SSC-JE
Staff Selection Commission

Junior Engineer

Electrical Engineering
Conventional Solved Questions
Previous Years Solved Papers

Also useful for State Service Examinations
and other Competitive Examinations

MADE EASY Publications

www.madeeasypublications.org
MADE EASY Publications

Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016
E-mail: infomep@madeeasy.in
Contact: 011-45124660, 08860378007
Visit us at: www.madeeasypublications.org

SSC-Junior Engineer : Electrical Engineering Previous Year Conventional Solved Papers

Copyright © by MADE EASY Publications.
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.

Second Edition: 2018

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

© All rights reserved by MADE EASY PUBLICATIONS. No part of this book may be reproduced or utilized in any form without the written permission from the publisher.
Staff Selection Commission-Junior Engineer has always been preferred by Engineers due to job stability. SSC-Junior Engineer examination is conducted every year. MADE EASY team has deeply analyzed the previous exam papers and observed that a good percentage of questions are repetitive in nature, therefore it is advisable to solve previous years papers before a candidate takes the exam.

The SSC JE exam is conducted in three stages as shown in table given below.

<table>
<thead>
<tr>
<th>Papers</th>
<th>Subject</th>
<th>Maximum Marks</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage 1:</strong></td>
<td>(i) General Intelligence &amp; Reasoning</td>
<td>50 Marks</td>
<td>2 hours</td>
</tr>
<tr>
<td>Paper-I:</td>
<td>(ii) General Awareness</td>
<td>50 Marks</td>
<td></td>
</tr>
<tr>
<td>Objective type</td>
<td>(iii) General Engineering : Electrical</td>
<td>100 Marks</td>
<td></td>
</tr>
<tr>
<td><strong>Stage 2:</strong></td>
<td>General Engineering : Electrical</td>
<td>300 Marks</td>
<td>2 hours</td>
</tr>
<tr>
<td>Paper-II Conventional Type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stage 3:</strong></td>
<td>Personal Interview</td>
<td>100 Marks</td>
<td>---</td>
</tr>
</tbody>
</table>

**Note:** In Paper-I, every question carry one mark and there is negative marking of ¼ marks for every wrong answer. Candidates shortlisted in Stage 1 are called for Stage 2. On the basis of combined score in Stage 1 and Stage 2, shortlisted candidates are called for Personal Interview.

In the second edition, the book has been thoroughly revised and Reasoning-Aptitude section is also added. MADE EASY has taken due care to provide complete solution with accuracy. Apart from Staff Selection Commission-Junior Engineer, this book is also useful for Public Sector Examinations and other competitive examinations for engineering graduates.

I have true desire to serve student community by providing good source of study and quality guidance. I hope this book will prove as an important tool to succeed in SSC-JE and other competitive exams. Any suggestion from the readers for improvement of this book is most welcome.

With Best Wishes

B. Singh
CMD, MADE EASY
Syllabus of Engineering Subjects

(For Conventional Type Papers)

Electrical Engineering

**Basic concepts:** Concepts of resistance, inductance, capacitance, and various factors affecting them. Concepts of current, voltage, power, energy and their units.

**Circuit law:** Kirchhoff’s law, Simple Circuit solution using network theorems.

**Magnetic Circuit:** Concepts of flux, mmf, reluctance, Different kinds of magnetic materials, Magnetic calculations for conductors of different configuration e.g. straight, circular, solenoidal, etc. Electromagnetic induction, self and mutual induction.

**AC Fundamentals:** Instantaneous, peak, R.M.S. and average values of alternating waves, Representation of sinusoidal wave form, simple series and parallel AC Circuits consisting of R, L and C, Resonance, Tank Circuit. Poly Phase system – star and delta connection, 3-phase power, DC and sinusoidal response of R-Land R-C circuit.

**Measurement and Measuring Instruments:** Measurement of power (1 phase and 3-phase, both active and re-active) and energy, 2 wattmeter method of 3-phase power measurement. Measurement of frequency and phase angle. Ammeter and voltmeter (both moving oil and moving iron type), extension of range wattmeter, Multimeters, Megger, Energy meter AC Bridges. Use of CRO, Signal Generator, CT, PT and their uses. Earth fault detection.

**Electrical Machines:** (a) D.C. Machine – Construction, Basic Principles of D.C. motors and generators, their characteristics, speed control and starting of D.C. Motors. Method of braking motor, Losses and efficiency of D.C. Machines. (b) 1 phase and 3 phase transformers – Construction, Principles of operation, equivalent circuit, voltage regulation, O.C. and S.C. Tests, Losses and efficiency. Effect of voltage, frequency and wave form on losses. Parallel operation of 1 phase /3 phase transformers. Auto transformers. (c) 3 phase induction motors, rotating magnetic field, principle of operation, equivalent circuit, torque-speed characteristics, starting and speed control of 3 phase induction motors. Methods of braking, effect of voltage and frequency variation on torque speed characteristics. Fractional Kilowatt Motors and Single Phase Induction Motors: Characteristics and applications.

