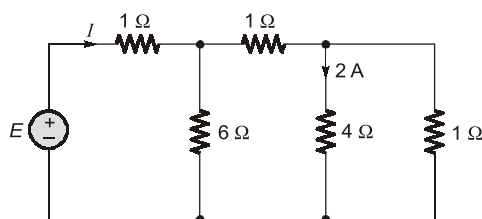
- (a) a resistance in series with an ideal current source.  
(b) a resistance in parallel with an ideal current source.  
(c) a resistance in parallel with an ideal voltage source.  
(d) None of these

[1997 : 1 M]

- 1.3** A 10 V battery with an internal resistance of  $1\ \Omega$  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.

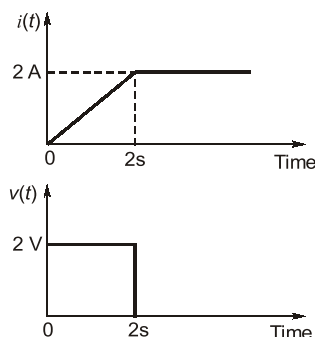
[1997 : 2 M]

- 1.4** The value of  $E$  and  $I$  for the circuit shown in the figure, are ..... V and ..... A.



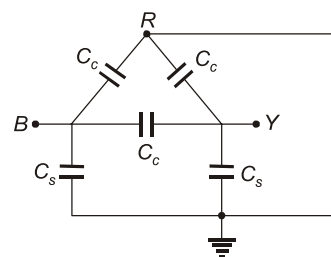
[1997 : 2 M]

- 1.5** The voltage and current waveforms for an element are shown in the figure. The circuit element is \_\_\_\_\_ and its value is \_\_\_\_\_.



[1997 : 2 M]

- 1.6** For the circuit shown in the figure, the capacitance measured between terminals  $B$  and  $Y$  will be



- (a)  $C_c + \left(\frac{C_s}{2}\right)$     (b)  $C_s + \left(\frac{C_c}{2}\right)$   
(c)  $\frac{(C_s + 3C_c)}{2}$     (d)  $3C_c + 2C_s$

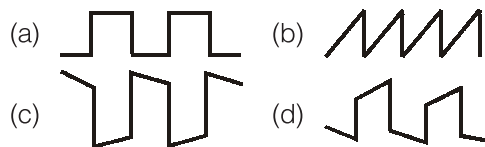
[1999 : 1 M]

- 1.7** 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  $1\ \Omega$     (b) 3 A and  $2\ \Omega$   
(c) 1 A and  $18\ \Omega$     (d) 6 A and  $0.5\ \Omega$

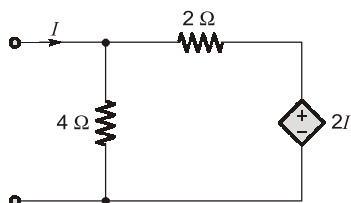
[1999 : 2 M]

- 1.8** When a periodic triangular voltage of peak amplitude 1 V and frequency 0.5 Hz is applied to a parallel combination of  $1\ \Omega$  resistance and 1 F capacitance, the current through the voltage source has waveform.



[1999 : 2 M]

- 1.9** The circuit shown in the figure is equivalent to a load of

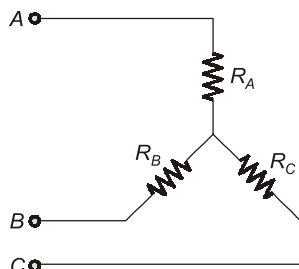


- (a)  $\frac{4}{3} \Omega$  (b)  $\frac{8}{3} \Omega$   
(c)  $4 \Omega$  (d)  $2 \Omega$  [2000 : 2 M]

- 1.10** Two incandescent light bulbs of 40 W and 60 W ratings are connected in series across the mains. Then

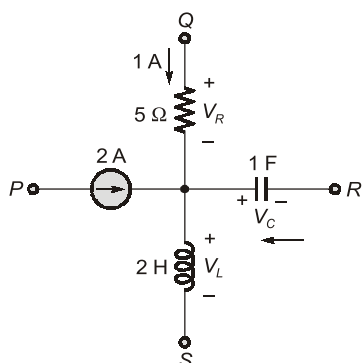
- (a) the bulbs together consume 100 W.  
(b) the bulbs together consume 50 W.  
(c) the 60 W bulb glows brighter.  
(d) the 40 W bulb glows brighter. [2001 : 1 M]

- 1.11** Consider the star network shown in the figure. The resistance between terminals A and B with terminal C open is  $6 \Omega$ , between terminals B and C with terminal A open is  $11 \Omega$ , and between terminals C and A with terminal B open is  $9 \Omega$ . Then



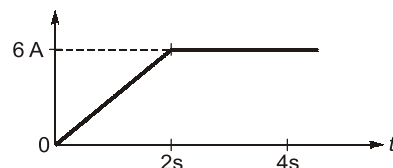
- (a)  $R_A = 4 \Omega, R_B = 2 \Omega, R_C = 5 \Omega$   
(b)  $R_A = 2 \Omega, R_B = 4 \Omega, R_C = 7 \Omega$   
(c)  $R_A = 3 \Omega, R_B = 3 \Omega, R_C = 4 \Omega$   
(d)  $R_A = 5 \Omega, R_B = 1 \Omega, R_C = 10 \Omega$  [2001 : 2 M]

- 1.12** A segment of a circuit is shown in the figure  $V_R = 5 \text{ V}$ ,  $V_C = 4 \sin 2t$ . The voltage  $V_L$  is given by



