Electrical Circuits

Authors

Dr. D. Shobha Rani
Professor and Controller of Examinations
Department of EEE
Institute of Aeronautical Engineering College
Dundigal, Hyderabad-500043

Ms. S. Swathi
Assistant Professor
Department of EEE
Institute of Aeronautical Engineering College
Dundigal, Hyderabad-500043

StudentsHelpline® Publishing House (P)Ltd.
(An ISO 9001:2015 Certified Publisher) *Expect more from us ...*

All rights reserved. No part of this publication which is material protected by this copyright notice may be reproduced or transmitted or utilized or stored in any form or by any means now known or hereinafter invented, electronic, digital or mechanical, including photocopying, scanning, recording or by any information storage or retrieval system, without prior written permission from the ***Publisher.***

Information contained in this book has been published by **StudentsHelpline Publishing House (P) Ltd. , Hyderabad** and has been obtained by its Authors from sources believed to be reliable and are correct to the best of their knowledge. However, the Publisher and its Authors shall in no event be liable for any errors, omissions or damages arising out of use of this information and specifically disclaim any implied warranties or merchantability or fitness for any particular use.

COPYRIGHT REGISTRATION DIARY NUMBER: **5603/2019-CO/L**

Head Office

326/C, 1st Floor, Surneni Nilayam
Near B K Guda Park, S R Nagar, Hyderabad - 500 038, INDIA
P.No:+91 40 23710657, 238000657 Fax: +91 40 23810657

Reg. Off

5-68, Pedda Gorpadu, Pakala, Tirupati, Chittoor - 517 112 AP, INDIA
mail:studentshelpline.in@gmail.com
www.**studentshelpline.**in

© StudentsHelpline Publishing House (P) Ltd.

First Edition–2019

ISBN 978-93-83959-61-7

` **424/- Student Edition**

` **624/- Library Edition with HB**

Printed at M/s StudentsHelpline Group, S R Nagar, Hyderabad-38
Published by Surneni Mohan Naidu for StudentsHelpline Publishing House (P) Ltd., Hyderabad - 38

Electrical Circuits

Module-I: Introduction to Electrical Circuits

Circuit Concept: Basic definitions, Ohm's law at constant temperature, classifications of elements, R,L,C parameters, independent and dependent sources, voltage and current relationships for passive elements (for different input signals like square,ramp, saw tooth, triangular and complex), temperature dependence of resistance, tolerance, source transformation, kirchhoff's laws, equivalent resistance of series, parallel and series parallel network.

Module-II: Analysis of Electrical Circuits

Circuit Analysis: Star to Delta and Delta to Star transformation, Mesh analysis and Nodal analysis by Kirchhoff's laws, inspection method, super mesh, super node analysis. Network Topology: Definitions, Incidence Matrix, Basic Tie set and Basic cut set Matrices for Planar Networks, Duality and Dual Networks.

Module-III: Single Phase AC Circuits

Single Phase AC Circuits: Representation of alternating quantities, Instantaneous, peak, RMS, average, form factor and peak factor for different periodic waveforms, phase and phase difference, 'j' notation, Concept of reactance, impedance, susceptance and admittance, rectangular and polar form. Concept of power, real, reactive and complex power, power factor.

Steady state analysis: Steady state analysis of RL, RC and RLC circuits (in series, parallel and series parallel combinations) with sinusoidal excitation; Resonance: series and parallel resonance, concept of band width and Q factor.

Module-IV: Magnetic Circuits and Three Phase Circuits

Magnetic Circuits: Faraday's laws of electromagnetic induction, conpect of self and mutual inductance, dot convention, coefficient of coupling, composite magnetic circuit, analysis of series and parallel magnetic circuits. Theree Phase Circuits: Star and delta connections, phase sequence, relation between line and phase voltages and currents in balanced systems (both Y & Δ), three phase three wire and three phase four wire systems, analysis of balanced and unbalanced three phase circuits, measurement of active and reactive power.