**Synchronous Machines:** Generation of 3-phase e.m.f. armature reaction, voltage regulation, parallel operation of two alternators, synchronizing, control of active and reactive power. Starting and applications of synchronous motors.

**Generation, Transmission and Distribution:** Different types of power stations, Load factor, diversity factor, demand factor, cost of generation, inter-connection of power stations. Power factor improvement, various types of tariffs, types of faults, short circuit current for symmetrical faults. Switchgears – rating of circuit breakers, Principles of arc extinction by oil and air, H.R.C. Fuses, Protection against earth leakage/over current, etc. Buchholtz relay, Merz-Price system of protection of generators & transformers, protection of feeders and bus bars. Lightning arresters, various transmission and distribution system, comparison of conductor materials, efficiency of different system. Cable – Different type of cables, cable rating and derating factor.

**Estimation and Costing:** Estimation of lighting scheme, electric installation of machines and relevant IE rules. Earthing practices and IE Rules.

**Utilization of Electrical Energy:** Illumination, Electric heating, Electric welding, Electroplating, Electric drives and motors.

**Basic Electronics:** Working of various electronic devices e.g. P N Junction diodes, Transistors (NPN and PNP type), BJT and JFET. Simple circuits using these devices.
**Contents**

Conventional Solved Papers (Paper-II)  

**Chapter 1**  
**Electrical Circuits**  
1. Basic Concepts ........................................... 1  
2. Circuit Laws ................................................. 5  
3. Magnetic Circuits .......................................... 22  
4. AC Fundamentals .......................................... 29  

**Chapter 2**  
**Measurements & Instrumentation**  
1. Measurement of Resistance and Basics ............. 38  
2. Electromechanical Indicating Instruments .......... 43  
4. AC Bridges and Instrument Transformer .......... 57  
5. CRO, Electronic Measuring Instruments and Earth Fault Detection ........................................ 58  

**Chapter 3**  
**Electrical Machines**  
1. DC Machines ............................................... 60  
2. Single-Phase and Three-Phase Transformers .......... 71  
3. Single-Phase & Three-Phase Induction Motors and Drives ...................................................... 82  
4. Synchronous Machines .................................... 100  

**Chapter 4**  
**Power Systems**  
1. Power Generation and Economics of Generation .... 109  
2. Transmission Line Design and Performance ........ 114  
3. Power System Control ....................................... 118  
4. Power System Studies ..................................... 123  
5. Power System Protection ................................... 126  
6. Power Distribution and Cables ......................... 131  

**Chapter 5**  
**Analog & Digital Electronics**  
1. Semiconductor Diodes ...................................... 138  
2. Transistors (BJT, UJT, JFET and MOSFET) ........ 145  

---

(ssc-JE) Electrical Engineering
1. Basic Concepts

Q1. An iron choke coil takes 4 A when connected to a 20 V dc supply and takes 5 A when connected to 65 V, 50 Hz ac supply. Determine:
(i) resistance and inductance of the coil
(ii) the power factor

Solution:

(i) Case-1: When coil is connected to 20 V dc supply.
Current, \( I = 4 \) A
For dc supply, frequency, \( f = 0 \) Hz
\[
I = \frac{V}{R} \Rightarrow R = \frac{V}{I} = \frac{20}{4} = 5 \, \Omega
\]
Resistance of coil = 5 \( \Omega \)

Case-2: When coil is connected to 65 V, 50 Hz ac supply frequency, \( f = 50 \) Hz
Current, \( I = 5 \) A
So,
\[
Z = \frac{V}{I} = \frac{65}{5} = 13 \, \Omega
\]
\[
X_L = \sqrt{Z^2 - R^2} = \sqrt{(13)^2 - (5)^2} = 12 \, \Omega
\]
\[
\frac{2\pi fL}{2\pi} = 12 \Rightarrow L = \frac{12}{2\pi \times 50} = 0.0381974 \text{ or } 38.197 \text{ mH}
\]
Inductance of coil, \( L = 38.197 \text{ mH} \)

(ii) The power factor:

Case-1: If circuit is resistive so power factor will be unity.
\[
\cos \phi = \frac{R}{Z} = \frac{R}{R} = 1
\]

Case-2: \( Z = 13 \) \( \Omega \)
Power factor,
\[
\cos \phi = \frac{R}{Z} = \frac{5}{13} = 0.3846 \text{ (lagging)}
\]

Q2. (i) An oven operates on a 15.0 A current from a 120 V source. How much energy will it consume in 3.0 h of operation?

