27 Years
Solved Papers

# GATE 2018

## Electrical Engineering

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

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**GATE - 2018 : Electrical Engineering** Topicwise Previous GATE Solved Papers (1991-2017)



| | | |
|---|---|---|
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# 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 2018 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

# Contents

# Unit .I

# Electric Circuits

## Contents

UNIT I

# Electric Circuits

**Syllabus :** Network graph, KCL, KVL, Node and Mesh analysis, Transient response of dc and ac networks, Sinusoidal steady-state analysis, Resonance, Passive filters, Ideal current and voltage sources, Thevenin's theorem, Norton's theorem, Superposition theorem, Maximum power transfer theorem, Two-port networks, Three phase circuits, Power and power factor in ac circuits.

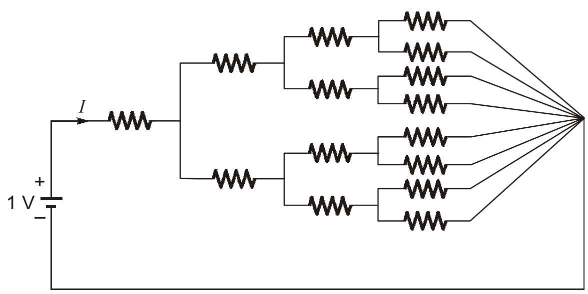
## Analysis of Previous GATE Papers

| Exam Year | 1 Mark Ques. | 2 Marks Ques. | 5 Marks Ques. | Total Marks |
|---|---|---|---|---|
| 1991 | – | – | – | **–** |
| 1992 | 4 | 2 | – | **8** |
| 1993 | 2 | – | – | **2** |
| 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** |

| Exam Year | 1 Mark Ques. | 2 Marks Ques. | Total Marks |
|---|---|---|---|
| 2009 | 2 | 6 | **14** |
| 2010 | 3 | 4 | **11** |
| 2011 | 3 | 5 | **13** |
| 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** |

# 1 KCL, KVL and Phasor Calculations

1.1 All resistances in figure are 1 Ω each. The value of current '$I$' is

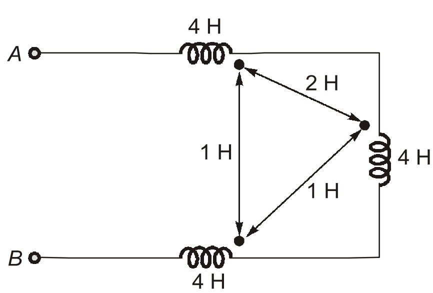



(a) $\frac{1}{15}$ A (b) $\frac{2}{15}$ A

(c) $\frac{4}{15}$ A (d) $\frac{8}{15}$ A

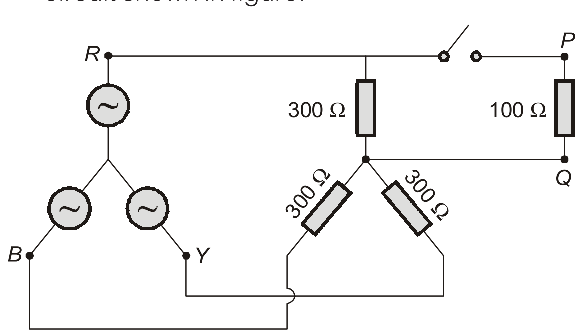
[1992 : 1 Mark]

1.2 The equivalent inductance seen at terminals $A-B$ in figure is ........... H.




[1992 : 2 Marks]

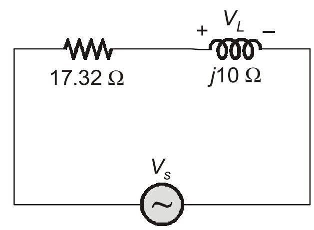
1.3 Using Thevenin equivalent circuit, determine the rms value of the voltage across the 100 ohm resistor after the switch is closed in the 3-phase circuit shown in figure.




400 V / $\sqrt{3}$ Phase balanced source

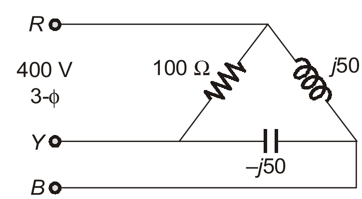
[1992 : 2 Marks]

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



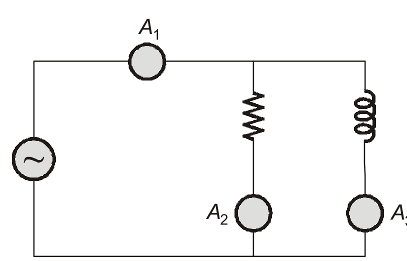

[1994 : 2 Marks]

1.5 A set of 3 equal resistors, each of value $R_x$, connected in star across $RYB$ of given figure consumes the same power as the unbalanced delta connected load shown. The value of $R_x$ is ______ Ω.




[1994 : 2 Marks]

1.6 In the circuit shown in figure, ammeter $A_2$ reads 12 A and $A_3$ reads 9 A. $A_1$ will read _____ A.




[1995 : 1 Mark]

1.7 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

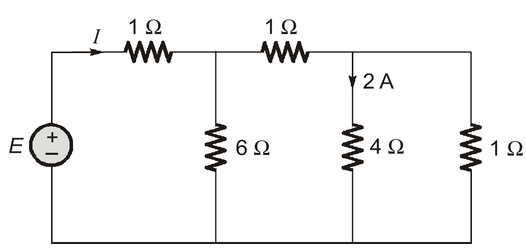
[1997 : 1 Mark]

1.8 Energy stored in capacitor over a cycle, when excited by an a.c. source is
(a) the same as that due to a d.c. source of equivalent magnitude.
(b) half of that due to a d.c. source of equivalent magnitude.
(c) zero.
(d) none of the above [1997 : 1 Mark]

1.9 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 ______ [1997 : 2 Marks]

1.10 A 10 V 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.
[1997 : 2 Marks]

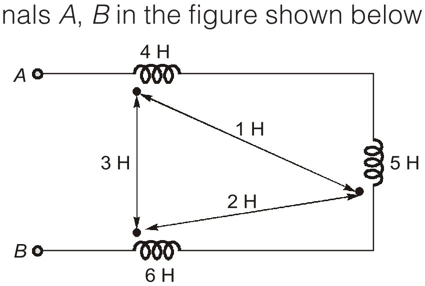
1.11 The value of *E* and *I* for the circuit shown in figure, are ......... V and .......... A.




