

Contents

CHAPTER 1

BASICS OF ELECTRICAL ENGINEERING

1.1	INTRODUCTION	1
1.2	CURRENT FLOW	1
1.2.1	Potential and Potential Difference	1
1.2.2	Electric Current	3
1.2.3	Resistance or Resistance Parameter	4
1.2.4	Effect of Temperature on Resistance	8
1.2.5	Electrical Conductance	9
1.3	SOURCES OF ELECTRICAL ENERGY	10
1.3.1	The Voltage Source	10
1.3.2	Current Source	11
1.3.3	D.C. & A.C. Sources	12
1.4	OHM'S LAW	14
1.4.1	Linear & Non-Linear Resistances	15
1.5	ELECTRICAL POWER	17
1.6	ENERGY CALCULATIONS	18
1.7	ELECTRICAL ENERGY	19

1.8	KIRCHOFF'S LAWS	20
1.8.1	Kirchoff's Voltage Law (KVL)	20
1.8.2	Kirchoff's Current Law (KCL or KIL)	21
1.9	RESISTANCES IN SERIES	26
1.10	RESISTANCES IN PARALLEL	30
1.10.1	Division of Currents in Parallel Circuits	32
1.11	SERIES-PARALLEL RESISTANCES	36
1.12	RESISTANCES IN STAR OR DELTA CONNECTIONS	41
1.12.1	The Equivalent Star Resistances For Given Delta Connected Resistances .	42
1.12.2	The Equivalent Delta Resistances For Given Star Connected Resistances .	43
1.13	FEATURES OF A RESISTANCE	49
1.14	USES OF RESISTANCE	50
1.15	DIFFERENCES BETWEEN ELECTRICAL & ELECTRONIC CIRCUITS	51
1.16	NETWORK THEOREMS	52
1.16.1	Introduction to Network Theorems	52
1.17	NETWORK CLASSIFICATION	53
1.17.1	Linear Networks	53
1.17.2	Passive Networks	53
1.17.3	Lamped Networks	54
1.17.4	Bilateral Networks	55
1.17.5	Time Invariant Networks	55
1.17.6	Reciprocity	55
1.18	SUPERPOSITION THEOREM	56
1.19	THEVENIN'S THEOREM	58
1.20.	NORTON'S THEOREM	63
1.21.	MAXIMUM POWER TRANSFER THEOREM	65
	COMPREHENSION - 1	69
	EXERCISE - 1	72

CHAPTER 2

D.C. CIRCUIT ANALYSIS USING MESH AND NODAL ANALYSIS

2.1	INTRODUCTION	81
2.1.1.	Controlled or dependent voltage and current sources :	82
2.1.2	Controlled Source or Dependent Source	82
2.1.3.	Controlled Voltage Source	82
2.1.4	Controlled Current Source	83
2.1.5	Combination of Energy Sources	84
2.1.6	Voltage Sources in Series	84
2.1.7.	Current Sources in Parallel	84
2.1.8	Voltage Sources in Parallel and Current Sources in Series & Parallel : ..	85
2.1.9	Source Transformations	86
2.1.10	Source Shifting	87
2.2	LOOP OR MESH ANALYSIS AND NODAL ANALYSIS	90
2.3	LOOP ANALYSIS FOR D.C. CIRCUITS	90
2.3.1	Redundant Elements	91
2.3.2	Identification of independant loops	91
2.3.3	Loop Analysis Using Independent Voltage Sources	92
2.3.4	Loop Analysis Using Independent Current Sources (Super Mesh)	95
2.3.5	Loop Analysis using Independent Voltage and Current Sources	96
2.4.	NODAL ANALYSIS	99
2.4.1	Identification of Independant Nodes	100
2.5	NODAL ANALYSIS FOR D.C. CIRCUITS	101
2.5.1	Nodal Analysis using Independent Current Sources	101
2.5.2	Nodal analysis using Independent Voltage Sources (Super Nodes)	103
2.5.3	Nodal Analysis using Independent Voltage and Current Sources	105
2.6	NODAL ANALYSIS WITH DEPENDENT SOURCES	112
	COMPREHENSION-2	113
	EXERCISE-2	115

CHAPTER 3

FUNDAMENTALS OF ALTERNATING CURRENT

3.1	INTRODUCTION	119
3.2	GENERATION OF ALTERNATING VOLTAGES & CURRENTS	119
3.2.1	D.C. Waveform or Steady Waveform	120
3.2.2	A.C. Waveforms	120
3.2.3	Periodic and Aperiodic Waveforms	121
3.2.4	Sinusoidal Waveforms	123
3.2.5	Generation of Sinusoidal Waveforms	124
3.3	EXPRESSION FOR THE E.M.F. GENERATED BY A SINGLE PHASE ALTERNATOR	126
3.3.1	Time Period (T)	128
3.3.2	Amplitude	128
3.3.3	Cycle	128
3.3.4	Frequency	128
3.3.5	Relation between Frequency and Time Period	128
3.3.6	Relation between Frequency and Angular Velocity	129
3.3.7	Relationship Between Frequency, Speed And Number of Pole Pairs ...	129
3.3.8	Average Value Of An Alternating Current	130
3.3.9	Root Mean Square (RMS) Value Of An Alternating Current	133
3.3.10	Form Factor And Peak Factor	137
3.4	DIFFERENT FORMS OF REPRESENTING ALTERNATING QUANTITIES	140
3.4.1	Phasor Representation of an Alternating Quantity	140
3.4.2	Lagging / Leading Waveforms With Phase & Phase Difference	143
3.4.3	Rectangular Coordinates Representation	144
3.4.3.1	j-Operator	144
3.4.3.2	Phasor Represented in Rectangular Coordinate Components	145
3.4.3.3	Trigonometrical Form of Phasor Representation	146
3.4.3.4	Exponential Form of Phasor Representation	147
3.4.3.5	Polar Form of Phasor Representation	147