(ii) How many 100 W light bulbs connected to a 120 V supply can be turned on at the same time without blowing a 15.0 A fuse?

(iii) 3.0 A, 125 V circuit contains a 10.0 \( \Omega \) resistor. What resistor must be added in series for the circuit to have a current of 5.0 A?

[SSC JE - 2008 : 10 Marks]

[SSC JE - 2013 : 10 + 10 + 10 = 30 Marks]
Solution:

(i) Given that:

Source voltage = 120 V
Current = 15 A

Energy consumed in 3 hours is

\[ E = 120 \times 15 \times 3 = 5400 \text{ Whr} = 5.4 \text{ kWh} \]

(ii) Supply voltage = 120 V
Power of bulb = 100 W

Also given bulbs turn on at the same time

Resistance of each bulb = \( \frac{(120)^2}{100} = 144 \Omega \)

‘n’ number of bulbs connected in parallel,

\[ \frac{144}{n} = \frac{120}{15} \]
\[ 8n = 144 \]
\[ n = \frac{144}{8} = 18 \]

So, 18 bulbs connected to a 120 V supply can be turned on at the same time without blowing a 15 A fuse.

(iii) \[ 125 \text{ V} - 3 \text{ A} \rightarrow 125 \text{ V} \]

\[ 10 \Omega \]

\[ R_{\text{res}} \]

\[ I = 5 \text{ A} \]

Note: Given data is incorrect, because by adding a resistor in series, the circuit current will decrease from 3 A.

Q.3 A copper wire has a resistance of 0.85 Ω at 20°C. What will be its resistance at 40°C? Temperature coefficient of resistance of copper at 0°C is 0.004° Ω/°C.

[SSC JE - 2014 : 10 Marks]

Solution:

Given that:

Temperature coefficient of copper at 0°C is 0.004° Ω/°C

\[ R_{20} = 0.85 \text{ Ω at 20°C} \]
\[ R_{20} = R_0 [1 + \alpha \Delta t] \]
\[ 0.85 = R_0 [1 + 0.004 (20 - 0)] \]
\[ R_0 = \frac{0.85}{1.004} = 0.787 \Omega \]

Resistance at 40°C,

\[ R_{40} = R_0 [1 + \alpha \Delta t] \]
\[ = 0.787 [1 + 0.004(40 - 0)] = 0.91 \Omega \]

Method-2:

At 20°,

Resistance = 0.85 Ω

At 40°, Change in temperature = \( \Delta t = 40 - 20 = 20°C \)

\[ R_{40} = R_{20} (1 + \alpha \Delta t) \]
\[ = 0.85(1 + 0.004 \times 20°C) \]
\[ = 0.91 \Omega \]
Q.4 Two conductors, one of copper and the other of iron, are connected in parallel and carry equal currents at 30° C. What proportion of current will pass through each, if the temperature is raised to 90°C? The temperature coefficients of resistance at 0°C are 0.0043/°C and 0.0063/°C for copper and iron respectively.

Solution:
Let resistance of copper and iron are \( R_1 \) and \( R_2 \) respectively at 30°C.

Now at 90°C, change in temperature,
\[
\Delta t = 90° - 30° = 60°
\]
\[
R_1' = R_1(1 + \alpha_1 \Delta t) = R_1(1 + 0.0043 \times 60)= 1.258 R_1 \quad \ldots (i)
\]

and
\[
R_2' = R_2(1 + \alpha_2 \Delta t) = R_2(1 + 0.0063 \times 60)= 1.378 R_2 \quad \ldots (ii)
\]

Given currents are equal at 30°C i.e. \( I_1 = I_2 \)

and
\[
I = \frac{1}{R}
\]

so,
\[
\frac{I_1}{I_2} = \frac{R_2}{R_1}
\]

i.e.,
\[
1 = \frac{R_2}{R_1} \Rightarrow R_1 = R_2
\]

so, at 90°C,
\[
\frac{I_1'}{I_2'} = \frac{R_2'}{R_1'}\quad \ldots (iii)
\]

Substituting the value of \( R_1' \) and \( R_2' \) in equation (iii), we get
\[
\frac{I_1'}{I_2'} = \frac{1.378}{1.258} = 1.173
\]

Q.5 Determine the resistance and the power dissipation of a resistor that must be placed in series with a 50 ohm resistor across a 220 V source in order to limit the power dissipation in the 50 ohm resistor to 200 watts.

Solution:
Let \( R \) is unknown resistance connected in series with 50 Ω.