[1997 : 2 Marks]

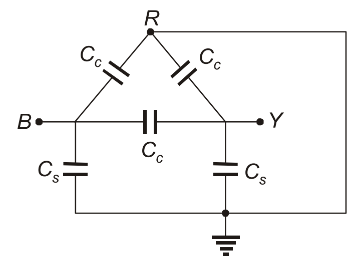
1.12 A sinusoidal source of voltage *V* and frequency *f* is connected to a series circuit of variable resistance *R* and a fixed reactance *X*. The locus of the tip of the current phasor *I* as *R* is varied from 0 to ∞ is
(a) a semicircle with a diameter of *V*/*X*.
(b) a straight line with a slope 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).
[1998 : 1 Mark]

1.13 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
[1998 : 2 Marks]

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

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

[1999 : 1 Mark]

1.15 The RMS value of a half wave rectified symmetrical square wave current of 2 A is
(a) $\sqrt{2}$ A (b) 1 A
(c) $\frac{1}{\sqrt{2}\text{ A}}$ (d) $\sqrt{3}$ A

[1999 : 1 Mark]

1.16 A fixed capacitor of reactance $-j0.02$ Ω is connected in parallel across a series combination of a fixed inductor of reactance $j0.01$ Ω and a variable resistance *R*. As *R* is varied from zero to infinity, the locus diagram of the admittance of this *R*–*L*–*C* circuit will be
(a) a semi-circle of diameter *j*100 and center at zero.
(b) a semi-circle of diameter *j*50 and center at zero.
(c) a straight line inclined at an angle.
(d) a straight line parallel to the *x*-axis.
[1999 : 2 Marks]

1.17 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

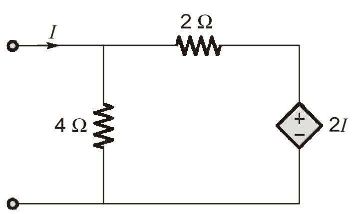
(a) $\sqrt{18}$ A and 1 Ω (b) 3 A and 2 Ω
(c) 1 A and 18 Ω (d) 6 A and 0.5 Ω

[1999 : 2 Marks]

1.18 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) $-14\sin(\omega t + 36.87°)$ mA
(d) $-10\cos(\omega t + 36.87°)$ mA

[1999 : 2 Marks]

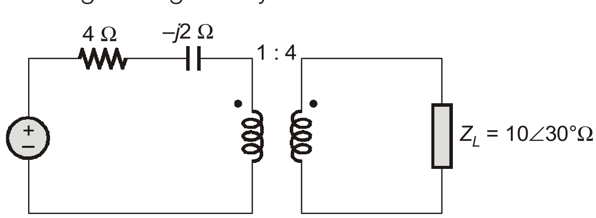
1.19 The circuit shown in the figure is equivalent to a load of




(a) $\frac{4}{3}$ ohms (b) $\frac{8}{3}$ ohms
(c) 4 ohms (d) 2 ohms

[2000 : 2 Marks]

1.20 The impedance seen by the source in the circuit in figure is given by




(a) $(0.54 + j0.313)$ ohms
(b) $(4 - j2)$ ohms
(c) $(4.54 - j1.69)$ ohms
(d) $(4 + j2)$ ohms

[2000 : 2 Marks]

1.21 Given two coupled inductors $L_1$ and $L_2$, their mutual inductance $M$ satisfies

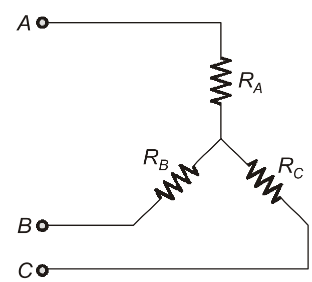
(a) $M = \sqrt{L_1^2 + L_2^2}$ (b) $M > \frac{(L_1 + L_2)}{2}$
(c) $M > \sqrt{L_1 L_2}$ (d) $M \le \sqrt{L_1 L_2}$

[2001 : 1 Mark]

1.22 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 Mark]

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

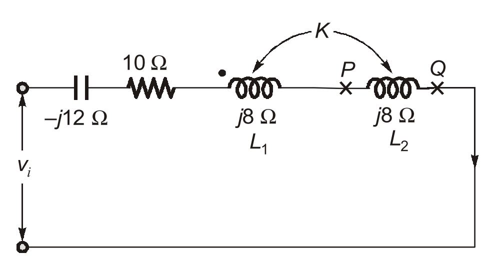



(a) $R_A = 4\ \Omega$, $R_B = 2\ \Omega$, $R_C = 5\ \Omega$
(b) $R_A = 2\ \Omega$, $R_B = 4\ \Omega$, $R_C = 7\ \Omega$
(a) $R_A = 3\ \Omega$, $R_B = 3\ \Omega$, $R_C = 4\ \Omega$
(a) $R_A = 5\ \Omega$, $R_B = 1\ \Omega$, $R_C = 10\ \Omega$

[2001 : 2 Marks]

1.24 In the circuit shown in figure it is found that the input ac voltage ($v_i$) and current $i$ are in phase.

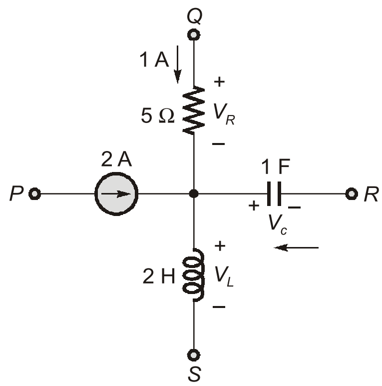
The coupling coefficient is $K = \frac{M}{\sqrt{L_1 L_2}}$, where $M$ is the mutual inductance between the two coils. The value of $K$ and the dot polarity of the coil $P$-$Q$ are




(a) $K = 0.25$ and dot at $P$
(b) $K = 0.5$ and dot at $P$
(c) $K = 0.25$ and dot at $Q$
(d) $K = 0.5$ and dot at $Q$

[2002 : 2 Marks]

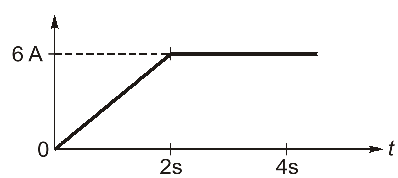
1.25 A segment of a circuit is shown in figure $V_R = 5$ V, $V_C = 4 \sin 2t$. The voltage $V_L$ is given by




(a) $3 - 8 \cos 2t$ (b) $32 \sin 2t$
(c) $16 \sin 2t$ (d) $16 \cos 2t$

[2003 : 1 Mark]

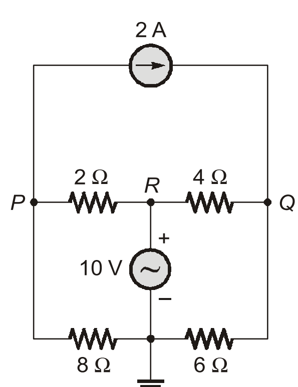
1.26 Figure shows the waveform of the current passing through an inductor of resistance 1 Ω and inductance 2 H. The energy absorbed by the inductor in the first four seconds is




(a) 144 J (b) 98 J
(c) 132 J (d) 168 J

[2003 : 1 Mark]

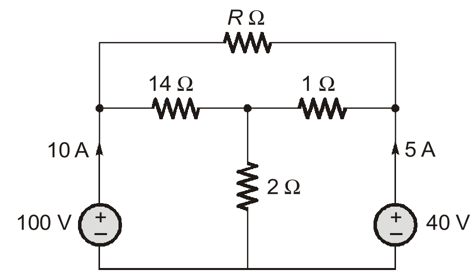
1.27 In figure, the potential difference between points $P$ and $Q$ is




(a) 12 V (b) 10 V
(c) –6 V (d) 8 V

[2003 : 2 Marks]

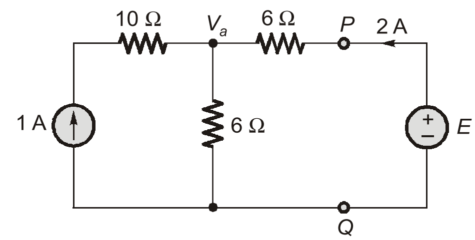
1.28 In figure, the value of $R$ is




(a) 10 Ω (b) 18 Ω
(c) 24 Ω (d) 12 Ω

[2003 : 2 Marks]

