

# Contents

## CHAPTER 1

---

### D.C.CIRCUIT CONCEPTS & CIRCUIT ELEMENTS

#### D.C.CIRCUIT CONCEPTS & CIRCUIT ELEMENTS - I

<b>1.1</b>	<b>INTRODUCTION TO BASICS OF ELECTRICAL ENGINEERING .....</b>	<b>1</b>
1.1.1.	Circuit Concepts - Concepts of Networks .....	1
<b>1.2</b>	<b>CURRENT FLOW .....</b>	<b>2</b>
1.2.1	Potential and Potential Difference .....	2
1.2.2	Electric Current .....	3
<b>1.3</b>	<b>ACTIVE AND PASSIVE ELEMENTS .....</b>	<b>4</b>
1.3.1	Sources of Electrical Energy - Voltage Source .....	4
1.3.2	Sources of Electrical Energy - Current Source .....	5
1.3.3	D.C. & A.C. Sources .....	6
1.3.4.	Unilateral and Bilateral Elements .....	8
1.3.5.	Effect of Temperature on Resistance .....	12
1.3.6.	Electrical Conductance .....	13
<b>1.4</b>	<b>OHM'S LAW .....</b>	<b>14</b>
1.4.1	Linear & Non-Linear Resistances .....	16

<b>1.5</b>	<b>ELECTRICAL POWER</b> .....	<b>17</b>
<b>1.6</b>	<b>ENERGY CALCULATIONS</b> .....	<b>19</b>
<b>1.7.</b>	<b>ELECTRICAL ENERGY</b> .....	<b>19</b>
<b>1.8</b>	<b>KIRCHOFF'S LAWS</b> .....	<b>20</b>
	1.8.1 Kirchoff's Voltage Law ( KVL ) .....	20
	1.8.2 Kirchoff's Current Law ( KCL or KIL ) .....	21
<b>1.9</b>	<b>RESISTANCES IN SERIES</b> .....	<b>26</b>
<b>1.10</b>	<b>RESISTANCES IN PARALLEL</b> .....	<b>30</b>
	1.10.1 Division of Currents in Parallel Circuits .....	32
<b>1.11</b>	<b>SERIES-PARALLEL RESISTANCES</b> .....	<b>36</b>
<b>1.12</b>	<b>RESISTANCES IN STAR OR DELTA CONNECTIONS</b> .....	<b>41</b>
	1.12.1 The Equivalent Star Resistances For Given Delta Connected Resistances .....	41
	1.12.2 The Equivalent Delta Resistances For Given Star Connected Resistances .....	43
<b>1.13</b>	<b>FEATURES OF A RESISTANCE</b> .....	<b>49</b>
<b>1.14</b>	<b>USES OF RESISTANCE</b> .....	<b>50</b>
<b>1.15</b>	<b>DIFFERENCES BETWEEN ELECTRICAL &amp; ELECTRONIC CIRCUITS</b> .....	<b>51</b>
	<b>D.C.CIRCUIT CONCEPTS &amp; CIRCUIT ELEMENTS - II</b>	
<b>1.16.</b>	<b>INTRODUCTION TO ENERGY STORING ELEMENTS</b> .....	<b>53</b>
<b>1.17.</b>	<b>CAPACITANCE PARAMETER</b> .....	<b>53</b>
	1.17.1 The Current Flowing Through A Capacitor .....	55
	1.17.2 Energy Stored In A Charged Capacitance .....	57
	1.17.3 Parallel Plate Capacitor with Guard Ring .....	62
	1.17.4 Capacitances in Series or Series Capacitors .....	62
	1.17.5 Capacitances in Parallel or Parallel Capacitors .....	70
	1.17.6 Variable Capacitors .....	75
	1.17.7 Capacitances in Series-Parallel .....	76
	1.17.8 Dielectric Strength and Breakdown .....	80
	1.17.9 Electrostatic Induction .....	81

1.17.10	Features of a Capacitance .....	81
1.17.11	Uses of Capacitors .....	81
<b>1.18.</b>	<b>INDUCTANCE .....</b>	<b>82</b>
1.18.1	Magnetic Field of a Solenoid.....	83
1.18.2	Self Inductance of a Coil .....	85
1.18.3	Voltage Drop across the Inductance .....	88
1.18.4	Energy Stored in an Inductor or Coil or Inductance .....	89
1.18.5	Inductances in Series or Series Inductors without Mutual Induction .....	94
1.18.6	Inductances in Parallel or Parallel Inductors without Mutual Induction ...	95
1.18.7	Inductances in Series-Parallel Without Mutual Induction .....	96
1.18.8	Mutual Induction Between Coils .....	97
1.18.9	Dot Convention for Mutual Inductances .....	100
1.18.10	Expression for Mutual Inductance M in Terms of Dimensions of Two Coils .....	103
1.18.11	Coefficient of Magnetic Coupling or Magnetic Coupling between two Coils .....	103
1.18.12	Principle of Constant Flux Linkages .....	108
1.18.13	Inductances in Series ( or Series Inductors ) with Mutual Inductance ..	109
1.18.14	Inductances in Parallel (or Parallel Inductors) with Mutual Inductance .....	111
1.18.15	Inductances in Series-Parallel with Mutual Inductances .....	112
1.18.16	Variable Inductance .....	113
1.18.17	Magnetic Hum .....	113
<b>1.19.</b>	<b>FEATURES OF AN INDUCTANCE .....</b>	<b>114</b>
<b>1.20.</b>	<b>USES OF INDUCTORS .....</b>	<b>115</b>
	<b>COMPREHENSION - 1 .....</b>	<b>117</b>
	<b>EXERCISE - 1 .....</b>	<b>123</b>