Module-V: Components of Electrical Systems

Components of Electrical Systems: Switch Fuse Unit (SFU), MCB, ELCB, MCCB, types of wires and cables, Earthing, Types of Batteries: Alkaline battery, Zinc-Carbon battery, dry cell battery, Nickel-Cadmium battery, lead acid battery, lithium ion battery, nickel metal hydride battery, important characteristics for batteries, applications, Elementary calculations for energy consumption.

Electrical Circuits

Chapter-I: Introduction to Electrical Circuits

1.0	Objectives	**2**
1.1	Inroduction	**2**
1.2	Circuit Concept: Basic Definitions	**2**
1.3	Electric Current	**5**
1.4	Electric Potential	**6**
1.5	Potential Difference	**7**
1.6	Voltage and E.M.F	**7**
1.7	Power	**8**
1.8	Ohm's Law at constant temperature	**8**
	1.8.1 Limitations of Ohm's Law	**9**
	1.8.2 Applications of Ohm's Law	**9**
	1.8.3 Solved Problems	**9**
1.9	Classifications of Elements	**12**
1.10	R-L-C Parameters	**13**
	1.10.1 Resistance (R)	**13**
	1.10.2 Classification of Resistors	**15**
	1.10.3 Colour Coding of Resistors	**16**
1.11	Inductor (L)	**16**
	1.11.1 Classifications of Inductors	**17**
	1.11.2 Specifications of Inductor	**18**
	1.11.3 Conductivity	**18**
1.12	Concept of Capacitor	**19**
	1.12.1 Classifications of Capacitors	**20**
	1.12.2 Specifications of the Capacitor	**21**
	1.12.3 Comparison of Active and Passive Components	**21**
	1.12.4 Solved Problems	**22**

1.13 Voltage and Current Sources **24**

1.14 Independent and Dependent Sources **25**

1.14.1 Solved Problems **27**

1.15 Voltage current Relationships for Passive Elements **28**

1.16 Temperature Dependence of Resistance **31**

1.17 Temperature Co-efficient of Resistance **33**

1.17.1 Expression for Resistance at any Temperature **34**

1.17.2 Formula for Co-efficient of Resistance at any Temperature **35**

1.17.3 Solved Problems **37**

1.18 Tolerance **42**

1.18.1 Tolerance in Resistors **42**

1.18.2 Tolerance in Capacitors **45**

1.18.3 Solved Problems **46**

1.19 Source Transformation **48**

1.19.1 Solved Problems **49**

1.20 Kirchhoff's Law's **53**

1.20.1 Kirchhoff's Current Law **54**

1.20.2 Kirchhoff's Voltage Law **55**

1.20.3 Application of Kirchhoff's Circuit Laws in the Analysis of Circuits **56**

1.20.4 Solved Problems **57**

1.21 Series Resistance **62**

1.21.1 Equivalent Resistance for Series Connections **63**

1.21.2 Voltage Divider Rule **65**

1.21.3 Solved Problems **66**

1.22 Resistance in Parallel **69**

1.22.1 Characteristics of a Parallel Circuits **71**

1.23 Series-Parallel Combination **71**

1.23.1 Division of Current in Parallel Branch Circuit **72**

1.23.2 Comparison of Series and Parallel Circuits **75**

1.23.3 Solved Problems **76**

1.24 Summary **88**

1.25 Review Questions **89**
1.26 Multiple Choice Questions **92**

Chapter-II: Analysis of Electrical Circuits

2.0 Objective **96**
2.1 Introduction **96**
2.2 Source Transformation **97**
2.2.1 Solved Problems **98**
2.3 Star to Delta or Delta to Star Transformations **102**
2.3.1 Delta-Star Transformation **103**
2.3.2 Star-Delta Transformation **105**
2.3.3 Conversion of Delta into Equivalent Star **106**
2.3.4 Conversion of Star into Equivalent Delta **107**
2.3.5 Solved Problems **108**
2.4 Mesh Analysis by Kirchhoff's laws **120**
2.5 Node Analysis by Kirchhoff's laws **132**
2.5.1 Concept of Nodal Analysis **133**
2.5.2 Nodal Analysis Illustration **133**
2.5.3 Solved Problems **134**
2.6 Inspection method **143**
2.6.1 Solved Problems **144**
2.6.2 Nodal Equations by Inspection Method **146**
2.6.3 Solved Problem **147**
2.7 Super Mesh for DC Excitations **148**
2.7.1 Solved Problems **151**
2.8 Super node for DC Excitations **152**
2.8.1 Solved Problems **153**
2.9 Comparison of Mesh and Nodal Analysis **155**
2.10 Summary **156**
2.11 Review Questions **157**
2.12 Multiple Choice Questions **159**