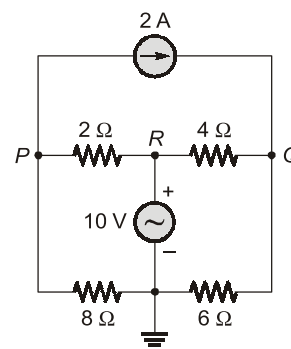
- (a)  $3 - 8 \cos 2t$  (b)  $32 \sin 2t$   
(c)  $16 \sin 2t$  (d)  $16 \cos 2t$  [2003 : 1 M]

- 1.13** The figure shows the waveform of the current passing through an inductor of resistance  $1 \Omega$  and inductance 2 H. The energy absorbed by the inductor in the first four seconds is



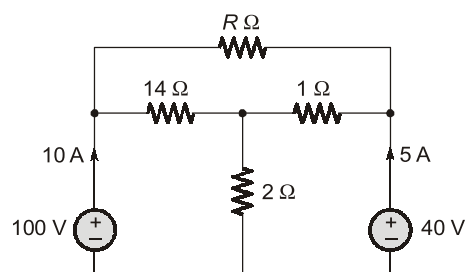
- (a) 144 J (b) 98 J  
(c) 132 J (d) 168 J [2003 : 1 M]

- 1.14** In the figure, the potential difference between points P and Q is



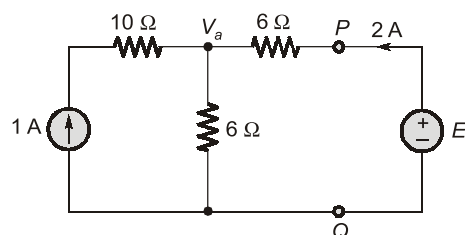
- (a) 12 V (b) 10 V  
(c) -6 V (d) 8 V [2003 : 2 M]

- 1.15** In the figure, the value of R is



- (a)  $10 \Omega$  (b)  $18 \Omega$   
(c)  $24 \Omega$  (d)  $12 \Omega$  [2003 : 2 M]

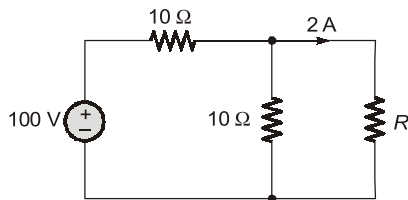
- 1.16** In the figure, the value of the source voltage is



- (a) 12 V (b) 24 V  
(c) 30 V (d) 44 V [2004 : 2 M]

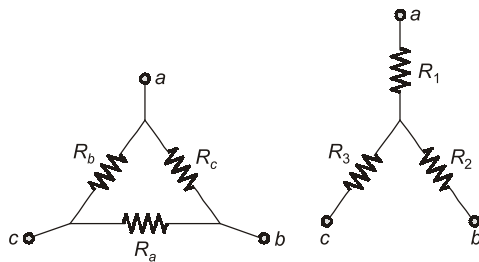


**1.17** In the figure, the value of resistance  $R$  in  $\Omega$  is



- (a) 10 (b) 20  
(c) 30 (d) 40 [2004 : 2 M]

**1.18** In the figure,  $R_a$ ,  $R_b$  and  $R_c$  are  $20\ \Omega$ ,  $10\ \Omega$  and  $10\ \Omega$  respectively. The resistances  $R_1$ ,  $R_2$  and  $R_3$  in  $\Omega$  of an equivalent star-connection are

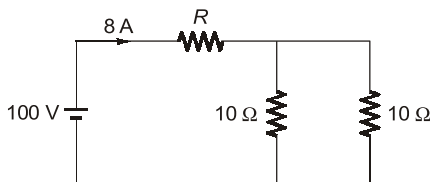


- (a) 2.5, 5, 5 (b) 5, 2.5, 5  
(c) 5, 5, 2.5 (d) 2.5, 5, 2.5 [2004 : 2 M]

**1.19** The rms value of the current in a wire which carries a d.c. current of 10 A and a sinusoidal alternating current of peak value 20 A is

- (a) 10 A (b) 14.14 A  
(c) 15 A (d) 17.32 A [2004 : 2 M]

**1.20** In the figure given below the value of  $R$  is

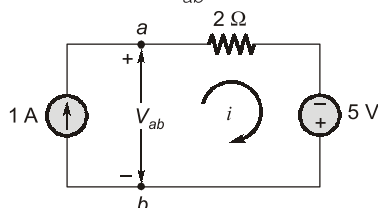


- (a) 2.5  $\Omega$  (b) 5.0  $\Omega$   
(c) 7.5  $\Omega$  (d) 10.0  $\Omega$  [2005 : 1 M]

**1.21** A 3 V dc supply with an internal resistance of  $2\ \Omega$  supplies a passive non-linear resistance characterized by the relation  $V_{NL} = I_{NL}^2$ . The power dissipated in the non linear resistance is

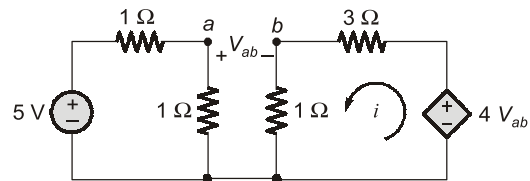
- (a) 1.0 W (b) 1.5 W  
(c) 2.5 W (d) 3.0 W [2007 : 2 M]

**1.22** Assuming ideal elements in the circuit shown below, the voltage  $V_{ab}$  will be



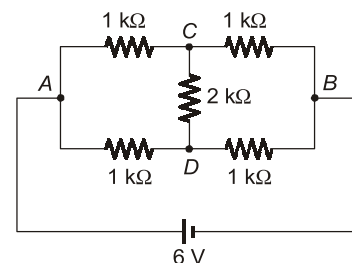
- (a) -3 V (b) 0 V  
(c) 3 V (d) 5 V [2008 : 2 M]