## CHAPTER 2

### D.C. CIRCUIT ANALYSIS & NETWORK THEOREMS

<b>2.1</b>	<b>INTRODUCTION</b> .....	<b>133</b>
2.1.1.	Controlled or dependent voltage and current sources.....	134
2.1.2	Controlled Source or Dependent Source .....	134
2.1.3.	Controlled Voltage Source.....	134
2.1.4	Controlled Current Source .....	135
2.1.5	Combination of Energy Sources.....	136
2.1.6	Voltage Sources in Series .....	136
2.1.7.	Current Sources in Parallel .....	136
2.1.8	Voltage Sources in Parallel and Current Sources in Series & Parallel .....	137
2.1.9	Source Transformations .....	138
2.1.10	Source Shifting .....	139
<b>2.2</b>	<b>LOOP OR MESH ANALYSIS AND NODAL ANALYSIS</b> .....	<b>142</b>
<b>2.3</b>	<b>LOOP ANALYSIS FOR D.C. CIRCUITS</b> .....	<b>142</b>
2.3.1	Redundant Elements .....	143
2.3.2	Identification of independant loops .....	143
2.3.3	Loop Analysis Using Independent Voltage Sources .....	144
2.3.4	Loop Analysis Using Independent Current Sources (Super Mesh).....	147
2.3.5	Loop Analysis using Independent Voltage and Current Sources .....	148
<b>2.4.</b>	<b>NODAL ANALYSIS</b> .....	<b>151</b>
2.4.1	Identification of Independant Nodes .....	152
<b>2.5</b>	<b>NODAL ANALYSIS FOR D.C. CIRCUITS</b> .....	<b>153</b>
2.5.1	Nodal Analysis using Independent Current Sources .....	153
2.5.2	Nodal analysis using Independent Voltage Sources (Super Nodes) .....	155
2.5.3	Nodal Analysis using Independent Voltage and Current Sources .....	157
<b>2.6</b>	<b>NODAL ANALYSIS WITH DEPENDENT SOURCES</b> .....	<b>164</b>
<b>2.7.</b>	<b>D.C. NETWORK THEOREMS</b> .....	<b>165</b>
2.7.1	Introduction to Network Theorems .....	165
<b>2.8.</b>	<b>NETWORK CLASSIFICATION</b> .....	<b>165</b>

2.8.1 Linear Networks .....	165
2.8.2 Passive Networks .....	166
2.8.3 Lumped Networks .....	167
2.8.4 Bilateral Networks .....	167
2.8.5 Time Invariant Networks .....	167
2.8.6 Reciprocity .....	167
<b>2.9. SUPERPOSITION THEOREM .....</b>	<b>168</b>
<b>2.10. THEVENIN'S THEOREM .....</b>	<b>172</b>
<b>2.11. NORTON'S THEOREM .....</b>	<b>182</b>
<b>2.12. MAXIMUM POWER TRANSFER THEOREM.....</b>	<b>186</b>
<b>    COMPREHENSION-2.....</b>	<b>190</b>
<b>    EXERCISE-2.....</b>	<b>192</b>

## CHAPTER 3

### FUNDAMENTALS OF ALTERNATING CURRENT

<b>3.1 INTRODUCTION.....</b>	<b>199</b>
<b>3.2 GENERATION OF ALTERNATING VOLTAGES &amp; CURRENTS .....</b>	<b>199</b>
3.2.1 D.C. Waveform or Steady Waveform .....	200
3.2.2 A.C. Waveforms .....	200
3.2.3 Periodic and Aperiodic Waveforms .....	201
3.2.4 Sinusoidal Waveforms .....	203
3.2.5 Generation of Sinusoidal Waveforms .....	204
<b>3.3 EXPRESSION FOR THE E.M.F. GENERATED BY A SINGLE PHASE .....</b>	<b>206</b>
<b>    ALTERNATOR .....</b>	<b>206</b>
3.3.1 Time Period ( T ) .....	208
3.3.2 Amplitude .....	208
3.3.4 Frequency .....	208
3.3.5 Relation between Frequency and Time Period .....	208
3.3.6 Relation between Frequency and Angular Velocity .....	209