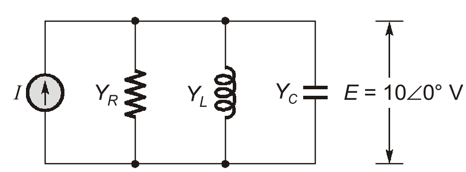
1.29 In figure, the value of the source voltage is




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

[2004 : 2 Marks]

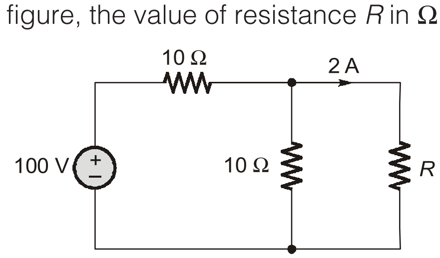
1.30 In figure, the admittance values of the elements in Siemens are $Y_R = 0.5 + j0$, $Y_L = 0 - j1.5$, $Y_C = 0 + j0.3$ respectively. The value of $I$ as a phasor when the voltage $E$ across the elements is $10\angle 0°$ V is




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

[2004 : 2 Marks]

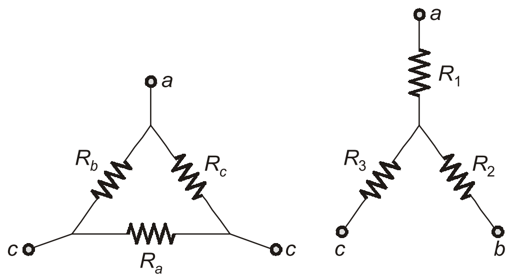
1.31 In figure, the value of resistance $R$ in Ω is




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

[2004 : 2 Marks]

1.32 In figure, $R_a$, $R_b$ and $R_c$ are 20 Ω, 10 Ω and 10 Ω respectively. The resistances $R_1$, $R_2$ 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

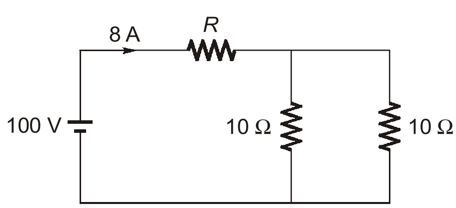
[2004 : 2 Marks]

1.33 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 Marks]

1.34 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

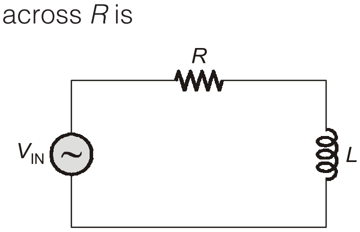
[2005 : 1 Mark]

1.35 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

[2005 : 1 Mark]

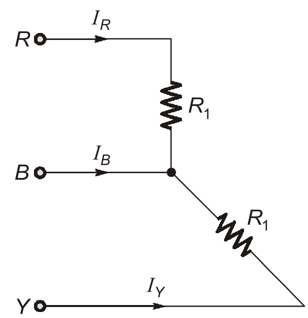
1.36 The $RL$ circuit of the figure is fed from a constant magnitude, variable frequency sinusoidal voltage source $V_{IN}$. At 100 Hz, the $R$ and $L$ elements each have a voltage drop $u_{RMS}$. If the frequency of the source is changed to 50 Hz, then new voltage drop across $R$ is




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

[2005 : 2 Marks]

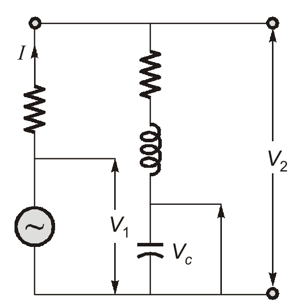
1.37 For the three-phase circuit shown in the figure the ratio of the currents $I_R : I_Y : I_B$ is given by




(a) $1 : 1 : \sqrt{3}$ (b) 1 : 1 : 2
(c) 1 : 1 : 0 (d) $1 : 1 : \sqrt{3/2}$

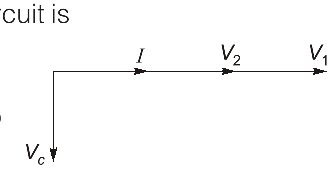
[2005 : 2 Marks]

1.38 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 $I$.

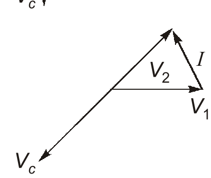



The phasor diagram which is applicable to this circuit is

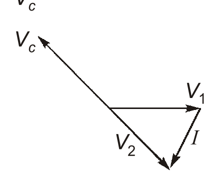
(a)

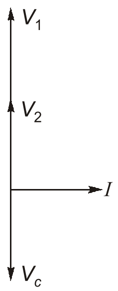



(b)




(c)



(d) 

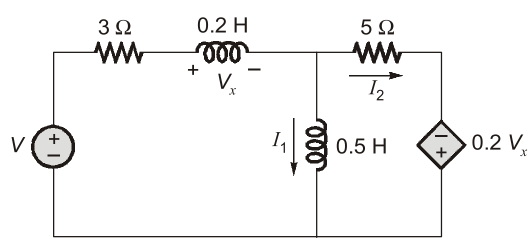

[2006 : 2 Marks]

1.39 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

[2006 : 2 Marks]

1.40 The state equation for the current $I_1$ shown in the network shown below in terms of the voltage $V_x$ and the independent source $V$, is given by




(a) $\frac{dI_1}{dt} = -1.4\,V_x - 3.75\,I_1 + \frac{5}{4}\,V$

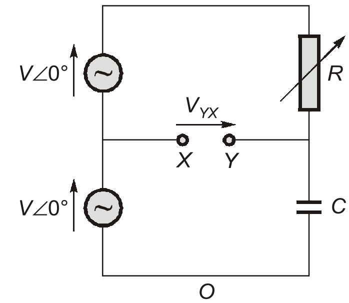
(b) $\frac{dI_1}{dt} = -1.4\,V_x - 3.75\,I_1 - \frac{5}{4}\,V$

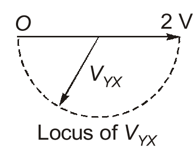
(c) $\frac{dI_1}{dt} = -1.4\,V_x + 3.75\,I_1 + \frac{5}{4}\,V$

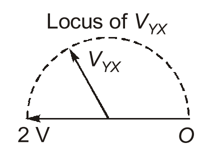
(d) $\frac{dI_1}{dt} = -1.4\,V_x + 3.75\,I_1 - \frac{5}{4}\,V$

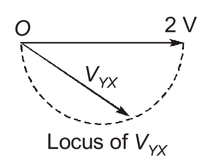
[2007 : 2 Marks]

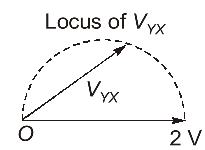
1.41 In the figure given below all phasors are with reference to the potential at point "$O$". The locus of voltage phasor $V_{YX}$ as $R$ is varied from zero to infinity is shown by




(a) 


(b) 


(c) 


(d) 


[2007 : 2 Marks]

1.42 A 3 V dc 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

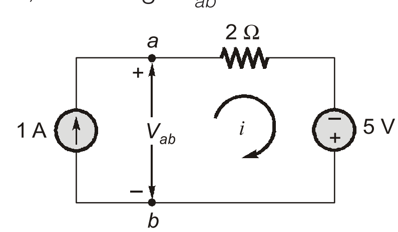
[2007 : 2 Marks]