Chapter-III: Network Topology

3.0	Objective	**164**
3.1	Introduction	**164**
3.2	Definition	**164**
3.3	Graph	**169**
3.4	Tree	**171**
3.5	Incidence Matrix	**173**
	3.5.1 Procedure for Constructing Incidence Matrix	**173**
	3.5.2 Properties of Incidence Matrix	**173**
	3.5.3 Solved Problems	**175**
3.6	Basic Tie set Matrices for Planar Networks	**180**
	3.6.1 Solved Problems	**183**
3.7	Cut-Set and Tree Branch Voltages	**194**
	3.7.1 Solved Problems	**199**
3.8	Duality and Dual Networks	**208**
	3.8.1 Solved Problems	**212**
3.9	Summary	**229**
3.10	Review Questions	**229**
3.11	Multiple Choice Questions	**231**

Chapter-IV: Single Phase AC Circuits

4.0	Objective	**236**
4.1	Introduction	**236**
4.2	Important Definitions	**236**
4.3	Comparison of Alternating Current and Direct Current	**240**
4.4	The sinusoidal waveform	**240**
	4.4.1 Significance of Sine Wave	**242**
	4.4.2 Different Forms of EMF Equation	**242**
4.5	Representation of Alternating Quantities	**242**
	4.5.1 Instantaneous Values	**242**
	4.5.2 RMS (or) Virtual (or) Effective Value of AC	**243**
	4.5.3 Average (or) Mean Value of AC	**244**

	4.5.4 Form Factor	**246**
	4.5.5 Peak Factor	**246**
	4.5.6 Peak Value (or) Time Period of A.C	**246**
	4.5.7 Solved Problems	**247**
4.6	Phase Relations	**251**
	4.6.1 Phase	**251**
	4.6.2 Phase Difference	**252**
	4.6.3 Solved Problems	**254**
4.7	Representation of an AC Quantity by a Rotating Vector	**255**
4.8	J-operator (or) J Notation	**256**
	4.8.1 Solved Problems	**258**
4.9	Polar and rectangular form of Complex Numbers	**258**
4.10	Phasor Algebra	**259**
4.11	Impedance Complex Number	**260**
4.12	Admittance of Complex Number	**261**
4.13	Concept of Reactance	**262**
4.14	Impedance	**263**
4.15	Susceptance	**264**
4.16	Admittance	**264**
4.17	Mathematical Representation of Phasors	**265**
4.18	Solved Problems	**266**
4.19	Concept of Real, Reactive Power	**269**
4.20	Apparent Power and Complex Power	**270**
4.21	Power Factor	**272**
	4.21.1 Solved Problems	**273**
4.22	AC Circuit	**274**
	4.22.1 AC Through Pure Resistance	**274**
	4.22.2 AC Through Pure Inductance	**275**
	4.22.3 AC Through Capacitance	**276**
4.23	Representation of AC Series Circuits	**277**