3.3.7	Relationship Between Frequency, Speed And Number of Pole Pairs ...	209
3.3.8	Average Value Of An Alternating Current .....	210
3.3.9	Root Mean Square ( RMS ) Value Of An Alternating Current .....	213
3.3.10	Form Factor And Peak Factor .....	217
<b>3.4.</b>	<b>NON-SINUSOIDAL WAVEFORMS .....</b>	<b>221</b>
3.4.1	R.M.S. & Average Values of Halfwave Rectifier Output .....	221
3.4.2	R.M.S. & Average Values of Fullwave Rectifier Output .....	223
<b>3.5</b>	<b>DIFFERENT FORMS OF REPRESENTING ALTERNATING QUANTITIES .....</b>	<b>235</b>
3.5.1	Phasor Representation of an Alternating Quantity .....	235
3.5.2	Lagging / Leading Waveforms With Phase & Phase Difference .....	238
3.5.3	Rectangular Coordinates Representation .....	
3.5.3.1	j-Operator .....	239
3.5.3.2	Phasor Represented in Rectangular Coordinate Components .....	239
3.5.3.3	Trigonometrical Form of Phasor Representation .....	240
3.5.3.4	Exponential Form of Phasor Representation .....	242
3.5.3.5	Polar Form of Phasor Representation .....	242
<b>3.6</b>	<b>ARITHMETIC OPERATIONS OF PHASORS .....</b>	<b>243</b>
3.6.1	Addition and Subtraction of Phasors .....	243
3.6.2	Multiplication and Division of Phasors .....	244
3.6.3	Power and Roots of Vectors .....	245
3.6.3.1	Powers .....	245
3.6.3.2	Roots .....	245
3.6.4	Conjugate of a Phasor and Rationalization .....	246
<b>3.7</b>	<b>INSTANTANEOUS &amp; AVERAGE POWER IN A.C. CIRCUITS .....</b>	<b>250</b>
3.7.1	A.C. Circuit with Pure Resistance As Load .....	251
3.7.2	A.C. Circuit with Pure Inductance as Load .....	254
3.7.3	A.C. Circuit with Pure Capacitance as Load .....	257
	<b>COMPREHENSION - 3 .....</b>	<b>263</b>
	<b>EXERCISE - 3 .....</b>	<b>265</b>

## CHAPTER 4

### A.C. CIRCUITS

#### A.C. CIRCUITS - I - SINGLE PHASE CIRCUITS

<b>4.1</b>	<b>INTRODUCTION</b> .....	<b>269</b>
<b>4.2</b>	<b>POWER AND POWER FACTOR IN SINGLE PHASE A.C. CIRCUITS</b> .....	<b>270</b>
<b>4.3</b>	<b>A.C. SERIES CIRCUITS</b> .....	<b>270</b>
4.3.1	R-L Series Circuit with A.C. Supply .....	270
4.3.2	Power Factor .....	273
4.3.3	Voltage Drop Triangle .....	274
4.3.4	Complex Power .....	274
4.3.5	VA or KVA Triangle .....	276
4.3.6	Wattfull and Wattless Component of Current .....	277
4.3.7.	R-C Series Circuit with A.C. Supply .....	279
4.3.8	Power Factor .....	283
4.3.9	Voltage Drop Triangle .....	283
4.3.10	Complex Power .....	283
4.3.11.	VA or KVA Triangle .....	285
4.3.12	Wattfull and Wattless Component of Current .....	285
4,3.13.	Admittance & Admittance Triangle .....	287
4.3.14	R-L-C Series Circuit .....	289
4.3.15.	A.C. Series Circuit with Two or More Impedances.....	291
<b>4.4</b>	<b>A.C. PARALLEL CIRCUITS</b> .....	<b>292</b>
4.4.1	A.C. Parallel Circuit with Two or More Impedances .....	293
<b>4.5</b>	<b>A.C. SERIES - PARALLEL CIRCUIT</b> .....	<b>295</b>
<b>4.6</b>	<b>A.C. STAR - DELTA CONNECTED CIRCUITS</b> .....	<b>299</b>
<b>4.7.</b>	<b>IMPORTANCE OF POWER FACTOR</b> .....	<b>304</b>
<b>4.8</b>	<b>FEATURES AND USES OF A.C. SINGLE PHASE CIRCUITS</b> .....	<b>304</b>