1.43 The Thevenin's equivalent of a circuit operating at $\omega$ = 5 rad/s, has $V_{oc}$ = 3.71∠–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

[2008 : 1 Mark]

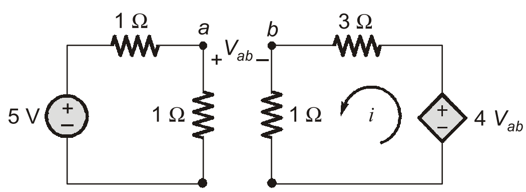
1.44 Assuming ideal elements in the circuit shown below, the voltage $V_{ab}$ will be



(a) –3 V (b) 0 V
(c) 3 V (d) 5 V

[2008 : 2 Marks]

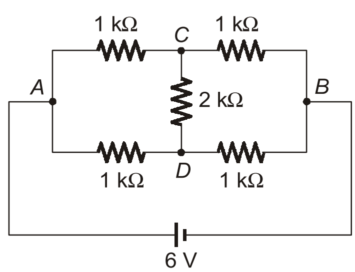
1.45 In the circuit shown in the figure, the value of the current $i$ will be given by




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

[2008 : 2 Marks]

1.46 The current through the 2 kΩ resistance in the circuit shown is




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

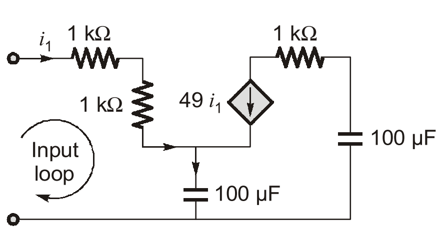
[2009 : 1 Mark]

1.47 How many 200 W/220 V incandescent $l$ amps 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 Mark]

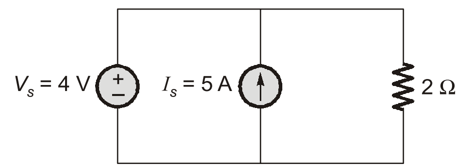
1.48 The equivalent capacitance of the input loop of the circuit shown is




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

[2009 : 2 Marks]

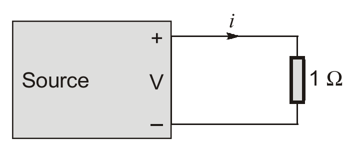
1.49 For the circuit shown, find out the current flowing through the 2 Ω resistance. Also identify the changes to be made to double the current through the 2 Ω resistance.




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

[2009 : 2 Marks]

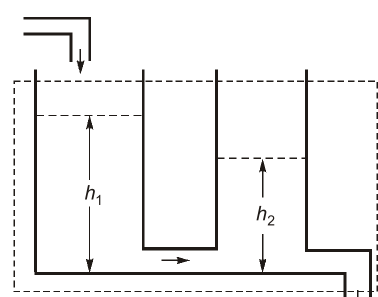
1.50 As shown in the figure, a 1 Ω resistance is connected across a source that has a load line $v + i = 100$. The current through the resistance is



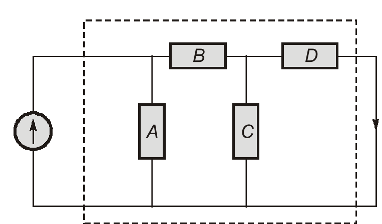

(a) 25 A (b) 50 A
(c) 100 A (d) 200 A

[2010 : 1 Mark]

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




(a) Coupled tank




(b) Electrical equivalent

(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 Mark]

## Answers KCL, KVL and Phasor Calculations

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1.1 (d) | 1.7 (b) | 1.8 (c) | 1.12 (a) | 1.13 (c) | 1.14 (a) | 1.15 (c) | 1.16 (a) | 1.17 (b) |
| 1.18 (d) | 1.19 (b) | 1.20 (c) | 1.21 (d) | 1.22 (d) | 1.23 (b) | 1.24 (c) | 1.25 (b) | 1.26 (c) |
| 1.27 (c) | 1.28 (d) | 1.29 (c) | 1.30 (d) | 1.31 (b) | 1.32 (a) | 1.33 (d) | 1.34 (c) | 1.35 (a) |
| 1.36 (c) | 1.37 (a) | 1.38 (a) | 1.39 (b) | 1.40 (a) | 1.41 (a) | 1.42 (a) | 1.43 (b) | 1.44 (a) |
| 1.45 (b) | 1.46 (a) | 1.47 (d) | 1.48 (a) | 1.49 (b) | 1.50 (b) | 1.51 (d) | 1.52 (b) | 1.53 (b) |
| 1.54 (b) | 1.55 (b) | 1.56 (d) | 1.57 (c) | 1.58 (b) | 1.59 (b) | 1.60 (a) | 1.61 (c) | 1.66 (a) |
| 1.68 (c) | 1.70 (a) | 1.71 (a) | 1.74 (b) | 1.75 (d) | 1.81 (d) | | | |

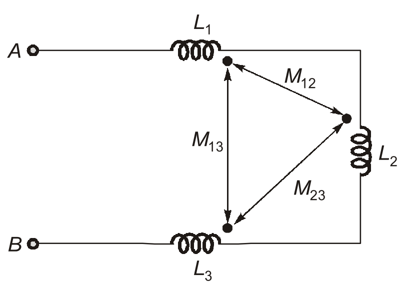
## Explanations KCL, KVL and Phasor Calculations

**1.1 (d)**

$$R = 1 + [(1 \,||\, 1 + 1) \,||\, (1 \,||\, 1 + 1) + 1] \,||\, [(1 \,||\, 1 + 1) \,||\, (1 \,||\, 1 + 1) + 1]$$

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

**1.2 Sol.**



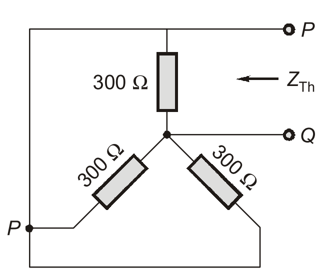

$$L = L_1 + L_2 + L_3 - 2M_{12} + 2M_{23} - 2M_{13}$$
$$= 4 + 4 + 4 - (2 \times 2) + (2 \times 1) - (2 \times 1)$$
$$= 8\text{ H}$$

**1.3 Sol.**

$$V_{Th} = V_{ph} = \frac{400}{\sqrt{3}} \simeq 231\text{ V}$$

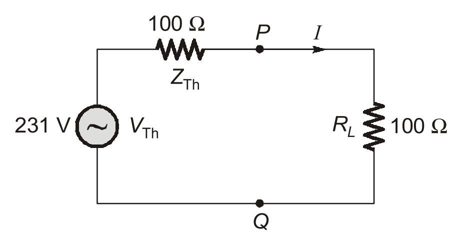
Now, to find $Z_{Th}$, replacing all the independent voltage sources by short circuit,

We have,




$$\therefore \quad Z_{Th} = 300 \,||\, 300 \,||\, 300 = 100\,\Omega$$

$\therefore$ Thevenin's equivalent circuit:




$\therefore$ Voltage across 100 Ω resistor

$$= 231 \times \frac{100}{100 + 100} \quad \text{(voltage division rule)}$$

$$= \frac{231}{2} = 115.5\text{ V}$$

**1.4 Sol.**

$$V_L = V_s \times \frac{j10}{17.32 + j10}$$

(Using voltage division rule)

$$= V_s \times 0.5\angle 60^\circ \text{ volts}$$

Hence, $V_L$ has a phase angle of 60° with respect to $V_s$.