Power dissipation in 50 Ω resistor is 200 W.
\[
P = I^2 R_{50} = I^2 \times (50) = 200 \text{ W}
\]

\[
I_2 = \frac{200}{50} = 4 \text{ A}
\]

\[
I = 2 \text{ A}
\]

Apply KVL in loop (1),
\[
V_s = (R + 50) I
\]

\[
(R + 50) = \frac{V_s}{I} = \frac{220}{2} = 110 \Rightarrow R = 60 \Omega
\]

Power dissipation of resistance, \( R \)
\[
I^2 R = (2)^2 \times 60 = 240 \text{ W}
\]
Q.6 A variable air capacitor has 10 movable plates and 11 stationary plates. The area of each plate is \(0.002 \text{ m}^2\) and separation between opposite plates is \(0.001 \text{ m}\). Determine the maximum capacitance of this variable capacitor.

[SSC JE - 2015 : 10 Marks]

Solution:
Given that:
10 movable plates,
11 variable plates,
Area of each plate, \(A = 0.002 \text{ m}^2\)
Distance between plates, \(d = 0.001 \text{ m}\)

![Diagram of a variable air capacitor with movable and stationary plates.]

Total 20 capacitors will be formed using 10 movable and 11 stationary plates.
To obtain maximum capacitance, the capacitors are connected in parallel.
In above diagram all stationary plates connected to positive terminal of voltage source and all movable plates connected to negative terminal of voltage source.

![Diagram of capacitors connected in parallel.]

Capacitance of each capacitor is

\[
C = \frac{\varepsilon_0 A}{d} = \frac{8.854 \times 10^{-12} \times 0.002}{0.001} = 17.708 \times 10^{-12} \text{ F}
\]

\(C_1 = C_2 = C_3 = \ldots\ldots = C_{20} = C\)

\(C_{eq} = C_1 + C_2 + C_3 + \ldots\ldots + C_{20} = 20C\)

\(= 20 \times 17.708 \times 10^{-12} = 354.16 \times 10^{-12} = 0.35416 \times 10^{-16} = 0.354 \text{ nF}\)

Q.7 A conducting wire has a resistance of \(5 \Omega\). What is the resistance of other wire of the same material but having half the diameter and four times the length?

[SSC JE - 2016 : 15 Marks]
Solution:

Given,

\[ R = 5 \, \Omega \]

\[ R = \frac{\rho l}{A} \]

\[ \Rightarrow \]

\[ R \propto \frac{l}{d^2} \]

Given,

\[ l_2 = 4l_1 \]

\[ d_2 = \frac{d_1}{2} \]

\[ \therefore \]

\[ \frac{R_2}{R_1} = \left( \frac{l_2}{l_1} \right) \times \left( \frac{d_1}{d_2} \right)^2 = 4 \times (2)^2 = 16 \]

\[ \Rightarrow \]

\[ R_2 = 16 \times 5 = 80 \, \Omega \]

Q.8 Two coils connected in parallel across a 100 V dc supply, take 10 A current from the supply. Power dissipated in one coil is 600 W. What is the resistance of each coil?

[SSC JE - 2016 : 15 Marks]

Solution:

Given,

Power dissipated in one coil = 600 W

\[
600 = 5^2 \times R
\]

\[ \Rightarrow \]

\[ R = \frac{600}{25} = 24 \, \Omega \]

Q.9 An aeroplane with a wing span of 52 meters is flying horizontally at 1100 km/h. If the vertical component of the earth’s magnetic field is \( 38 \times 10^{-6} \) T, find the emf generated between the wing-tips.

[SSC JE - 2016 : 10 Marks]

Solution:

Given,

\[ l = 52 \, m \]

\[ V = 1100 \, km/h \]

\[ = 1100 \times \frac{1000}{3600} \]

\[ B = 38 \times 10^{-6} \, T \]

\[ \Rightarrow \]

\[ V = 1100 \times \frac{1000}{3600} = 305.56 \, m/s \]

\[ \text{emf} = BIV = 38 \times 10^{-6} \times 52 \times 305.56 \]

\[ \text{emf} = 0.6 \, \text{Volts} \]

2. Circuit Laws

Q.10 State and explain Norton’s theorem.

[SSC JE - 2007 : 15 Marks]

Solution:

Norton’s theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a current source \( I_N \) in parallel with a resistor \( R_N \), where \( I_N \) is the short-circuit current through the terminals and \( R_N \) is the input or equivalent resistance at the terminals when the independent sources are turned-off.
**Explanation:**

In order to find the current through the load $R_L$ by Norton’s theorem, replace $R_L$ by short-circuit.

\[
I = \frac{V_s}{R_1 + \left(\frac{R_2 R_3}{R_2 + R_3}\right)} \quad \text{and} \quad I_N = I \cdot \left(\frac{R_3}{R_2 + R_3}\right)
\]

Next, the short-circuit is removed and the independent source is deactivated.

\[
R_{in} = R_2 + \left(\frac{R_1 R_3}{R_1 + R_3}\right)
\]

As per Norton’s theorem, the equivalent source circuit would contain a current source in parallel to the internal resistance, the current source being the short-circuited current across the shorted terminals of the load resistor.