<b>4.9. SINGLE PHASE CIRCUITS WITH VARIABLE ELEMENTS -</b>	
<b>    RESONANCE :</b>	<b>305</b>
<b>4.10 RESONANCE IN A.C. CIRCUITS</b>	<b>306</b>
4.10.1 Frequency Variation	306
4.10.2 Series Resonance	306
4.10.3 Series Resonance Frequency	308
4.10.4 Effects of Series Resonance	312
4.10.5 Selectivity & Bandwidth	314
4.10.6 Effect of Resistance in Series Resonance	319
4.10.7 Parallel Resonance	321
4.10.8 Parallel Resonant Frequency	322
4.10.9 Effects of Parallel Resonance	324
4.10.10 Quality Factor Of A Parallel Resonant Circuit	325
4.10.11 Comparison of Series And Parallel Resonant Circuits	328
<b>4.11. SINGLE PHASE CIRCUITS WITH VARIABLE ELEMENTS - CURRENT</b>	
<b>    LOCUS DIAGRAMS</b>	<b>331</b>
4.11.1 Series RL And RC Circuits with Variable R & Constant Reactance	332
4.11.1.1 RL Circuit with variable resistance	333
4.11.1.2 RC Circuit with variable resistance	335
4.11.2 Locus of Voltage	338
4.11.2.1 RL Circuit with variable resistance	338
4.11.2.2 RC Circuit with variable resistance	339
4.11.2.3 Series RL And RC Circuits with Variable Reactance & Constant R	339
4.11.2.4 RL Circuit with variable reactance	340
4.11.2.5 RC Circuit with variable reactance	343
4.11.2.6 Properties of Constant Reactance, Variable Resistance	346
4.11.2.7 Maximum Current	346
4.11.2.8 Maximum Power Supplied To The Circuit	346
4.11.2.9 Power Factor at Maximum Power Condition	347
4.11.3 Properties of Constant Resistance, Variable Reactance	348
4.11.3.1 Maximum Current	348
4.11.3.2 Maximum Power Supplied To The Circuit	348

4.11.3.3	Power Factor at Maximum Power Condition .....	348
4.11.3.4	Points to be Considered in Locus Diagrams .....	348
<b>4.12.</b>	<b>THEOREMS IN A.C. CIRCUITS .....</b>	<b>352</b>
4.12.1.	Superposition Theorem .....	352
<b>4.13.</b>	<b>THEVENIN'S THEOREM .....</b>	<b>356</b>
<b>4.14.</b>	<b>NORTON'S THEOREM .....</b>	<b>358</b>
<b>4.15.</b>	<b>MAXIMUM POWER TRANSFER THEOREM.....</b>	<b>360</b>
<b>4.16</b>	<b>INTRODUCTION TO THREE-PHASE SYSTEMS .....</b>	<b>365</b>
	<b>A.C. CIRCUITS - II - THREE PHASE CIRCUITS</b>	
<b>4.17</b>	<b>POLY-PHASE SYSTEM .....</b>	<b>365</b>
<b>4.18</b>	<b>ADVANTAGES OF THREE PHASE SYSTEMS .....</b>	<b>366</b>
<b>4.19</b>	<b>GENERATION OF THREE-PHASE E.M.F.S .....</b>	<b>366</b>
4.19.1	Phasor Diagram .....	368
4.19.2	Phase Sequence .....	369
4.19.3	Change of Phase Sequence .....	370
<b>4.20</b>	<b>BALANCED &amp; UNBALANCED THREE-PHASE CIRCUITS .....</b>	<b>370</b>
4.20.1	Balanced Three-Phase System.....	370
4.20.2	Unbalanced Three-Phase System.....	371
<b>4.21</b>	<b>THREE PHASE CONNECTIONS.....</b>	<b>371</b>
4.21.1	Six Line Conductors .....	372
4.21.2	Star or WYE Connection with 3 wires or 4 wires .....	372
4.21.3	Delta or Mesh Connection .....	373
<b>4.22</b>	<b>THREE-PHASE VOLTAGES &amp; CURRENTS - PHASE &amp; LINE VALUES.....</b>	<b>376</b>
4.22.1	Star Connection - Phase & Line Voltages .....	376
4.22.2	Star Connection - Phase & Line Currents .....	377
4.22.3	Delta Connection - Phase & Line Voltages.....	378
4.22.4	Delta Connection - Phase & Line Currents .....	379
<b>4.23</b>	<b>BALANCED OR UNBALANCED THREE - PHASE LOADS .....</b>	<b>381</b>
4.23.1	Three-Phase Balanced Load .....	381
4.23.2	Three-Phase Unbalanced Load .....	389