4.23.1 RL Series Circuit **277**

4.23.2 RC Series Circuit **279**

4.23.3 RLC Series Circuit **281**

4.24 Representation Parallel AC Circuits **283**

4.24.1 RL Parallel Circuit **283**

4.24.2 RC Parallel Circuit **284**

4.24.3 RLC Parallel Circuit **285**

4.25 Solved Problems **286**

4.26 Advantages of Alternating current over Direct current **293**

4.27 Disadvantages of A.C over D.C **294**

4.28 Summary **294**

4.29 Review questions **295**

4.30 Multiple Choice questions **297**

Chapter-V: Resonance

5.0 Objectives **302**

5.1 Introduction **302**

5.2 Stedy State Concept **302**

5.3 Steady state analysis of RL, RC and RLC Series Circuits **303**

5.3.1 RL Series Circuit **303**

5.3.2 RC Series Circuit **306**

5.3.3 RLC Series Circuit **308**

5.4 Representation Parallel AC Circuits **310**

5.4.1 RL Parallel Circuit **310**

5.4.2 RC Parallel Circuit **311**

5.4.3 RLC Parallel Circuit **312**

5.5 AC parallel circuits **313**

5.5.1 Solved Problems **314**

5.6 Resonance **328**

5.7 Resonance in Series Circuit **329**

5.8 Parallel Resonance in RLC Circuit **333**

5.9 Q - Factor, Selectivity and Bandwidth **337**

5.9.1 Selectivity, Bandwidth and Q-factor of a Series Circuit **337**
5.9.2 Selectivity, Bandwidth and Q-factor of Parallel Resonant Circuit **339**
5.10 Compare series and parallel resonance circuits **341**
5.11 Tank circuit-LC oscillations **342**
5.12 Solved Problems **343**
5.13 Summary **352**
5.14 Review Questions **352**
5.15 Multiple Choice Questions **354**

Chapter-VI: Magnetic Circuits

6.0 Objectives **358**
6.1 Introduction **358**
6.2 Magnetic Circuit **358**
6.3 Important definitions **361**
6.3.1 Solved Examples **365**
6.4 Electro Magnetic Induction **368**
6.5 Faraday's Law of Electromagnetic Induction **369**
6.5.1 Faraday's First Law **369**
6.5.2 Faraday's Second Law **370**
6.5.3 Applications of Faraday's Law **370**
6.5.4 Integral Form of Faraday's Law **370**
6.5.5 Differential Form of Faraday's Law **371**
6.5.6 Solved Examples **372**
6.6 Direction of Induced E.M.F. and Current **374**
6.6.1 Lenz's Law **375**
6.6.2 Fleming's Right Hand Rule **376**
6.6.3 Fleming's Left-Hand Rule **376**
6.7 Induced E.M.F **377**
6.7.1 Dynamically Induced E.M.F **377**
6.7.2 Statically Induced E.M.F **378**
6.8 Motional Electromotive Force **380**
6.9 Time Varying Magnetic Fields **381**

6.10 Self and Mutual Inductance **382**
6.10.1 Self Inductance **382**
6.10.2 Mutual Inductance **383**
6.10.3 Solved Example **384**
6.11 Dot Convention **389**
6.11.1 Solved Examples **392**
6.12 Co-efficient of coupling **393**
6.12.1 Solved Problems **394**
6.13 Composite Magnetic Circuit **398**
6.14 Analysis of Series and Parallel Magnetic Circuits **401**
6.14.1 Analysis of Series Magnetic Circuits **401**
6.14.2 Analysis of Parallel Magnetic Circuits **402**
6.14.3 Magnetic Leakage (or) Leakage Flux **403**
6.14.4 Solved Examples **404**
6.15 Comparison between Magnetic and Electric Circuits **417**
6.16 Summary **418**
6.17 Review Questions **419**
6.18 Objective Questions **421**

Chapter-VII: Three Phase Circuits

7.0 Objectives **426**
7.1 Introduction **426**
7.2 Important Definitions **426**
7.3 Three-Phase Circuits **427**
7.4 Generation of Three-Phase Voltages **428**
7.5 Phase Sequence **430**
7.6 Interconnection of Phases **431**
7.6.1 Star and Delta Connections **431**
7.7 Relation between Line and Phase Voltages and Currents in Balanced System **432**
7.7.1 Relationship between Line, Phase Values & Expression for Power for Balanced Star Connection **433**