**1.5 Sol.**

$\because$ Only resistor consumes power, neither inductor nor capacitor.

$\therefore$ Power consumed in unbalanced delta connected load $= \dfrac{V_{ph}^2}{R} = \dfrac{V_L^2}{R} = \dfrac{(400)^2}{100} = 1600$ W

Power consumed in a balanced star connection containing a set of equal resistors (in all three phases), each of value

$$R_x = 3\left[\frac{V_{ph}^2}{R_x}\right] = \frac{V_L^2}{R_x} = \frac{(400)^2}{R}$$

∵ According to the ques, power consumed in both the cases is equal.

$$\therefore \quad 1600 = \frac{(400)^2}{R}$$

$$\Rightarrow \quad R = 100\ \Omega$$

**1.6 Sol.**

∵ Currents in resistor and inductor will be in quadrature for same voltage across them.

$$\therefore \quad I_{A_1} = \sqrt{I_{A_2}^2 + I_{A_3}^2} = \sqrt{12^2 + 9^2} = 15\ \text{A}$$

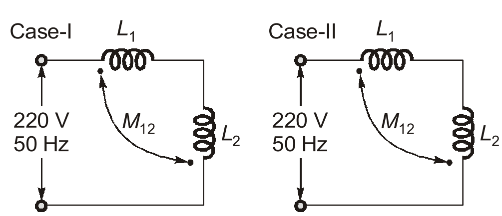
**1.7 (b)**

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.

**1.8 (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.

**1.9 Sol.**




$$|I_1| = \frac{V}{\omega(L_1 + L_2 - 2M_{12})}$$

$$|I_2| = \frac{V}{\omega(L_1 + L_2 + 2M_{12})}$$

From above expressions, it is clear that

$$|I_1| > |I_2|$$

∴ Taking, $|I_1| = 10$ A and $|I_2| = 8$ A

and putting, $V = 220$ V

and $L_1 = L_2 = L$

We have,

$$10 = \frac{200}{\omega(2L - 2M_{12})} \quad \text{...(i)}$$

$$8 = \frac{200}{\omega(2L + 2M_{12})} \quad \text{...(ii)}$$

On solving equation (i) and equation (ii)

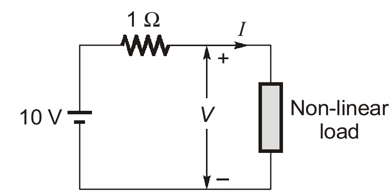
We get, $M_{12} = \frac{1}{9}L$

Which can be written as:

$$M_{12} = \frac{1}{9}\sqrt{L \cdot L} = \frac{1}{9}\sqrt{L_1 \cdot L_2}$$

Hence, coefficient of coupling $= \frac{1}{9}$.

**1.10 Sol.**




Using KVL,

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

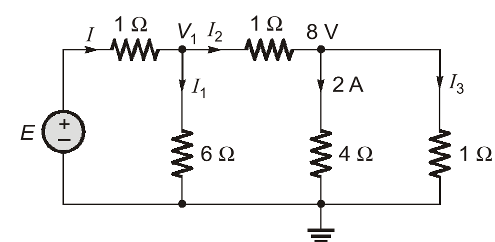
Given, $7I = V^2 + 2V$ ...(ii)

On solving equation (i) and equation (ii)

we get, $V = 5$ V

$I = 5$ A

**1.11 Sol.**




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

Current through 1 Ω resistor,

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

$$I_2 = I_3 + 2$$
$$= 10\ \text{A}$$
$$V_1 = 8 + 1 \times 10$$
$$= 18\ \text{V}$$

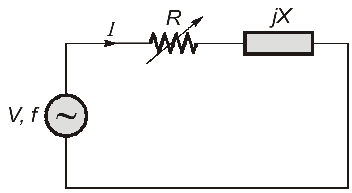
Current through 6 Ω resistor,

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

Current through 1 Ω resistor,

$$I = I_1 + I_2 = 3 + 10 = 13\ \text{A}$$
$$E = V_1 + I \cdot 1$$
$$E = 18 + 13 \times 1 = 31\ \text{V}$$

**1.12 (a)**



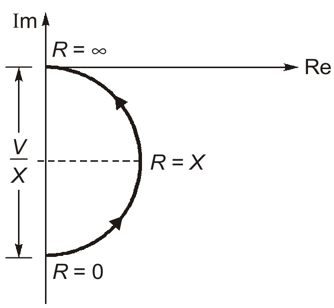

$$I = \frac{V}{R + jX} = \frac{V}{\sqrt{R^2 + X^2}} \angle -\tan^{-1}\left(\frac{X}{R}\right)$$

For $R = 0, \quad I = \frac{V}{X} \angle -90°$

For $R = X, \quad I = \frac{V}{\sqrt{2}X} \angle -45°$

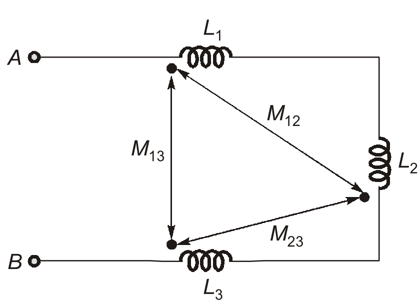
For $R = \infty, \quad I = 0\angle 0°$

On plotting these three points we get,




Hence locus of $\vec{I}$ is a semi-circle having diameter of $V/X$.

**1.13 (c)**

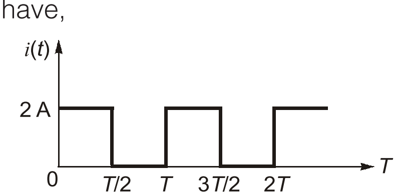



$$\begin{aligned} L &= L_1 + L_2 + L_3 - 2M_{12} + 2M_{23} - 2M_{13} \\ &= 4 + 5 + 6 - (2 \times 1) + (2 \times 2) - (2 \times 3) \\ &= 11 \text{ H} \end{aligned}$$

**1.14 (a)**

To find: RMS value of $i(t)$

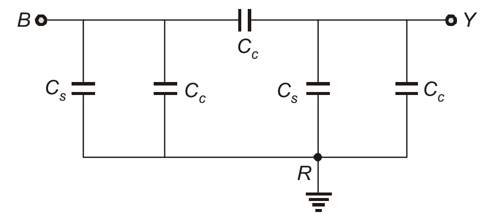
we have,




$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt} = \sqrt{\frac{1}{T} \times 4 \times \frac{T}{2}} = \sqrt{2} \text{ A}$$

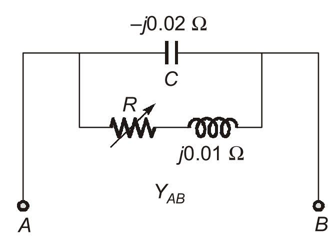
**1.15 (c)**

Given circuit can be redrawn as:




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

**1.16 (a)**



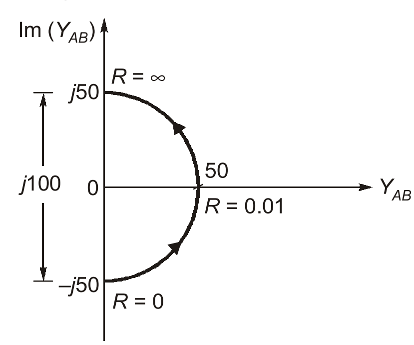

$$Y_{AB} = \frac{1}{-j0.02} + \frac{1}{R + j0.01}$$

For $R = 0$, $\quad Y_{AB} = -j50 = 50\angle -90°$

For $R = 0.01$, $\quad Y_{AB} = 50$

For $R = \infty$, $\quad Y_{AB} = j50 = 50\angle 90°$

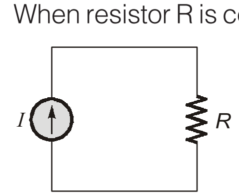
On plotting these three points,




Hence, locus of $\vec{Y}_{AB}$ is a semicircle of diameter j100 and center at zero.