**1.23** 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 [2008 : 2 M]

**1.24** The current through the  $2\ \text{k}\Omega$  resistance in the circuit shown is

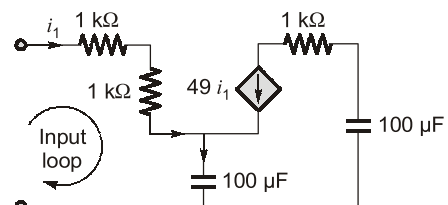


- (a) 0 mA (b) 1 mA  
(c) 2 mA (d) 6 mA [2009 : 1 M]

**1.25** 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?

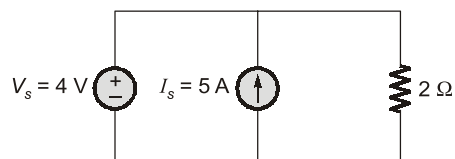
- (a) Not possible (b) 4  
(c) 3 (d) 2 [2009 : 1 M]

**1.26** The equivalent capacitance of the input loop of the circuit shown is



- (a) 2  $\mu\text{F}$  (b) 100  $\mu\text{F}$   
(c) 200  $\mu\text{F}$  (d) 4  $\mu\text{F}$  [2009 : 2 M]

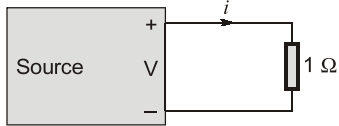
**1.27** For the circuit shown, find out the current flowing through the  $2\ \Omega$  resistance. Also identify the changes to be made to double the current through the  $2\ \Omega$  resistance.



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

[2009 : 2 M]

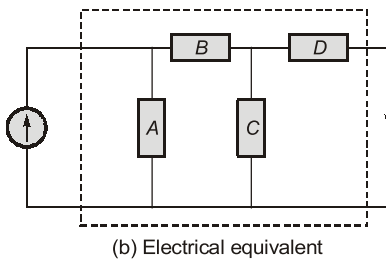
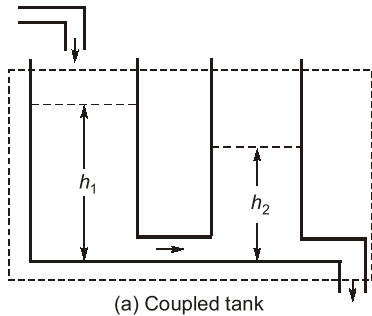
- 1.28** As shown in the figure, a  $1\ \Omega$  resistance is connected across a source that has a load line  $v + i = 100$ . The current through the resistance is



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

[2010 : 1 M]

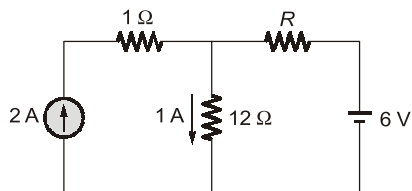
- 1.29** If the electrical circuit of figure (b) is an equivalent of the coupled tank system of figure (a), then



- (a) A, B are resistances and C, D capacitances  
 (b) A, C are resistances and B, D capacitances  
 (c) A, B are capacitances and C, D resistances  
 (d) A, C are capacitances and B, D resistances

[2010 : 1 M]

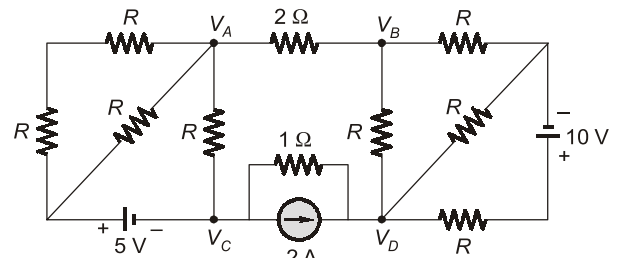
- 1.30** If the  $12\ \Omega$  resistor draws a current of 1 A as shown in the figure, the value of resistance  $R$  is



- (a)  $4\ \Omega$  (b)  $6\ \Omega$   
 (c)  $8\ \Omega$  (d)  $18\ \Omega$

[2010 : 2 M]

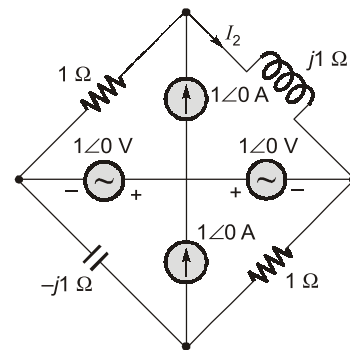
- 1.31** If  $V_A - V_B = 6$  V, then  $V_C - V_D$  is



- (a) -5 V (b) 2 V  
 (c) 3 V (d) 6 V

[2012 : 2 M]

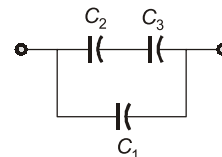
- 1.32** In the circuit shown below, the current through the inductor is



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

[2012 : 1 M]