**Norton’s Equivalent Circuit:**

\[
I_L = I_N \left(\frac{R_{in}}{R_{in} + R_L}\right)
\]

Norton’s theorem is always valid irrespective of

(i) Nature of elements contain in the network.

(ii) Nature of voltage and current sources.

Norton’s theorem is not valid for the network containing

(i) Non-linear elements

(ii) Unilateral elements such as p-n junction diode, transistor etc.

Steps for solving a network using Norton’s theorem:

**Step-1:** Remove the load resistor and find the internal resistance of source network by deactivating the independent sources:

(a) all independent voltage sources are short-circuited or replaced by their internal impedances.

(b) all independent current sources are open-circuited or replaced by their internal impedances.

(c) all dependent voltage and current sources remain as it is.

**Step-2:** Short the load terminal and find the short-circuit current flowing through the shorted load terminals.

**Step-3:** Norton’s equivalent circuit is drawn by keeping $R_{in}$ in parallel to $I_N$

**Step-4:** Reconnect the load resistance $R_L$ across the load terminals and the current through it is $I_L$.

\[
I_L = I_N \left(\frac{R_{in}}{R_{in} + R_L}\right)
\]
Q.11 Use Thevenin’s theorem to find the current through the switch $S$ when it is closed.

Solution:

When switch is closed.

Step-1: Remove 6 Ω resistor and find $V_{th}$.

From figure,

$$V_1 = 10 \times \left( \frac{8}{10 + 8} \right) = \frac{80}{18} \text{ V}$$

and

$$V_2 = 10 \times \left( \frac{4}{4 + 15} \right) = \frac{40}{19} \text{ V}$$

So,

$$V_{th} = V_2 - V_1 = \frac{40}{19} - \frac{80}{18}$$

$$= -2.339 \text{ Volt}$$

Step-2: Find $Z_{eq}$ after deactivating active source.

$Z_{eq} = (8 \parallel 10) + (4 \parallel 15) = 7.602 \Omega$

Step-3: Redraw Thevenin's equivalent circuit.

Step-4: Find out the current $I$

$$I = \frac{V_{th}}{Z_{eq} + 6} = \frac{-2.339}{7.602 + 6} = -0.17196 \text{ A}$$

Negative sign shows current flowing from $B$ to $A$ is 0.17196 A.
Q.12 Use Nodal analysis to find the currents in various resistors of the circuit shown in figure.

Solution:

Let node A, B and C has a voltage $V_A$, $V_B$ and $V_C$ respectively.
Applying nodal analysis at node ‘A’. (Considering the unknown currents direction from point A to other points).

\[
\frac{V_A}{2} + \frac{V_A - V_B}{3} + \frac{V_A - V_C}{5} = 10
\]

or,

\[31V_A - 10V_B - 6V_C = 300 \quad \text{...(i)}\]

Applying nodal analysis at node ‘B’ (Considering all the currents leaving the point B).

\[
\frac{V_B - V_A}{3} + \frac{V_B}{5} + \frac{V_B - V_C}{1} = 0
\]

or,

\[-5V_A + 23V_B - 15V_C = 0 \quad \text{...(ii)}\]

Similarly applying nodal analysis at node ‘C’

\[
\frac{V_C - V_A}{5} + \frac{V_C - V_B}{1} + \frac{V_C}{4} + 2 = 0
\]

or,

\[-4V_A - 20V_B + 29V_C = -40 \quad \text{...(iii)}\]

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

\[V_A = 12.00 \text{ V}\]
\[V_B = 5.1 \text{ V}\]
\[V_C = 3.80 \text{ V}\]

Now current,

\[I_1 = \frac{V_A}{2} = \frac{12.06}{2} = 6.03 \text{ Amp.}\]
\[I_2 = \frac{V_A - V_B}{3} = \frac{12.06 - 5.10}{3} = 2.32 \text{ Amp.}\]
\[I_3 = \frac{V_B}{5} = \frac{5.10}{5} = 1.02 \text{ Amp.}\]
\[ I_s = \frac{V_o - V_C}{1} = \frac{5.10 - 3.80}{1} = 1.30 \text{ Amp.} \]

\[ I_5 = \frac{V_C}{4} = \frac{3.80}{4} = 0.95 \text{ Amp.} \]

and

\[ I_6 = \frac{V_A - V_C}{5} = \frac{12.06 - 3.80}{5} = 1.652 \text{ Amp.} \]

Q.13 State and prove maximum power transfer theorem for dc circuits.