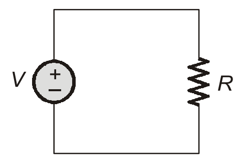
**1.17 (b)**

When resistor R is connected to a current source,




$P = I^2R = 18$ W

When resistor $R$ is connected to a voltage source




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

Given, $V = I$ (in magnitude)

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

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

On solving these two equations, we get

$I = 3$ A

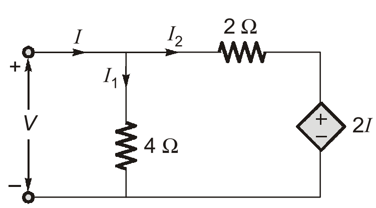
$R = 2\ \Omega$

**1.18 (d)**

$I_1 + I_2 + I_3 = 0$

$$I_3 = -I_1 - I_2$$
$$= -[-6 \sin(\omega t)] - 8 \cos\omega t$$
$$= 10\left[\frac{6}{10}\sin\omega t - \frac{8}{10}\cos\omega t\right]$$
$$= -10[\cos(36.87°)\cos\omega t - \sin(36.87°)\sin\omega t]$$
$$= -10 \cos(\omega t + 36.87°) \text{ mA}$$

**1.19 (b)**




Current through 4 Ω resistor,

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

Current through 2 Ω resistor,

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

Total current,

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

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

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

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

**1.20 (c)**

$$Z = (4 - j2) + \left(\frac{1}{4}\right)^2 \times 10\angle 30°$$
$$= (4.54 - j1.69)\Omega$$

**1.21 (d)**

$$M = K\sqrt{L_1 L_2}$$

Where, $K$ = coefficient of coupling

$\because$ $0 < K < 1$

$\therefore$ $M \leq \sqrt{L_1 L_2}$

**1.22 (d)**

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

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.

**1.23 (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 $R_C = 7\ \Omega$

**1.24 (c)**

Input ac voltage and current will be in phase only at resonance condition,

i.e. $X_C = X_L$

$$|-j12| = \left|j8 + j8 + 2k\sqrt{(j8)\times(j8)}\right|$$
$$12 = 8 + 8 + 16\,k$$
$$\Rightarrow \quad k = -\frac{4}{16} = -\frac{1}{4} = -0.25$$

Hence coupling will be opposite

$\therefore$ Dot will be at $Q$.

**1.25 (b)**

By KCL,

$I_P + I_Q + I_C + I_L = 0$

$2 + 1 + I_C + I_L = 0$

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

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

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

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

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

$$= 32\sin 2t$$

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

**1.26 (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,

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

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

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

$$= 18\int_0^2 t\,dt = 18 \times \left.\frac{t^2}{2}\right|_0^2$$

$$= 18 \times \left[\frac{4}{2} - 0\right] = 30\text{ J}$$

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

$$E_{L_2} = \int_2^4 Li\left(\frac{di}{dt}\right)dt$$

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

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.

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

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

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

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

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

The total energy absorbed by the inductor in 4 sec

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

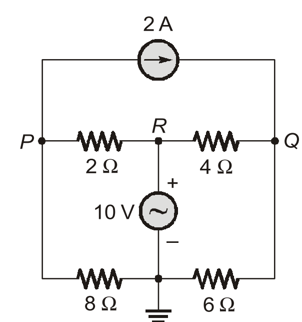
**1.27 (c)**

Given: $V_R = 10$ V

By KCL,

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

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




From equation (i),

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

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

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

$$V_P = 4.8$$

From equation (ii),

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

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

$\therefore$ $V_Q = 10.8$

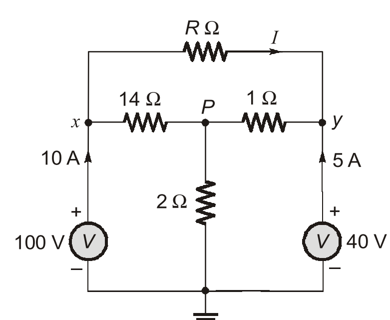
$\therefore$ $V_P - V_Q = -6$ V

**1.28 (d)**

By KCL,

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

$$22\,V_P = 660$$



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

Potential diffence between node $x$ and $y = 60$ V

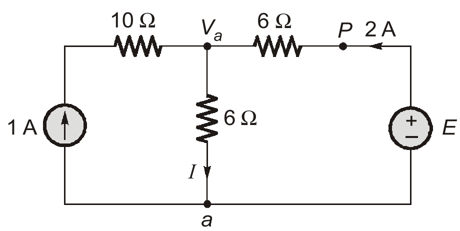
by taking KCL at node $y$

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

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

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

**1.29 (c)**




**Method-1:**

Using KCL,

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

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

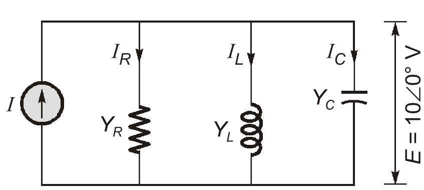
Where, $\quad \dfrac{E - V_a}{6} = 2$

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

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

$$V_a = 18\text{ V and } E = 30\text{ V}$$

**1.30 (d)**




$$I_R = Y_R E = (0.5 + j0) \times 10\angle 0° = 5\text{ A}$$

$$I_Y = Y_L E = (0 - j1.5) \times 10\angle 0° = -j15\text{ A}$$

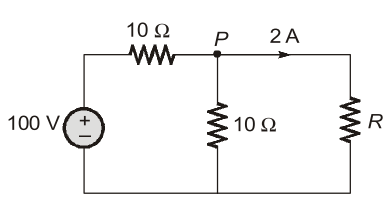
$$I_C = Y_C E = (0 + j0.3) \times 10\angle 0° = j3\text{ A}$$

$$I = I_R + I_Y + I_C$$

$$= 5 + (-j15) + j3$$

$$= 5 - j12\text{ A}$$

**1.31 (b)**



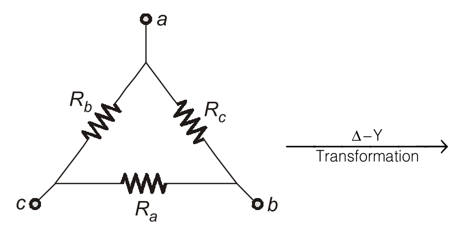

$$\frac{V_P - 100}{10} + \frac{V_P}{10} + 2 = 0$$

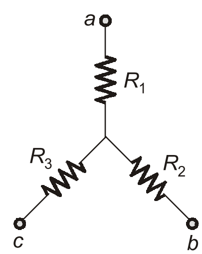
$$2\,V_P - 100 + 20 = 0$$

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

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

**1.32 (a)**




Given: $\quad R_a = 20\ \Omega$

$\quad R_b = 10\ \Omega$

and $\quad R_c = 10\ \Omega$

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

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

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

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

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

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

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

**1.33 (d)**

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

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

R:M:S value of resultant,

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

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

**1.34 (c)**

The Resultant (R) when viewed from voltage

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

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

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

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

**1.35 (a)**

R.M.S value of d.c voltage $= V_{dc}^{(rms)} = 3$ V

R.M.S value of a.c voltage $= V_{ac}^{(rms)}$

$$= \left(\frac{4}{\sqrt{2}}\right) \text{V}$$

$\therefore$ R.M.S value of the voltage

$$= \sqrt{3^2 + \left(\frac{4}{\sqrt{2}}\right)^2} = \sqrt{9+8} = \sqrt{17} \text{ V}$$