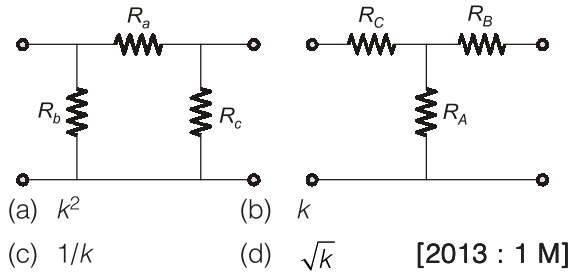
- 1.33** Three capacitors  $C_1$ ,  $C_2$  and  $C_3$  whose values are  $10\ \mu\text{F}$ ,  $5\ \mu\text{F}$ , and  $2\ \mu\text{F}$  respectively, have breakdown voltages of 10 V, 5 V and 2 V respectively. For the interconnection shown below, the maximum safe voltage in volts that can be applied across the combination, and the corresponding total charge in  $\mu\text{C}$  stored in the effective capacitance across the terminals are, respectively



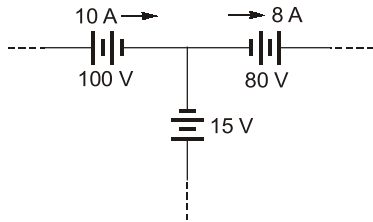
- (a) 2.8 and 36 (b) 7 and 119  
 (c) 2.8 and 32 (d) 7 and 80

[2013 : 2 M]

- 1.34** 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



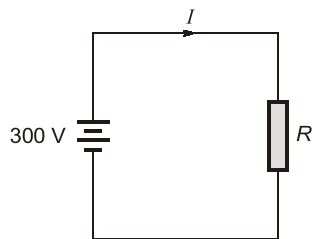
- 1.35** The three circuit elements shown in the figure are part of an electric circuit. The total power absorbed by the three circuit elements in watts is \_\_\_\_\_.



[2014 : 1 M, Set-1]

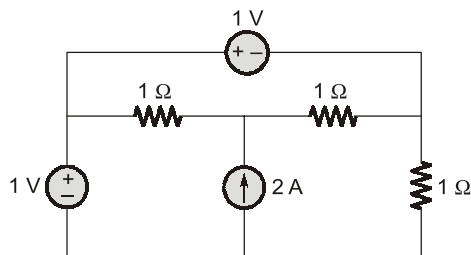
- 1.36** An incandescent lamp is marked 40 W, 240 V. If resistance at room temperature ( $26^\circ\text{C}$ ) is  $120\ \Omega$ , and temperature coefficient of resistance is  $4.5 \times 10^{-3}/^\circ\text{C}$ , then its 'ON' state filament temperature in  $^\circ\text{C}$  is approximately \_\_\_\_\_. [2014 : 2 M, Set-1]

- 1.37** In the figure, the value of resistor  $R$  is  $\left(25 + \frac{I}{2}\right)$  ohms, where  $I$  is the current in amperes. The current  $I$  is \_\_\_\_\_.



[2014 : 2 M, Set-1]

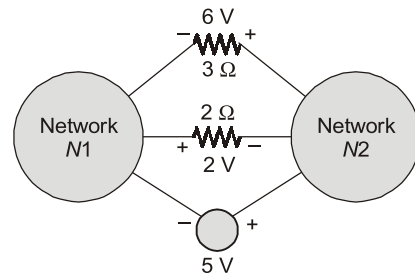
- 1.38** The power delivered by the current source, in the figure, is \_\_\_\_\_.



[2014 : 2 M, Set-3]

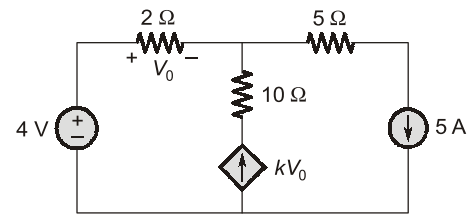
- 1.39** The voltages developed across the  $3\ \Omega$  and  $2\ \Omega$  resistors shown in the figure are 6 V and 2 V respectively, with the polarity as marked. What is

the power (in Watt) delivered by the 5 V voltage source?



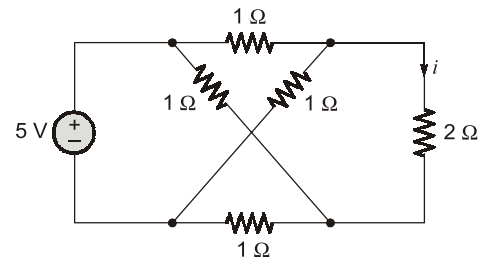
- (a) 5 (b) 7 (c) 10 (d) 14 [2015 : 1 M, Set-1]

- 1.40** In the given circuit, the parameter  $k$  is positive, and the power dissipated in the  $2\ \Omega$  resistor is 12.5 W. The value of  $k$  is \_\_\_\_\_.



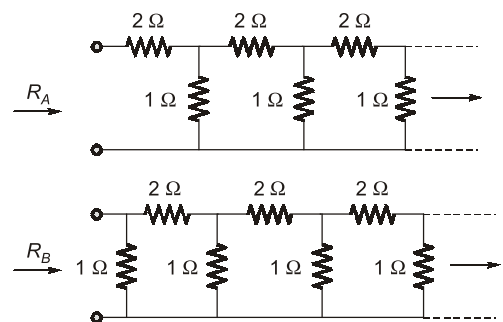
[2015 : 2 M, Set-1]

- 1.41** The current  $i$  (in Ampere) in the  $2\ \Omega$  resistor of the given network is \_\_\_\_\_.



[2015 : 1 M, Set-2]

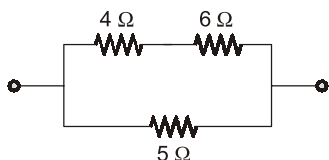
- 1.42**  $R_A$  and  $R_B$  are the input resistances of circuits as shown below. The circuits extend infinitely in the direction shown. Which one of the following statements is TRUE?