7.7.2 Relationship between Line and Phase Values and Expression for Power for Balanced Delta Connection **435**
7.7.3 Comparison between Star and Delta Systems **436**
7.7.4 Solved Examples **437**
7.8 Advantages of Star and Delta Connected Systems **442**
7.9 Three Phase Three Wire and three Phase Four Wire System **442**
7.9.1 Three phase three wire systems **442**
7.9.2 Three Phase four Wire Systems **444**
7.10 Analysis of Balanced Three-Phase Circuits **444**
7.10.1 Solved Examples **447**
7.11 Analysis of Unbalanced Three Phase Circuits **453**
7.11.1 Circulating Current in Unbalanced Δ -connected Sources **456**
7.11.2 Solved Examples **456**
7.12 Symmetrical Components **458**
7.12.1 Three-phase Circuits with Unbalanced Sources and Balanced Loads **458**
7.13 Measurement of Power in 3-Phse Circuits Two Wattmeter Method-Balanced Load **459**
7.13.1 Power Factor - Balanced 3-phase load **460**
7.13.2 Advantages of Two Wattmeter Method **461**
7.13.3 Disadavantages of Two Wattmeter Method **462**
7.13.4 Soolved Examples **462**
7.14 Summary **472**
7.15 Review Questions **472**
7.16 Multiple Choice Questions **474**

Chapter-VIII: Components of Electrical Systems

8.0 Objectives **480**
8.1 Introduction **480**
8.2 Definitions **480**
8.3 Fuses **481**
8.3.1 Types of Fuses **482**
8.3.2 Advantages and Disadvantages of Fuses **483**

8.4 Switch Fuse Units **483**
8.5 Circuit Breaker **485**
8.5.1 The Trip-Circuit **485**
8.6 Miniature Circuit Breaker **486**
8.6.1 Advantages, Disadvantages and Applications **487**
8.7 Earth Leakage Circuit Breaker (ELCB) **488**
8.7.1 Advantages and Disadvantages **488**
8.8 Moulded Case Circuit Breaker **489**
8.8.1 Features **490**
8.8.2 Advantages and Disadvantages **490**
8.9 Wires and Cables **491**
8.9.1 Types of Wires **491**
8.9.2 Types of Cables **491**
8.10 Earthing **493**
8.10.1 Necessity of Earthing **494**
8.11 Components of Earthing System **495**
8.12 Types of earthing **497**
8.13 Advantages of Earthing **501**
8.14 Uses of earthing **501**
8.15 Batteries **501**
8.16 Lead-Acid Battery **502**
8.16.1 Working Principle of Lead-Acid Cell **504**
8.16.2 Maintenance of Lead-Acid Batteries **506**
8.16.3 Applications of Lead-Acid Batteries **507**
8.17 Alkaline Batteries **507**
8.17.1 Nickel-Iron Alkaline Cell **507**
8.17.2 Electrical Characterictics **508**
8.17.3 Advantages and Disadvantages **508**
8.18 Comparison Between Lead-Acid and Nickel-Iron Alkaline Cell **509**
8.19 Nickel-Cadmium Cell **510**

8.19.1 Working **511**
8.19.2 Electrical Characteristics **511**
8.19.3 Advantages and Disadvantages **511**
8.20 Nickel-metal Hydride Battery **511**
8.20.1 Construction **512**
8.20.2 Cell Reactions **513**
8.20.3 Features **513**
8.20.4 General Characteristics **514**
8.20.5 Self Discharge Characteristics **514**
8.20.6 Recharging Characteristics **515**
8.20.7 Safety Precautions **516**
8.20.8 Applications **516**
8.21 Zinc-carbon battery **516**
8.21.1 Construction **516**
8.21.2 Chemical Reactions **517**
8.21.3 Applications **518**
8.22 Dry Cell Battery **518**
8.22.1 Applications **519**
8.23 Lithium-ion battery **519**
8.23.1 Construction **519**
8.23.2 Electrochemistry **520**
8.23.3 Applications **521**
8.24 Capacity of A Battery **522**
8.24.1 Factors Affecting Capacity of a Battery **523**
8.25 Efficiency of A Battery **523**
8.25.1 Solved Problems **524**
8.26 Energy consumption **527**
8.26.1 Solved Problems **527**
8.27 Summary **528**
8.28 Review Questions **528**
8.29 Multiple Choice Questions **529**