4.23.3	Line & Phase Values of Voltages & Currents - Phasor Relationships	392
4.23.3.1	Star Connected Load	392
4.23.3.2	Delta Connected Load	394
<b>4.24</b>	<b>POWER IN THREE - PHASE CIRCUITS</b>	<b>401</b>
<b>4.25</b>	<b>POWER MEASUREMENT IN THREE - PHASE CIRCUITS</b>	<b>402</b>
<b>4.26</b>	<b>THREE WATTMETER METHOD</b>	<b>404</b>
<b>4.27</b>	<b>TWO-WATTMETER METHOD</b>	<b>405</b>
<b>4.28</b>	<b>TWO WATTMETER METHOD FOR BALANCED LOAD</b>	<b>407</b>
4.28.1	Power Measurement for Star Connected Load	408
4.28.2	Determination of Power Factor from Wattmeter Readings	410
4.28.3	Power Measurement for Delta Connected Load	410
4.28.4	Determination of Reactive Power from two Wattmeter Reading	410
<b>4.29</b>	<b>EFFECT OF POWER FACTOR ON THE WATTMETER READINGS</b>	<b>411</b>
<b>4.30</b>	<b>LEADING POWER FACTOR</b>	<b>413</b>
<b>4.31</b>	<b>OTHER METHODS OF CONNECTING TWO WATTMETERS</b>	<b>414</b>
<b>4.32</b>	<b>SINGLE WATTMETER METHOD</b>	<b>416</b>
<b>4.33</b>	<b>MEASUREMENT OF REACTIVE POWER</b>	<b>416</b>
<b>4.34</b>	<b>THREE PHASE WATTMETER</b>	<b>418</b>
<b>4.35</b>	<b>POWER FACTOR METER</b>	<b>418</b>
<b>4.36</b>	<b>PHASE SEQUENCE METER</b>	<b>425</b>
<b>4.37</b>	<b>FREQUENCY METER</b>	<b>425</b>
<b>4.38</b>	<b>COMPARISON BETWEEN STAR &amp; DELTA CONNECTIONS</b>	<b>426</b>
<b>4.39</b>	<b>COMPARISON BETWEEN 1-PHASE &amp; 3-PHASE SUPPLY SYSTEMS</b>	<b>427</b>
<b>4.40</b>	<b>SINGLE PHASE CIRCUITS WITH VARIABLE ELEMENTS - RESONANCE</b>	<b>427</b>
<b>4.41</b>	<b>RESONANCE IN A.C. CIRCUITS</b>	<b>428</b>
4.41.1	Frequency Variation	428
4.41.2	Series Resonance	42
4.41.3	Series Resonance Frequency	43
4.41.4	Effects of Series Resonance	434

4.41.5	Selectivity & Bandwidth .....	436
4.41.6	Effect of Resistance in Series Resonance .....	441
4.41.7	Parallel Resonance .....	443
4.41.8	Parallel Resonant Frequency .....	444
4.41.9	Effects of Parallel Resonance .....	446
4.41.10	Quality Factor Of A Parallel Resonant Circuit .....	447
4.41.11	Comparison of Series And Parallel Resonant Circuits .....	450
<b>4.42</b>	<b>SINGLE PHASE CIRCUITS WITH VARIABLE ELEMENTS - CURRENT ...</b>	
	<b>LOCUS DIAGRAMS .....</b>	<b>453</b>
4.42.1	Series RL And RC Circuits with Variable R & Constant Reactance .....	454
4.42.1.1	RL Circuit with variable resistance .....	455
4.42.1.2	RC Circuit with variable resistance : .....	457
<b>4.43.</b>	<b>LOCUS OF VOLTAGE .....</b>	<b>460</b>
4.43.1.	RL Circuit with variable resistance .....	460
4.43.1.1	RC Circuit with variable resistance .....	461
4.43.2	Series RL And RC Circuits with Variable Reactance & Constant R .....	461
4.43.2.1	RL Circuit with variable reactance .....	462
4.43.2.2	RC Circuit with variable reactance .....	465
4.43.3	Properties of Constant Reactance, Variable Resistance .....	468
4.43.3.1	Maximum Current .....	468
4.43.3.2	Maximum Power Supplied To The Circuit .....	468
4.43.3.3	Power Factor at Maximum Power Condition .....	469
4.43.4	Properties of Constant Resistance, Variable Reactance .....	470
4.43.4.1	Maximum Current .....	470
4.43.4.2	Maximum Power Supplied To The Circuit .....	470
4.43.4.3	Power Factor at Maximum Power Condition .....	470
4.43.5	Points to be Considered in Locus Diagrams .....	470
<b>4.44</b>	<b>COMPARISON BETWEEN 1-PHASE &amp; 3-PHASE SUPPLY</b>	
	<b>SYSTEMS .....</b>	<b>474</b>
	<b>COMPREHENSION - 4 .....</b>	<b>475</b>
	<b>EXERCISE - 4 .....</b>	<b>481</b>

## CHAPTER 5

### MAGNETIC CIRCUITS & ELECTRO - MAGNETIC INDUCTION

<b>5.1</b>	<b>INTRODUCTION .....</b>	<b>493</b>
<b>5.2</b>	<b>MAGNETIC CIRCUITS .....</b>	<b>493</b>
5.2.1	Magnetization or Magnetizing Force ( H ) .....	493
5.2.1.1	Right Hand Screw Rule .....	494
5.2.1.2	Right Hand Thumb Rule .....	494
5.2.1.3	Right Hand Grip Rule .....	494
5.2.2	Magnetic Flux Density .....	495
5.2.3	Magnetic Flux .....	495
5.2.4	Magnetic Circuits .....	495
5.2.5	Permeance .....	496
5.2.6	Reluctivity .....	496
5.2.7	Leakage Flux .....	496
5.2.7.1	Leakage Coefficient or Leakage Factor .....	497
5.2.7.2	Fringing .....	497
5.2.7.3	Ampere-Turns Calculations .....	500
5.2.8	Series Magnetic Circuit .....	501
5.2.9	Parallel Magnetic Circuit .....	508
<b>5.3</b>	<b>MAGNETIZATION CURVE OR B-H CURVE .....</b>	<b>512</b>
5.3.1	Magnetic Calculations from B-H Curves .....	514
<b>5.4</b>	<b>MAGNETIC HYSTERESIS .....</b>	<b>515</b>
5.4.1	Residual Magnetism and Retentivity .....	516
5.4.2	Coercive Force .....	517
5.4.3	Hysteresis Loss .....	517
5.4.4	Magnitude of Hysteresis Loss .....	518
5.4.5	Importance Of Hysteresis Loop .....	519
5.4.6	Methods of Reducing Hysteresis Loss .....	521
<b>5.5</b>	<b>EDDY CURRENT LOSS .....</b>	<b>522</b>
5.5.1	Method of Reducing Eddy Current Loss .....	523
5.5.2	Core Loss .....	523