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

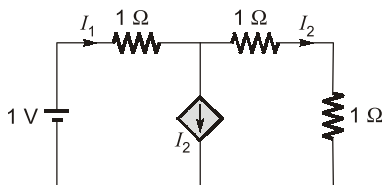
[2016 : 1 M, Set-1]

- 1.43** In the portion of a circuit shown, if the heat generated in  $5\ \Omega$  resistance is 10 calories per second, then heat generated by the  $4\ \Omega$  resistance, in calories per second, is \_\_\_\_.



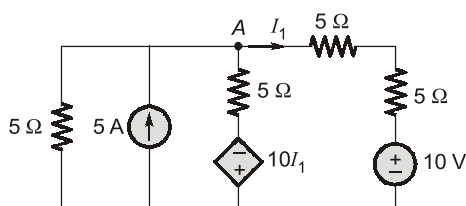
[2016 : 1 M, Set-1]

- 1.44** In the given circuit, the current supplied by the battery (in Ampere) is \_\_\_\_.



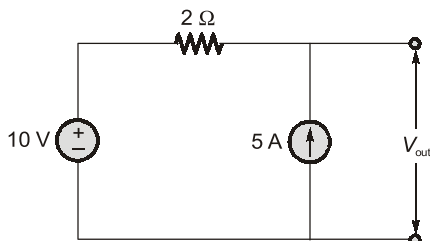
[2016 : 1 M, Set-1]

- 1.45** In the circuit shown below, the node voltage  $V_A$  is \_\_\_\_ V.



[2016 : 2 M, Set-1]

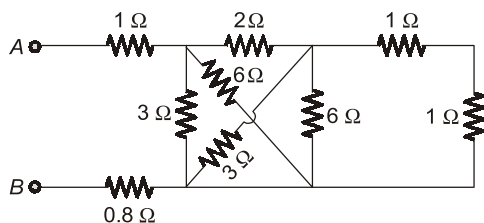
- 1.46** In the circuit shown below, the voltage and current sources are ideal. The voltage ( $V_{out}$ ) across the current source, in volts, is



- (a) 0 (b) 5  
(c) 10 (d) 20

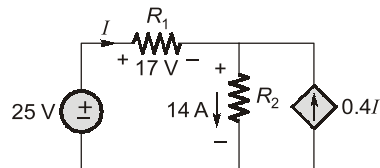
[2016 : 1 M]

- 1.47** The equivalent resistance between the terminals A and B is \_\_\_\_  $\Omega$ .



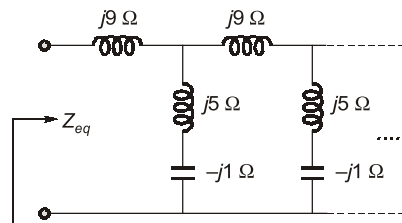
[2017 : 1 M, Set-1]

- 1.48** The power supplied by the 25 V source in the figure shown below is \_\_\_\_ W.



[2017 : 1 M, Set-1]

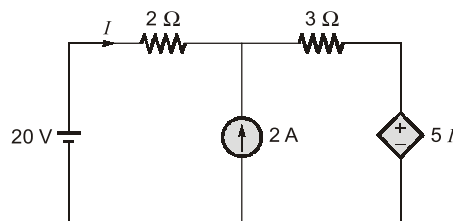
- 1.49** The equivalent impedance  $Z_{eq}$  for the infinite ladder circuit shown in the figure is



- (a)  $j12\ \Omega$  (b)  $-j12\ \Omega$   
(c)  $j13\ \Omega$  (d)  $13\ \Omega$

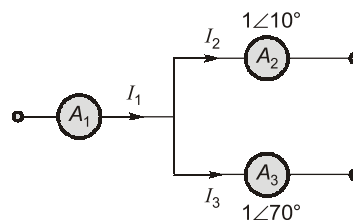
[2018 : 2 M]

- 1.50** The current  $I$  flowing in the circuit shown below in Amperes (round off to one decimal place) is \_\_\_\_.



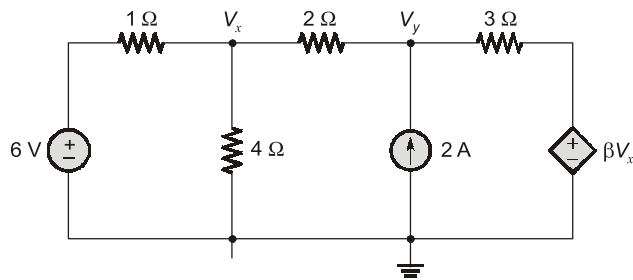
[2019 : 1 M]

- 1.51** Currents through ammeters  $A_2$  and  $A_3$  in fig. are  $1\angle 10^\circ$  and  $1\angle 70^\circ$  respectively. The reading of the ammeter  $A_1$  (rounded off to 3 decimal places) is \_\_\_\_ A.



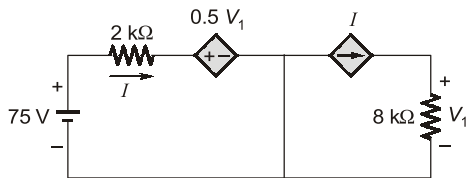
[2020 : 1 M]

- 1.52** In given circuit, for voltage  $V_y$  to be zero, value of  $\beta$  should be \_\_\_\_\_. (Round off to 2 decimal places).



[2021 : 1 M]

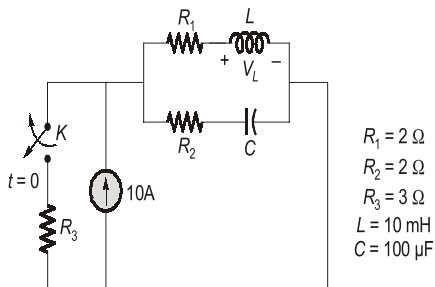
- 1.53** In circuit shown below, the magnitude of voltage  $V_1$  in volts, across the  $8\text{ k}\Omega$  resistor is \_\_\_\_.