**1.36 (c)**

At $\quad f = 100$ Hz

$$|V_R| = |V_L|$$

as $R$ and $L$ are series connected, current through $R$ and $L$ is same, so

$$IR = IX_L = I\omega L$$

$$\Rightarrow \quad R = X_L = \omega L$$

$$I = \frac{V_{in}}{\sqrt{R^2 + X_L^2}}$$

$$= \frac{V_{in}}{\sqrt{R^2 + R^2}} = \frac{V_{in}}{\sqrt{2}R}$$

$$V_R = u_{rms} = IR$$

$$V_R = \left(\frac{V_{in}}{\sqrt{2}R}\right) \times R = \frac{V_{in}}{\sqrt{2}}$$

$$\Rightarrow \quad V_{in} = \sqrt{2}\, u_{rms} \quad \text{...(i)}$$

At $\quad f = 50$ Hz

$$X_L \propto f$$

So

$$X_L' = X_L \times \frac{50}{100} = \frac{X_L}{2} = \frac{R}{2}$$

$$I' = \frac{V_{in}}{\sqrt{R^2 + (X_L')^2}}$$

$$= \frac{V_{in}}{\sqrt{R^2 + \left(\frac{R}{2}\right)^2}} = \frac{2V_{in}}{\sqrt{5}R}$$

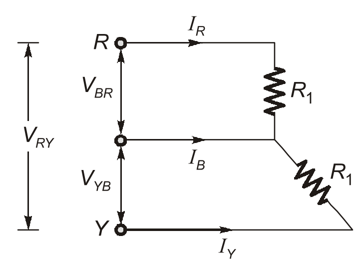
$$V_R' = I'R = \left(\frac{2V_{in}}{\sqrt{5}R}\right) R = \frac{2}{\sqrt{5}} V_{in}$$

From equation (i),

$$V_R' = \frac{2}{\sqrt{5}} \times (\sqrt{2}\, u_{rms})$$

$$= \frac{2\sqrt{2}}{\sqrt{5}} u_{rms} = \sqrt{\frac{8}{5}}\, u_{rms}$$

**1.37 (a)**




Assuming phase-sequence to be $RYB$

Taking $V_{RY}$ as the reference,

$$V_{RY} = V\angle 0°$$

$$V_{YB} = V\angle{-120°}$$

$$V_{BR} = V\angle{-240°}$$

$$I_R = \frac{V_{RB}}{R_1} = -\frac{V_{BR}}{R_1}$$

$$= -\frac{V\angle -240°}{R_1} = \frac{V}{R_1}\angle -60°$$

$$I_Y = \frac{V_{YB}}{R_1} = \frac{V\angle -120°}{R_1}$$

Using KCL,

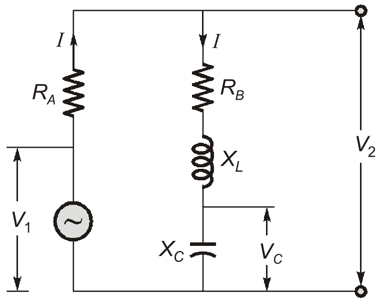
$$I_R + I_Y + I_B = 0$$

$$\frac{V}{R_1}\angle -60° + \frac{V}{R_1}\angle -120° + I_B = 0$$

$$\Rightarrow \quad I_B = \sqrt{3}\frac{V}{R_1}\angle 90°$$

So, $I_R : I_Y : I_B = \frac{V}{R_1} : \frac{V}{R_1} : \sqrt{3}\frac{V}{R_1} = 1 : 1 : \sqrt{3}$

**1.38 (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 $V_2 < V_1$

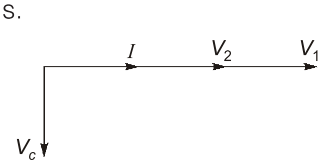
Voltage across the capacitor,

$$V_C = I \times X_C = I \times \frac{1}{j\omega C}$$

$$V_C = \frac{I}{\omega C} \angle -90°$$

So, $V_C$ lags the current by 90°.

The phasor diagram on the basis of above analysis.




**1.39 (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 or 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

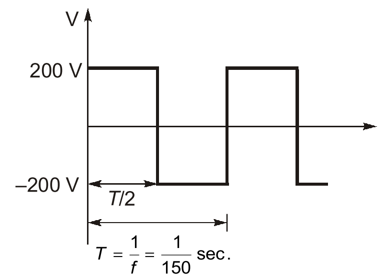
$$= V_{rms} = 230 \text{ V}$$

$$P_1 = \frac{V_{rms}^2}{R}$$

$$\Rightarrow \quad 2.3 \times 10^3 = \frac{230^2}{R}$$

$$\Rightarrow \quad R = 23\ \Omega$$

(ii) When heater connected to 400 V (peak to peak) square wave source of 150 Hz




$V_{rms}$ value of the input voltage

$$V_{rms} = \left[\frac{1}{T}\int_0^T V^2 dt\right]^{1/2}$$

$$= \left[\frac{1}{T}\left\{\int_0^{T/2} 200^2 dt + \int_{T/2}^{T} (-200)^2 dt\right\}\right]^{1/2}$$

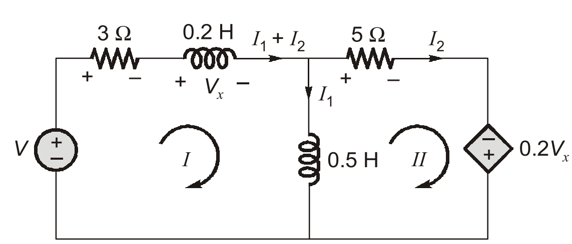
$$V_{rms} = 200 \text{ V}$$

$$P_2 = \frac{V_{rms}^2}{R} = \frac{200^2}{23} \times 10^{-3} \text{ kW}$$

$$= 1.739 \text{ kW}$$

**1.40 (a)**

Any state equation represents the dynamical behaviour of the given network. State equations usually follow a specific 'format' while being represented. On the left side of each state equation, the derivative of only one variable is used. On the right hand side a mathematical function is represented involving any or all the state variables and the sources.