<b>5.6</b>	<b>FARADAY’S LAWS OF ELECTROMAGNETIC INDUCTION .....</b>	<b>524</b>
5.6.1	First Law .....	524
5.6.2	Second Law .....	526
<b>5.7</b>	<b>DIRECTION OF INDUCED E.M.F. ....</b>	<b>527</b>
5.7.1	Fleming’s Right Hand Rule .....	527
5.7.2	Lenz’s Law .....	527
<b>5.8</b>	<b>INDUCED E.M.F. ....</b>	<b>528</b>
<b>5.9</b>	<b>DYNAMICALLY INDUCED E.M.F. ....</b>	<b>529</b>
<b>5.10</b>	<b>STATICALLY INDUCED E.M.F. ....</b>	<b>532</b>
5.10.1	Self Induced E.M.F. ....	532
5.10.2	Mutually Induced E.M.F. ....	534
5.10.3	Force on a Current Carrying Conductor in a Magnetic Field .....	535
5.10.4	Force Between Two Parallel Conductors in a Magnetic Field .....	536
<b>5.11</b>	<b>LIFTING POWER OF MAGNET .....</b>	<b>540</b>
	<b>COMPREHENSION - 5 .....</b>	<b>543</b>
	<b>EXERCISE - 5 .....</b>	<b>545</b>

## CHAPTER 6

### TRANSFORMERS

<b>6.1</b>	<b>INTRODUCTION.....</b>	<b>549</b>
<b>6.2</b>	<b>USES OF TRANSFORMERS .....</b>	<b>550</b>
<b>6.3</b>	<b>PRINCIPLE OF OPERATION OF A TRANSFORMER.....</b>	<b>550</b>
<b>6.4.</b>	<b>IDEAL TRANSFORMER .....</b>	<b>551</b>
<b>6.5</b>	<b>TRANSFORMER CONSTRUCTION .....</b>	<b>551</b>
<b>6.6.</b>	<b>E.M.F EQUATION OF TRANSFORMER .....</b>	<b>553</b>
<b>6.7.</b>	<b>TRANSFORMER ON NO LOAD .....</b>	<b>556</b>
<b>6.8</b>	<b>TRANSFORMER ON LOAD .....</b>	<b>557</b>
<b>6.9.</b>	<b>REGULATION OF A TRANSFORMER .....</b>	<b>561</b>
<b>6.10.</b>	<b>OPEN CIRCUIT AND SHORT-CIRCUIT TESTS ON TRANSFORMER ..</b>	<b>561</b>

<b>6.11 OPEN CIRCUIT OR NO LOAD TEST .....</b>	<b>561</b>
6.11.1 Short Circuit Tests : .....	562
<b>6.12. EQUIVALENT CIRCUIT OF A TRANSFORMER .....</b>	<b>566</b>
<b>6.13. EFFICIENCY OF A TRANSFORMER .....</b>	<b>569</b>
<b>6.14. TRANSFORMER EFFICIENCY : .....</b>	<b>570</b>
<b>6.15 CONDITION FOR MAXIMUM EFFICIENCY : .....</b>	<b>570</b>
<b>6.16. ALL-DAY EFFICIENCY .....</b>	<b>574</b>
<b>6.17 AUTO TRANSFORMERS .....</b>	<b>575</b>
<b>COMPREHENSION - 6 .....</b>	<b>579</b>
<b>EXERCISE - 6 .....</b>	<b>580</b>

## CHAPTER 7

### ROTATING MACHINES - I - D.C. MACHINES

<b>7.1 INTRODUCTION .....</b>	<b>583</b>
D.C. GENERATORS	
<b>7.2. GENERATOR PRINCIPLE .....</b>	<b>583</b>
<b>7.3 PARTS OF A D.C. GENERATOR .....</b>	<b>584</b>
<b>7.4 PRINCIPLE OF OPERATION .....</b>	<b>587</b>
<b>7.5 E.M.F. INDUCED IN THE GENERATOR .....</b>	<b>590</b>
<b>7.6 NO LOAD MAGNETIZATION CURVE .....</b>	<b>592</b>
<b>7.7 THE VOLTAGE BUILD-UP PHENOMENON : .....</b>	<b>593</b>
<b>7.8 REASONS FOR A GENERATOR NOT BUILDING UP : .....</b>	<b>594</b>
<b>7.9 TYPES OF GENERATORS .....</b>	<b>595</b>
<b>7.10 LOAD CHARACTERISTICS .....</b>	<b>596</b>
<b>7.11 APPLICATIONS OF DC GENERATORS .....</b>	<b>603</b>
<b>7.12 ARMATURE REACTION .....</b>	<b>603</b>
D.C. MOTORS	
<b>7.13 INTRODUCTION .....</b>	<b>604</b>
<b>7.14 PRINCIPLE OF OPERATION .....</b>	<b>604</b>