[2022 : 2 M]

- 1.54** The value of parameters of the circuit shown in the figure are :

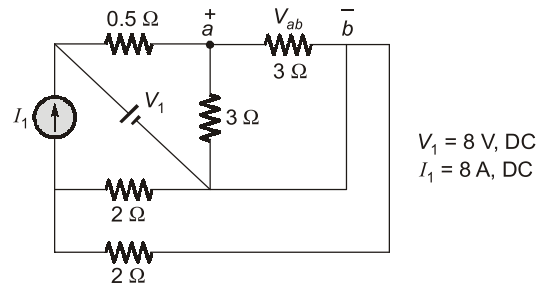
$$R_1 = 2\ \Omega, R_2 = 2\ \Omega, R_3 = 3\ \Omega, L = 10\text{ mH}, C = 100\ \mu\text{F}$$



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).

[2023 : 1 Mark]

- 1.55** For the circuit shown in the figure,  $V_1 = 8\text{ V}$ , DC and  $I_1 = 8\text{ A}$ , DC. The voltage  $V_{ab}$  in Volts is \_\_\_\_ (Round off to 1 decimal place).



[2023 : 1 Mark]

## Answers Basics

1.1 (c)	1.2 (b)	1.3 (5)	1.4 (31)	1.5 (2)	1.6 (c)	1.7 (b)
1.8 (d)	1.9 (b)	1.10 (d)	1.11 (b)	1.12 (b)	1.13 (c)	1.14 (c)
1.15 (d)	1.16 (c)	1.17 (b)	1.18 (a)	1.19 (d)	1.20 (c)	1.21 (a)
1.22 (a)	1.23 (b)	1.24 (a)	1.25 (d)	1.26 (a)	1.27 (b)	1.28 (b)
1.29 (d)	1.30 (b)	1.31 (a)	1.32 (c)	1.33 (c)	1.34 (b)	1.35 (330)
1.36 (2470.44°)	1.37 (10)	1.38 (3)	1.39 (a)	1.40 (0.5)	1.41 (0)	1.42 (d)
1.43 (2)	1.44 (0.5)	1.45 (11.42)	1.46 (d)	1.47 (3)	1.48 (250)	1.49 (a)
1.50 (1.4)	1.51 (1.732)	1.52 (-3.25)	1.53 (100)	1.54 (8)	1.55 (6)	

## Explanations Basics

**1.1 (c)**

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

By putting the options, it can be concluded that for  $i = 5\text{ A}$ .

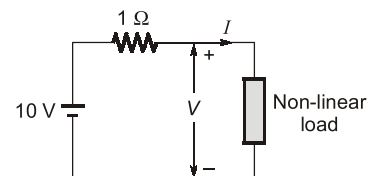
$$P_x = (6 \times 5) - (5^2 \times 1) = 5\text{ W}$$

Option (c) is correct.

**1.2 (b)**

A practical current source is usually represented by a resistance in parallel with an ideal current source and a practical voltage source is usually represented by a resistance in series with an ideal voltage source.

**1.3 Sol.**

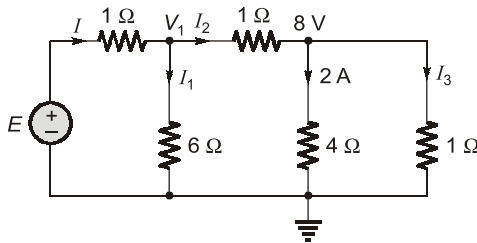


$$\text{Using KVL, } V + I = 10 \quad \dots(i)$$

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

On solving equation (i) and equation (ii) we get,

$$V = 5\text{ V}, I = 5\text{ A}$$

**1.4 Sol.**

Voltage across  $4\ \Omega$  resistor  $= 4 \times 2 = 8\text{ V}$

Current through  $1\ \Omega$  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  $6\ \Omega$  resistor,

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

Current through  $1\ \Omega$  resistor,

$$I = I_1 + I_2 = 3 + 10 = 13\text{ A}$$

$$E = V_1 + I \cdot 1 = 18 + 13 \times 1 = 31\text{ V}$$

**1.5 Sol.**

For the given waveforms,

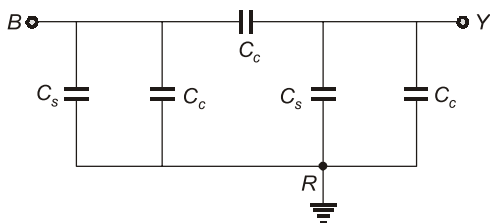
$$v(t) = 2 \frac{di(t)}{dt}$$

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

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

**1.6 (c)**

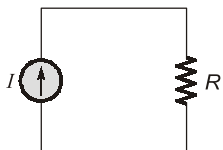
Given circuit can be redrawn as:



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

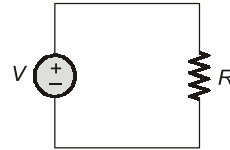
**1.7 (b)**

When resistor  $R$  is connected to a current source,



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

When resistor  $R$  is connected to a voltage source,



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

Given,

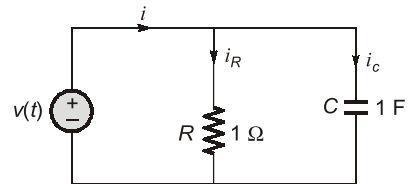
$$V = I \text{ (in magnitude)}$$

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

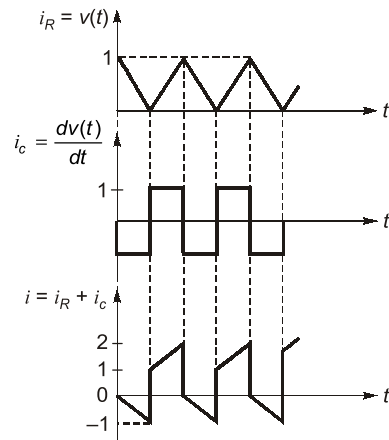
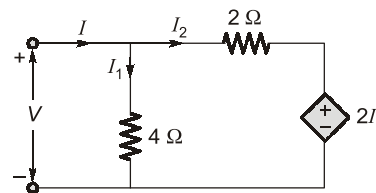
$$\frac{I^2}{R} = 4.5 \quad \dots(ii)$$

On solving these two equations, we get,

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

**1.8 (d)**

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

**1.9 (b)**

$$\text{Current through } 4\ \Omega \text{ resistor, } I_1 = \frac{V}{4}$$

$$\text{Current through } 2\ \Omega \text{ resistor, } I_2 = \frac{V - 2I}{2}$$

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

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

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

**1.10 (d)**

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

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

For series connection, current through both the bulbs will be same  $P = I^2 R$  (for series connection). Power consumed by 40 W bulb > power consumed by 60 W bulb.

Hence, the 40 W bulb glows brighter.

**1.11 (b)**

When C is open,  $R_{AB} = R_A + R_B = 6 \Omega$

When B is open,  $R_{AC} = R_A + R_C = 9 \Omega$

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  $R_C = 7 \Omega$

**1.12 (b)**

By KCL,

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

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

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

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

$$\therefore I_L = -(2 + 1 + 8 \cos 2t) \\ = -3 - 8 \cos 2t$$

$$\therefore V_L = L \left( \frac{di}{dt} \right) = 2 \times 2 \times 8 \sin 2t \\ = 32 \sin 2t$$

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

**1.13 (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,

$$E_L = \int_0^T Li \frac{di}{dt} dt = E_{L_1} + E_{L_2}$$

$$E_{L_1} = \int_0^2 Li \left( \frac{di}{dt} \right) dt = \int_0^2 2 \times 3t \times 3 dt$$

$$= 18 \int_0^2 t dt = 18 \times \left[ \frac{t^2}{2} \right]_0^2 = 18 \times \left[ \frac{4}{2} - 0 \right] = 36 J$$

The energy absorbed by the inductor in  $(2s < t < 4s)$  second,

$$E_{L_2} = \int_2^4 Li \left( \frac{di}{dt} \right) dt = \int_2^4 2 \cdot 6 \cdot 0 dt = 0 J$$

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.

$$E_R = \int_0^T i^2 R dt = \int_0^2 (3t)^2 \times 1 dt + \int_2^4 6^2 \times 1 dt \\ = \int_0^2 (9t^2) dt + 36 \int_2^4 1 dt \\ = 9 \times \left[ \frac{t^3}{3} \right]_0^2 + 36t \Big|_2^4 = 9 \times \left( \frac{8}{3} \right) + 36 \times 2 \\ = 24 + 72 = 96 J$$

The total energy absorbed by the inductor in 4 sec =  $96 J + 36 J = 132 J$

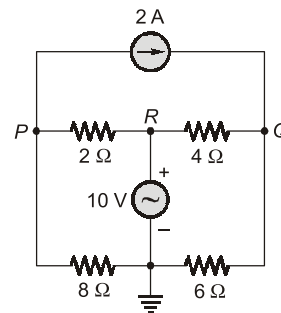
**1.14 (c)**

Given:  $V_R = 10 V$

By KCL,

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

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



From equation (i),

$$4(V_P - 10) + 2 \times 8 + V_P = 0 \\ 4V_P - 40 + 16 + V_P = 0 \\ 5V_P - 24 = 0 \Rightarrow V_P = 4.8$$

From equation (ii),

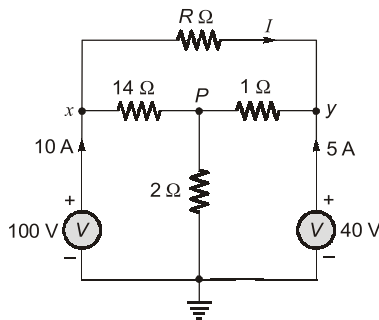
$$6(V_Q - 10) - 2 \times 4 \times 6 + 4V_Q = 0 \\ 10V_Q - 108 = 0 \\ \therefore V_Q = 10.8 \\ \therefore V_P - V_Q = -6 V$$

**1.15 (d)**

By KCL,

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

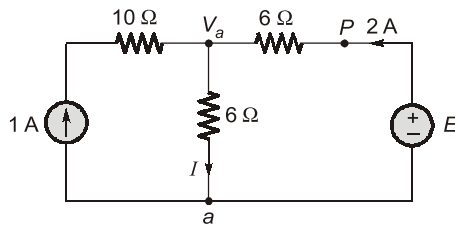
$$22V_P = 660$$



$\therefore V_P = 30 \text{ V}$   
Potential difference between node x and y = 60 V  
By taking KCL at node y