Using KVL in Loop-I,

$$V - 3(I_1 + I_2) - V_x - 0.5\frac{dI_1}{dt} = 0 \qquad \text{...(i)}$$

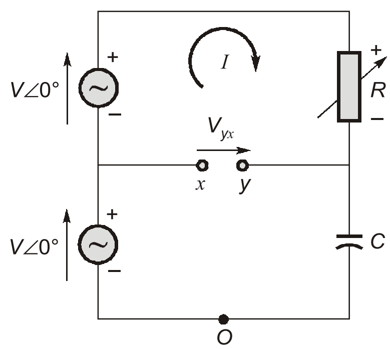
Using KVL in Loop-II,

$$0.5\frac{dI_1}{dt} - 5I_2 + 0.2V_x = 0 \qquad \text{...(ii)}$$

Eliminating $I_2$ from equation (i) and (ii), we get,

$$\frac{dI_1}{dt} = -1.4V_x - 3.75I_1 + \frac{5}{4}V$$

**1.41 (a)**




Let capacitive reactance = $X_C$

$$I = \frac{V\angle 0° + V\angle 0°}{R - jX_C} = \frac{2V}{R - jX_C}$$

Using KVL,

$$V_{YX} + IR - V = 0$$

$$\Rightarrow \quad V_{YX} = V - IR$$

$$V_{YX} = V - \left(\frac{2V}{R - jX_C}\right)R$$

$$= \frac{V(R - jX_C) - 2VR}{R - jX_C}$$

$$= -\frac{V(R + jX_C)}{(R - jX_C)}$$

**Method-1:**

$$V_{YX} = -V\left[\frac{R + jX_C}{R - jX_C}\right]$$

When, $R = 0$

$$V_{YX} = -V\left[\frac{0 + jX_C}{0 - jX_C}\right] = V$$

$$V_{YX} = -V \times \left[\frac{1 + j\dfrac{X_C}{R}}{1 - j\dfrac{X_C}{R}}\right]$$

When, $R \to \infty$

$$V_{YX} = -V$$

**Method-2:**

$$V_{YX} = -V\left[\frac{R + jX_C}{R - jX_C}\right]$$

$$= V\angle 180° \times \left(\frac{\sqrt{R^2 + X_C^2}\angle \tan^{-1}\left(\dfrac{X_C}{R}\right)}{\sqrt{R^2 + X_C^2}\angle \tan^{-1}\left(\dfrac{-X_C}{R}\right)}\right)$$

$$= V\angle\left(180° + 2\tan^{-1}\left(\frac{X_C}{R}\right)\right)$$

Magnitude of $V_{YX}$ = V

So, option (c) and (d) can not be correct, as magnitude is 2 V in these two options.

Angle of $V_{YX} = 180° + 2\tan^{-1}\left(\dfrac{X_C}{R}\right)$

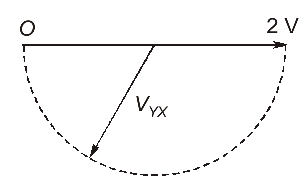
When, $R = 0$

$$\angle V_{YX} = 180° + 2\tan^{-1}(\infty)$$
$$= 180° + 2 \times 90° = 360°$$

When, $R = \infty$

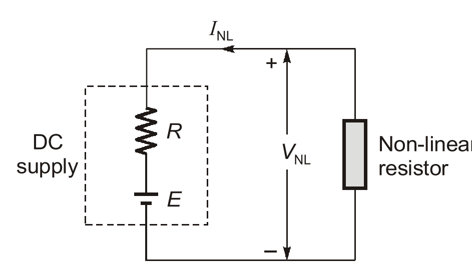
$$\angle V_{YX} = 180° + 2\tan^{-1}(0) = 180°$$

on the basis of above analysis, the locus of $V_{YX}$ is drawn below:




Locus of $V_{YX}$

**1.42 (a)**




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

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

where, $E = 3$ 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

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

**1.43 (b)**

Thevenin's Impedance:

$$Z_0 = 2.38 - j0.667\ \Omega$$

as real part is not 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.

**1.44 (a)**

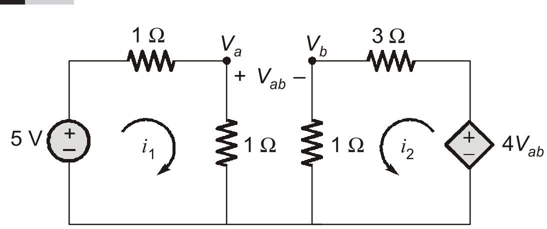
$$i = 1\text{ A}$$

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.

**1.45 (b)**




By KVL in Loop-1,

$$5 - i_1 - i_1 = 0$$
$$i_1 = \frac{5}{2} = 2.5\text{ A}$$
$$\therefore \quad V_a = 2.5\text{ V}$$

By KVL in Loop-2,

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

$$\therefore \quad V_b = 1 \times i_2 = V_{ab}$$
$$V_b = V_a - V_b$$
$$V_b = \frac{V_a}{2} = \frac{2.5}{2} = 1.25\text{ V}$$
$$i_2 = V_{ab} = V_b$$
$$i_2 = 1.25\text{ A}$$

**1.46 (a)**

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

**1.47 (d)**

Let resistance of a single incandescent lamp = $R$.

Power consumed by a single lamp, $P = 200$ W.

When connected across voltage, $V = 220$ V.

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

Let n number of lamps are connected is series across voltage $V = 200$ V.

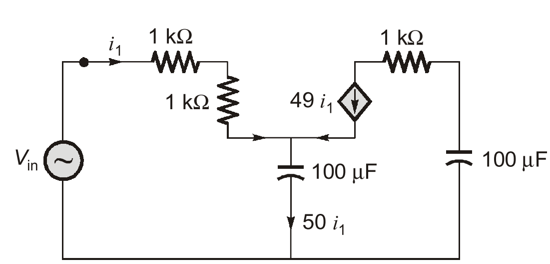
So total resistance of lamps,

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

Total power consumed,

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

**1.48 (a)**




Applying KVL,

$$V_{in} - i_1(1 + 1) - 50\,i_1(-jX_C) = 0$$
$$\Rightarrow \quad V_{in} = i_1[2 - j50\,X_C]$$

$$\text{Input impedance} = \frac{V_{in}}{i_1} = 2 - j50X_C$$

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

$$X_{C\,eq.} = 50\,X_C$$

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

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

**1.49 (b)**

Voltage across 2 Ω resistance

$$= V_s = 4\text{ V}$$

Current through 2 Ω 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 though 2 Ω resistance, voltage source is doubled i.e.

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

**1.50 (b)**

A resistor has linear characteristics

i.e. $V = Ri$

$\Rightarrow$ $V = i$

Load line,

$$V + i = 100$$

$$i + i = 100$$

Current through resistance

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

**1.51 (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

$\rho$ = Density of the fluid

$g$ = Acceleration due to gravity

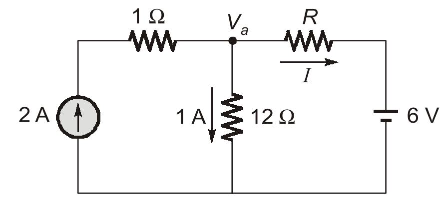
The hydraulic capacitance is represented by $A$ and $C$.

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 $D$.

**1.52 (b)**

Assuming voltage of the node $V_a$




$$V_a = 1 \times 12 = 12\text{ V}$$

Applying KCL,

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

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

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

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

$$\Rightarrow \quad R = 6\ \Omega$$

**1.53 (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

$$= \frac{1}{\sqrt{2}}\text{ A}$$

**1.54 (b)**

$$V(t) = 100\sqrt{2}\cos(100\pi t)$$

Voltage represented in phasor form:

$$V_{ph} = V_{rms}\angle\phi$$

$$V_{ph} = \frac{100\sqrt{2}}{\sqrt{2}}\angle 0°$$

$$i(t) = 10\sqrt{2}\sin\left(100\pi t + \frac{\pi}{4}\right)$$