7.15. BACK EM.....	605
7.16 TORQUE DEVELOPED: .....	606
7.17 SPEED EQUATION: .....	610
7.18 CHARACTERISTICS OF D.C. MOTORS: .....	611
7.19. COMPOUND MOTORS .....	613
7.20 APPLICATIONS OF D.C. MOTORS: .....	614
7.21 STARTERS FOR D.C. MOTORS: .....	615
7.22 CHANGING THE DIRECTION OF ROTATION: .....	617
7.23 SPEED CONTROL OF D.C. MOTORS: .....	617
7.24 EFFICIENCY OF D.C. MACHINES: .....	628
7.25 TESTING OF D.C. MACHINES: .....	632
COMPREHENSION - 7 .....	638
EXERCISE - 7 .....	640

## CHAPTER 8

### ROTATING MACHINES - II - SYNCHRONOUS MACHINES

8.1. INTRODUCTION.....	647
ALTERNATORS	
8.2. PRINCIPLE OF OPERATION OF AN ALTERNATOR .....	648
8.3 ARRANGEMENT OF WINDINGS .....	648
8.4 CONSTRUCTIONAL DETAILS.....	649
8.5 EMF EQUATION OF AN ALTERNATOR .....	649
8.6. VOLTAGE DROP IN AN ALTERNATOR .....	652
8.7. VOLTAGE REGULATION .....	653
SYNCHRONOUS MOTORS	
8.8 INTRODUCTION.....	656
8.9 ROTATING MAGNETIC FIELD .....	656
8.10. THE SYNCHRONOUS MOTOR ON LOAD .....	658

<b>8.11 SYNCHRONOUS MOTOR CHARACTERISTICS .....</b>	<b>658</b>
<b>8.12 APPLICATIONS OF SYNCHRONOUS MOTORS.....</b>	<b>659</b>
<b>COMPREHENSION - 8 .....</b>	<b>660</b>
<b>EXERCISE - 8 .....</b>	<b>661</b>

## CHAPTER 9

---

### ROTATING MACHINES-III - INDUCTION MOTORS AND SPECIAL MOTORS

<b>9.1 INTRODUCTION.....</b>	<b>663</b>
<b>9.2 CONSTRUCTION .....</b>	<b>663</b>
<b>9.3 PRODUCTION OF ROTATING MAGNETIC FIELD .....</b>	<b>664</b>
<b>9.4 MATHEMATICAL PROOF .....</b>	<b>668</b>
<b>9.5 PRINCIPLE OF OPERATION .....</b>	<b>668</b>
<b>9.6 FREQUENCY OF ROTOR E.M.F. AND CURRENT .....</b>	<b>669</b>
<b>9.7 TORQUE OF AN INDUCTION MOTOR .....</b>	<b>671</b>
<b>9.8 TORQUE SLIP CURVE.....</b>	<b>672</b>
<b>9.9 STARTING OF THREE-PHASE INDUCTION MOTORS .....</b>	<b>673</b>
<b>9.10 COMPARISON OF INDUCTION MOTORS AND SYNCHRONOUS MOTORS .....</b>	<b>674</b>
<b>9.11 SINGLE-PHASE INDUCTION MOTORS .....</b>	<b>674</b>
<b>9.12 SPLIT-PHASE MOTOR.....</b>	<b>675</b>
<b>9.13 CAPACITOR START MOTORS .....</b>	<b>675</b>
<b>9.14 CAPACITOR START AND RUN MOTOR .....</b>	<b>676</b>
<b>9.15 SHADED-POLE MOTORS .....</b>	<b>676</b>
<b>9.16 SPECIAL MOTORS - STEPPER MOTORS : .....</b>	<b>676</b>
9.16.1 Introduction to Stepper Motors and Drives : .....	676
9.16.2 Advantages of Stepper Motors: .....	677
9.16.3 Disadvantages of Stepper Motors: .....	677
9.16.4 Open Loop Operation : .....	677