[SSC JE - 2008 : 10 Marks]

Solution:

Statement:
A resistive load, being connected to a dc network, receives maximum power when the load resistance is equal to the internal resistance of the source internal as seen from the load terminals.

Explanation:
A variable resistance \( R_L \) is connected to a dc source network as shown in figure.

Current,

\[ I = \frac{V_0}{R_{Th} + R_L} \]

while the power delivered to the resistance load \( R_L \) is

\[ P_L = I^2 \cdot R_L = \left( \frac{V_0}{R_{Th} + R_L} \right)^2 \cdot R_L \]

...(i)

\( P_L \) can be maximized by varying \( R_L \) and hence maximum power can be delivered when \( \frac{dP_L}{dR_L} = 0 \).

\[ \frac{dP_L}{dR_L} = \frac{(R_{Th} + R_L)^2 \cdot V_0^2 - V_0^2 \cdot R_L \cdot 2(R_{Th} + R_L)}{(R_{Th} + R_L)^4} \]

\[ = \frac{V_0^2 (R_{Th} + R_L - 2 R_L)}{(R_{Th} + R_L)^3} = \frac{V_0^2 (R_{Th} - R_L)}{(R_{Th} + R_L)^3} \]

\[ = 0 \]

So,

\[ \frac{V_0^2 (R_{Th} - R_L)}{(R_{Th} + R_L)^3} = 0 \Rightarrow R_{Th} - R_L = 0 \Rightarrow R_L = R_{Th} \text{ (Condition for } P_{L\text{,max}}) \]
Again with,

\[ R_L = R_{th} \]

\[ P_{\text{max}} = \frac{V_0^2}{(R_{th} + R_L)^2} \cdot R_L = \frac{V_0^2}{(R_{th} + R_{th})^2} \cdot R_{th} = \frac{V_0^2}{4R_{th}} \]

Since, the power transfer by the source would be \[ \frac{V_0^2}{4R_{th}} \], the load power and source power being the same.

The total power supplied is,

\[ P = 2 \left( \frac{V_0^2}{4R_{th}} \right) = \frac{V_0^2}{2R_{th}} = 2P_{\text{max}} \]

During maximum power transfer the efficiency,

\[ \% \eta = \frac{P_{\text{max}}}{P} \times 100 = 50\% \]

Q.14 State Norton’s theorem.

Solution:
Norton’s theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a current source \( I_N \) in parallel with a resistor \( R_N \), where \( I_N \) is the short-circuit current through the terminals and \( R_N \) is the input or equivalent resistance at the terminals when the independent sources are turned-off.

Norton’s Equivalent Circuit:
Steps for solving a network using Norton’s theorem:

**Step-1:** Remove the load resistor and find the internal resistance of the source network by deactivating the independent sources:
   (a) all independent voltage sources are short-circuited or replaced by their internal impedances.
   (b) all independent current sources are open-circuited or replaced by their internal impedances.
   (c) all dependent voltage and current sources remain as it is.

**Step-2:** Short the load terminal and find the short-circuit current flowing through the shorted load terminals.

**Step-3:** Norton’s equivalent circuit is drawn by keeping \( R_{in} \) in parallel to \( I_N \).

**Step-4:** Reconnect the load resistance \( R_L \) across the load terminals and the current through it is \( I_L \).

\[ I_L = I_N \left( \frac{R_{in}}{R_{in} + R_L} \right) \]

Q.15 Determine the current-I in the network shown in figure by Thévenin’s theorem.

![Network Diagram]

[SSC JE - 2009 : 10 Marks]
Solution:
Given that:

\[
\begin{align*}
2 \Omega & \quad 1 \Omega \\
10 V & \quad 10 A \\
3 \Omega
\end{align*}
\]

Step-1: Remove the load resistance 3 \(\Omega\) and find the open-circuit voltage \(V_{OC}\) across the open circuited load terminals.

\[
\begin{align*}
2 \Omega & \quad 1 \Omega \\
10 V & \quad 10 A \\
V_1 & \quad V_{OC}
\end{align*}
\]

Applying KCL at node (1), we get
\[
\frac{V_1 - 10}{2} + \frac{V_1}{2} = 10
\]
\[V_1 = 15 \text{ V}\]

Current flow through 1 \(\Omega\) resistance is zero.