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

$$\therefore I = 5 \text{ A} \Rightarrow I = \frac{60}{5} = 12 \Omega$$

**1.16 (c)**

**Method-1:** Using KCL,

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

$$\Rightarrow 2V_a - E = 6 \quad \dots(i)$$

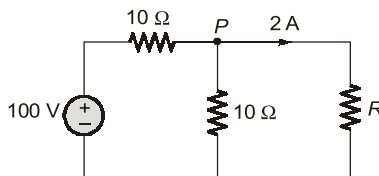
Where,  $\frac{E - V_a}{6} = 2$

$$\Rightarrow E - V_a = 12 \quad \dots(ii)$$

Solving equation (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,  
 $E = 2 \times 6 + 3 \times 6 = 30 \text{ V}$

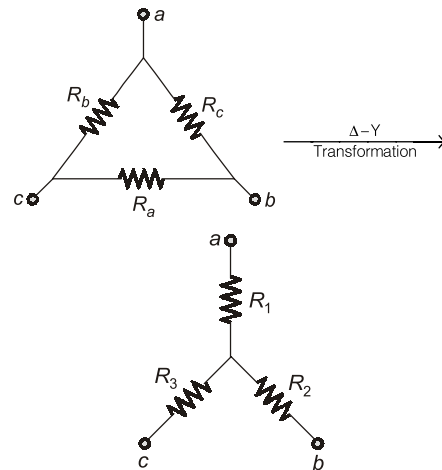
**1.17 (b)**

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

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

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

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

**1.18 (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  $\Delta$ -connection has same impedance  $Z$ , then impedance of branch of Y-connection be  $Z/3$ .

**1.19 (d)**

R.M.S value of d.c current =  $10 \text{ A} = I_{dc}$

R.M.S value of sinusoidal current =  $\left(\frac{20}{\sqrt{2}}\right) \text{ A} = I_{ac}$

R.M.S value of resultant,

$$I_R = \sqrt{I_{dc}^2 + I_{ac}^2} = \sqrt{10^2 + \left(\frac{20}{\sqrt{2}}\right)^2} = 17.32 \text{ A}$$

**1.20 (c)**

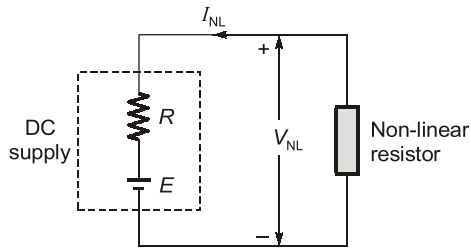
The Resultant ( $R$ ) when viewed from voltage source

$$= \frac{100}{8} = 12.5$$

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

$$\therefore R = 12.5 - 10 \parallel 10 = 12.5 - 5 = 7.5 \Omega$$



**1.21 (a)**

$$V_{NL} = I_{NL}^2 \quad \dots(i)$$

$$V_{NL} = E - I_{NL}R \quad \text{where, } E = 3 \text{ V}$$

$$R = 2 \Omega$$

and

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

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

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

-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

$$= V_{NL} I_{NL} = I_{NL}^2 I_{NL} = I_{NL}^3 = 1^3 = 1 \text{ W}$$

**1.22 (a)**

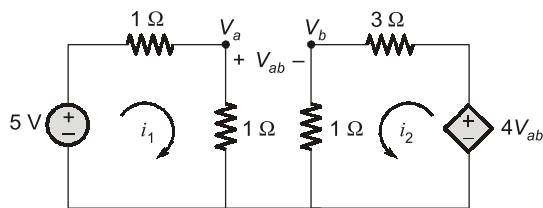
$$i = 1 \text{ A}$$

Applying KVL, we get

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

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

**Note:** KVL is based on the conservation of energy.

**1.23 (b)**

By KVL in Loop-1,

$$5 - i_1 - i_1 = 0$$

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

∴

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

By KVL in Loop-2,

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

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

∴

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

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

$$i_2 = V_{ab} = V_b \Rightarrow i_2 = 1.25 \text{ A}$$

**1.24 (a)**

Bridge is balanced i.e., node C and node D are at same potential. Therefore, no current flows through  $2 \text{ k}\Omega$  resistor.

**1.25 (d)**

Let resistance of a single incandescent lamp =  $R$ .  
Power consumed by a single lamp,  $P = 200 \text{ W}$ .  
When connected across voltage,  $V = 220 \text{ V}$ .

$$\text{So, } P = \frac{V^2}{R} \Rightarrow 200 = \frac{220^2}{R} \Rightarrow R = 242 \Omega$$

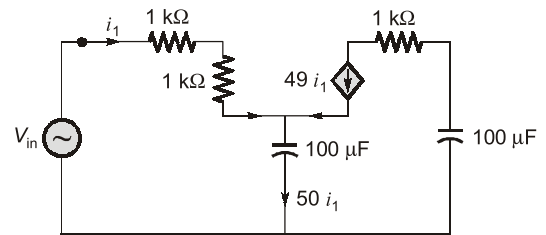
Let,  $n$  number of lamps are connected in series across voltage  $V = 200 \text{ V}$ .

So total resistance of lamps,

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

Total power consumed,

$$P = \frac{V^2}{R_{eq.}} \Rightarrow 100 = \frac{220^2}{242n} \Rightarrow n = 2$$

**1.26 (a)**

Applying KVL, we get

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

$$\Rightarrow V_{in} = i_1[2 - j50 X_C]$$

$$\text{Input impedance} = \frac{V_{in}}{i_1} = 2 - j50 X_C$$

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

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

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

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

**1.27 (b)**

Voltage across  $2 \Omega$  resistance =  $V_s = 4 \text{ V}$

$$\text{Current through } 2 \Omega \text{ resistance} = \frac{V_s}{R} = \frac{4}{2} = 2 \text{ A}$$

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

So, to double current through  $2 \Omega$  resistance, voltage source is doubled, i.e.,

$$V_s = 8 \text{ V}$$