9.16.5	Stepper Motor Types .....	677
9.16.6.	Size and Power .....	679
9.16.7.	When to Use a Stepper Motor : .....	680
9.16.8.	The Rotating Magnetic Field .....	680
9.16.9.	Torque Generation .....	681
9.16.10.	Phases, Poles and Stepping Angles : .....	681
<b>9.17.</b>	<b>STEPPING MODES : .....</b>	<b>682</b>
<b>9.18.</b>	<b>TORQUE VS, ANGLE CHARACTERISTICS : .....</b>	<b>682</b>
<b>9.19.</b>	<b>SINGLE STEP RESPONSE AND RESONANCES : .....</b>	<b>683</b>
<b>9.20.</b>	<b>SERIES AND PARALLEL CONNECTION : .....</b>	<b>684</b>
<b>9.21.</b>	<b>UNIVERSAL MOTORS .....</b>	<b>685</b>
9.21.1.	Types .....	685
9.21.2	Non-Compensated motor : .....	685
9.21.3.	Compensated type motor .....	686
9.21.4.	Direction of rotation: .....	686
9.21.5.	Speed/Load characteristics : .....	686
9.21.6.	Speed control: .....	687
9.21.7.	Applications of Universal Motors : .....	687
	<b>COMPREHENSION - 9 .....</b>	<b>688</b>
	<b>EXERCISE - 9 .....</b>	<b>690</b>

## CHAPTER 10

### ELECTRICAL MEASURING INSTRUMENTS

<b>10.1</b>	<b>INTRODUCTION .....</b>	<b>693</b>
<b>10.2</b>	<b>TYPES OF INSTRUMENTS .....</b>	<b>694</b>
10.2.1	Absolute Instruments .....	694
10.2.2	Secondary Instruments .....	694
10.2.3	Effects Used in the Secondary Instruments : .....	694

<b>10.3 CLASSIFICATION OF INSTRUMENTS .....</b>	<b>695</b>
<b>10.4 ESSENTIAL FEATURES OF INDICATING INSTRUMENTS .....</b>	<b>695</b>
<b>10.5 DEFLECTING MECHANISM.....</b>	<b>695</b>
<b>10.6 CONTROLLING MECHANISM .....</b>	<b>696</b>
<b>10.7 DAMPING MECHANISM.....</b>	<b>697</b>
<b>10.8 MOVING-COIL AMMETERS AND VOLTMETERS .....</b>	<b>698</b>
<b>10.9 MOVING-IRON AMMETERS AND VOLTMETERS .....</b>	<b>703</b>
<b>10.10 DYNAMOMETER TYPE WATTMETER.....</b>	<b>704</b>
<b>10.11 INDUCTION TYPE ENERGY METER (WATT-HOUR METER) .....</b>	<b>705</b>
<b>10.12 THE MEGGER.....</b>	<b>706</b>
<b>COMPREHENSION - 10 .....</b>	<b>707</b>
<b>EXERCISE - 10 .....</b>	<b>708</b>

## **CHAPTER 11**

### **INTRODUCTION TO POWER SYSTEM**

<b>11.1 INTRODUCTION TO ELECTRIC GRID .....</b>	<b>709</b>
11.1.1 Electricity generation - Generating plants .....	710
<b>11.2 ELECTRIC POWER TRANSMISSION .....</b>	<b>710</b>
11.2.1 Bulk power transmission at extra high voltage Lines .....	710
11.2.2 Bulk power <i>transmission</i> at high voltage <i>D.C. Lines</i> .....	710
11.2.3 Bulk power transmission using Six Phase at high Voltage Lines .....	711
<b>11.3. ELECTRIC POWER DISTRIBUTION .....</b>	<b>712</b>
11.3.1 Primary distribution system .....	712
11.3.1.1 Radial System .....	712
11.3.1.2 Looped system (ring main system) .....	713
11.3.1.3 Comparison between radial system and looped system .....	714
11.3.2 Feeder and Distributors .....	714
11.3.3 Secondary Distribution System .....	715

11.3.3.1 Types and applications of different secondary distribution systems .....	715
11.3.3.2 Banked secondary system .....	715
<b>11.4. METHOD OF DISTRIBUTION .....</b>	<b>716</b>
11.4.1 Comparison of Under Ground Cable and Over Head Lines .....	717
<b>11.5. EARTHING .....</b>	<b>717</b>
<b>11.6. EMERGING SMART GRID .....</b>	<b>718</b>
<b>11.7. NETWORKED ISLANDABLE MICROGRIDS .....</b>	<b>719</b>
<b>11.8. REGIONAL, INTER-REGIONAL AND NATIONAL OR SUPER GRIDS .....</b>	<b>720</b>
<b>11.9. AUGUMENTATION OF GENERATION USING NON CONVENTIONAL . ENERGY SOURCES.....</b>	<b>721</b>
<b>11.10. THE DETAILS OF THE EXISTING TRANSMISSION SYSTEM IN INDIA ARE GIVEN IN TABLE .....</b>	<b>722</b>
<b>11.11.SUBSTATIONS .....</b>	<b>722</b>
<b>11.12.VOLTAGES IN INDIA FROM GENERATION UNTIL COMPLETE ..... DISTRIBUTION .....</b>	<b>722</b>
<b>COMPREHENSION - 11 .....</b>	<b>723</b>
<b>EXERCISE - 11 .....</b>	<b>724</b>

\* \* \* \*