So,
\[V_{OC} = V_1 = 15 \text{ V}\]

Step-2: Deactivate the independent sources (for voltage source, remove it by internal resistance and for current source delete the source by open circuit) and find the internal resistance (Thevenin’s resistance) of the source side looking through the open circuited load terminals.

\[
\begin{align*}
2 \Omega & \quad 1 \Omega \\
10 V & \quad 10 A \\
V_{OC} & \quad R_{th}
\end{align*}
\]

\[R_{th} = (2 \parallel 2) + 1 = 2 \Omega\]

Step-3: Obtain Thevenin’s equivalent circuit.

\[
\begin{align*}
R_{th} = 2 \Omega \\
V_{OC} = 15 \text{ V} \\
R_L = 3 \Omega
\end{align*}
\]

\[
\begin{align*}
R_{th} & \quad V_{OC} = 15 \text{ V} \\
R_L & \quad b
\end{align*}
\]
**Step-4:** Reconnect $R_L$ across the load terminal $a-b$.

\[ I = \frac{V_{oc}}{R_{th} + R_L} = \frac{15}{2 + 3} = \frac{15}{5} = 3 \text{ A} \]

So, current ($I$) flowing through 3 Ω resistor is 3 A.

**Q.16** In the Network shown in figure find resistance $R_L$ so that maximum power is developed across $R_L$.

![Network Diagram](image)

[SSC JE - 2010 : 10 Marks]

**Solution:**

**Step-1:** Remove the load resistance ($R_L$) and find Thevenin’s resistance ($R_{th}$) of the source network looking through open circuited load terminals.

![Thevenin's Network Diagram](image)

\[ R_{th} = \frac{(10 \| 10 + 2) \| 3 + 5}{10 \| 10 + 2} = \frac{10 \times 3}{7 + 3} = \frac{30}{10} = 3 \Omega \]

**Step-2:** As per maximum power transfer theorem, this $R_{th}$ is the load resistance of the network.

i.e.

\[ R_L = R_{th} \quad \text{(that allows maximum power transfer)} \]

\[ R_L = R_{th} = 7.1 \Omega \]

**Q.17** Find current through 5 Ω resistor in the circuit shown in figure, using Thevenin’s theorem.

![Thevenin's Network Diagram](image)

[SSC JE - 2010 : 10 Marks]
Solution:

Step-1: Remove 5 Ω resistance and find the open circuit voltage \(V_{OC}\) across the open circuited load terminals.

Using source conversion method:

\[
I = \frac{12 - 10}{1 + 2 + 2} = \frac{2}{5} = 0.4 \text{ A}
\]

So,

\[
V_{OC} = 10 + 4(0.4) = 11.6 \text{ V}
\]

Step-2: Deactivate the independent sources (for voltage source, remove it by internal resistance and for current source delete the source and replace it by open circuit) and find the internal resistance (Thevenin's resistance) of the source side looking through the open circuited load terminals.

\[
R_{th} = 1 || (2 + 2) = \frac{4 \times 1}{4 + 1} = 0.8 \text{ Ω}
\]
Step-3: Obtain Thevenin’s equivalent circuit.

\[ V_{oc} = 11.6 \text{ V} \]

\[ R_{th} = 0.8 \]

\[ R_L = 5 \text{ } \Omega \]

\[ I = \frac{V_{dc}}{R_{th} + R_L} = \frac{11.6}{0.8 + 5} = 2 \text{ A} \]

The current through 5 \( \Omega \) resistor is 2 A.

Q.18 Find \( I_L \) for the circuit shown in figure, \( I \) using superposition theorem.

Solution:

Step-1: Take only one independent source of voltage/current and deactivate the other independent voltage/current sources. Let us first take 50 V source, deactivate the other source.

\[ R_{eq} = \frac{20 \times 30}{20 + 30} = 12 \Omega \]

\[ i = \frac{50}{12 + 10} = \frac{50}{22} \text{ A} \]
Using current division rule,

\[ I'_{L} = \frac{i \times 20}{20 + 30} = \frac{\left( \frac{50}{22} \right) \times 20}{50} = \frac{20}{22} \text{ A} \]

**Step-2**: Repeat the above step-1 for each of the independent source.

Now taking 20 V source and deactivate other sources.

From the above figure resistance 10 Ω and 30 Ω are in parallel.

\[ R_{\text{eq}} = 10 || 30 = \frac{10 \times 30}{10 + 30} = 7.5 \Omega \]

\[ i_1 = \frac{20}{20 + 7.5} = \frac{8}{11} \text{ A} \]

Using current division rule,

\[ I''_{L} = i_1 \times \frac{10}{10 + 30} = \frac{8}{11} \times \frac{10}{40} = \frac{2}{11} \text{ A} \]

**Step-3**: To determine the net branch current utilizing superposition theorem just add the currents obtained in step-1 and step-2.

\[ I_{L} = I'_{L} + I''_{L} \]

\[ = \frac{20}{22} + \frac{2}{11} = \frac{24}{22} = 1.0909 \approx 1.091 \text{ A} \]

Q.19 For the network shown in figure, find the current in each resistor using superposition principle.

[SSC JE - 2012 : 30 Marks]

Solution:

Given that:
Take 50 V voltage source and other active sources deactivated.

\[ R_{eq} = \frac{3 \parallel 5}{3 + 5} = \frac{15}{8} = 1.875 \Omega \]

Then,

\[ I_1' = \frac{50}{10 + 1.875} = 4.21 \text{ A} \]

Using current division rule,

\[ I_2' = \frac{4.21 \times 5}{(3 + 5)} = 2.63 \text{ A} \]

and

\[ I_3' = \frac{4.21 \times 3}{(3 + 5)} = 1.578 \text{ A} \]

Now take 25 V voltage source and other active sources deactivated.

From shown figure resistance 10 \( \Omega \) and 3 \( \Omega \) are in parallel,

\[ R_{eq} = \frac{10 \parallel 3}{10 + 3} = \frac{30}{13} = 2.3077 \Omega \]

\[ I_3'' = \frac{25}{2.3077 + 5} = 3.421 \text{ A} \]

Using current division rule,

\[ I_2'' = 3.421 \times \frac{10}{(10 + 3)} = 2.631 \text{ A} \]

and

\[ I_1'' = 3.421 \times \frac{3}{(10 + 3)} = 0.789 \text{ A} \]

so net current in each resistor is

\[ I_{(10 \Omega)} = I_1 = I_1' - I_1'' = 4.21 - 0.789 = 3.421 \text{ A} \]

and

\[ I_{(3 \Omega)} = I_2 = I_2' + I_2'' = 2.63 + 2.631 = 5.261 \text{ A} \]

and

\[ I_{(5 \Omega)} = I_3 = I_3' - I_3'' = 1.578 - 3.421 = -1.843 \text{ A} \]

(As \( I_3 \) is negative of directional of \( I_3 \) is opposite to the assumed direction)

**Q.20** In the following circuit, find the total resistance \( R_3 \), \( V_2 \) and \( I_4 \).

\[ R_1 = 9 \Omega, \quad R_2 = 4 \Omega, \quad R_4 = 12 \Omega, \quad R_5 = 36 \Omega, \quad V_1 = 12 \text{ V}, \quad I_1 = 1.0 \text{ A} \]

[SSC JE - 2013 : 30 Marks]
Solution:

Given that:
R₁ = 9 Ω, R₂ = 4 Ω, R₄ = 12 Ω, R₅ = 36 Ω, V₁ = 12 Ω, I₁ = 1.0 A, R₃ = ?, V₂ = ?, I₄ = ?

As shown in diagram,
Resistance R₁ and R₃ are in series,

\[ R_{eq} = R₁ + R₃ = (9 + R₃) \Omega \]

and resistance R₄ and R₅ are in parallel,

\[ R_{eq} = \frac{R₄ R₅}{R₄ + R₅} = \frac{12 \times 36}{12 + 36} = 9 \Omega \]

Total equivalent resistance of the circuit is

\[ (R_{eq})₇ = \frac{(9 + R₃)4}{13 + R₃} + 9 = \frac{V₁}{I₁} = \frac{12}{1} = 12 \Omega \]

\[ \frac{(9 + R₃)4}{13 + R₃} - 12 - 9 = 3 \]

\[ 36 + 4R₃ = 3(13 + R₃) = 39 + 3R₃ \]

\[ R₃ = 3 \Omega \]

Now, resistance (R₁ + R₃) and R₂ are in parallel so using current division rule,

\[ I₂ = I₉ = \frac{I₁ \times (R₁ + R₃)}{(R₁ + R₃) + R₂} = \frac{1 \times (9 + 3)}{(9 + 3) + 4} = \frac{12}{16} = 0.75 \text{ A} \]

So, voltage across resistance ‘R₂’ is

\[ V₂ = (I₂)R₂ = 0.75 \times 4 = 3 \text{ V} \]

Now, resistance R₄ and R₅ are in parallel.
So, using current division rule,

\[ I₄ = I₉ = \frac{I₁ \times R₅}{R₄ + R₅} = \frac{1 \times 36}{12 + 36} = \frac{36}{48} = 0.75 \text{ A} \]

So,

\[ R₃ = 3 \Omega \]

\[ V₂ = 3 \text{ V} \]

\[ I₄ = 0.75 \text{ A} \]

Q.21 In the circuit shown in figure, what is the value of V?

Solution:

Given circuit is,
Apply KVL in above circuit,

\[ -6 + V + 5 = 0 \]

\[ V = 1 \text{ volt} \]