3.5	ARITHMETIC OPERATIONS OF PHASORS	148
3.5.1	Addition and Subtraction of Phasors	148
3.5.2	Multiplication and Division of Phasors	149
3.5.3	Power and Roots of Vectors	150
3.5.3.1	Powers	150
3.5.3.2	Roots	150
3.5.4	Conjugate of a Phasor and Rationalization	151
3.6	INSTANTANEOUS & AVERAGE POWER IN A.C. CIRCUITS	155
3.6.1	A.C. Circuit with Pure Resistance As Load (3.6.5a)	156
3.6.2	A.C. Circuit with Pure Inductance as Load	159
3.6.3	A.C. Circuit with Pure Capacitance as Load	162
	COMPREHENSION - 3	168
	EXERCISE - 3	170

CHAPTER 4

A.C. SINGLE PHASE AND THREE PHASE CIRCUITS

4.1	INTRODUCTION	173
4.2	POWER AND POWER FACTOR IN SINGLE PHASE A.C. CIRCUITS	174
4.3	A.C. SERIES CIRCUITS	174
4.3.1	R-L Series Circuit with A.C. Supply	174
4.3.2	Power Factor	177
4.3.3	Voltage Drop Triangle	178
4.3.4	Complex Power	178
4.3.5	VA or KVA Triangle	180
4.3.6	Wattfull and Wattless Component of Current	181
4.3.7	R-C Series Circuit with A.C. Supply	183
4.3.8	Power Factor	187
4.3.9	Voltage Drop Triangle	187
4.3.10	Complex Power	187

4.3.11	VA or KVA Triangle	189
4.3.12	Wattfull and Wattless Component of Current	189
4.3.13	Admittance & Admittance Triangle	191
4.3.14	R-L-C Series Circuit	193
4.3.15	A.C. Series Circuit with Two or More Impedances	195
4.4	A.C. PARALLEL CIRCUITS	196
4.4.1	A.C. Parallel Circuit with Two or More Impedances	197
4.5	A.C. SERIES - PARALLEL CIRCUIT	199
4.6	A.C. STAR - DELTA CONNECTED CIRCUITS	203
4.7	IMPORTANCE OF POWER FACTOR	208
4.8	FEATURES OF A.C. SINGLE PHASE CIRCUITS	208
4.9	USES OF A.C. SINGLE PHASE CIRCUITS	209
4.10	INTRODUCTION TO THREE-PHASE SYSTEMS	210
4.11	POLY-PHASE SYSTEM	210
4.12	ADVANTAGES OF THREE PHASE SYSTEMS	211
4.13	GENERATION OF THREE-PHASE E.M.F.S	211
4.13.1	Phasor Diagram	213
4.13.2	Phase Sequence	214
4.13.3	Change of Phase Sequence	215
4.14	BALANCED & UNBALANCED THREE-PHASE CIRCUITS	215
4.14.1	Balanced Three-Phase System	215
4.14.2	Unbalanced Three-Phase System	216
4.15	THREE PHASE CONNECTIONS	216
4.15.1	Six Line Conductors	217
4.15.2	Star or WYE Connection with 3 wires or 4 wires	217
4.15.3	Delta or Mesh Connection	218
4.16	THREE-PHASE VOLTAGES&CURRENTS-PHASE & LINE VALUES ..	221
4.16.1	Star Connection - Phase & Line Voltages	221
4.16.2	Star Connection - Phase & Line Currents	222
4.16.3	Delta Connection - Phase & Line Voltages	223
4.16.4	Delta Connection - Phase & Line Currents	224

4.17	BALANCED OR UNBALANCED THREE - PHASE LOADS	226
4.17.1	Three-Phase Balanced Load	226
4.17.2	Three-Phase Unbalanced Load	234
4.17.3	Line & Phase Values of Voltages & Currents - Phasor Relationships .	237
	4.17.3.1 Star Connected Load	237
	4.17.3.2 Delta Connected Load	239
4.18	POWER IN THREE - PHASE CIRCUITS	246
4.19	POWER MEASUREMENT IN THREE - PHASE CIRCUITS	247
4.20.	THREE WATTMETER METHOD	249
4.21	TWO-WATTMETER METHOD	250
4.22	TWO WATTMETER METHOD FOR BALANCED LOAD.....	252
4.22.1	Power Measurement for Star Connected Load	253
4.22.2	Determination of Power Factor from Wattmeter Readings	255
4.22.3	Power Measurement for Delta Connected Load	255
4.22.4	Determination of Reactive Power from two Wattmeter Reading.....	255
4.23	EFFECT OF POWER FACTOR ON THE WATTMETER READINGS	256
4.24	LEADING POWER FACTOR	258
4.25.	OTHER METHODS OF CONNECTING TWO WATTMETERS	259
4.26	SINGLE WATTMETER METHOD	261
4.27	MEASUREMENT OF REACTIVE POWER	261
4.28	THREE PHASE WATTMETER	263
4.29	POWER FACTOR METER	263
4.30	PHASE SEQUENCE METER	270
4.31	FREQUENCY METER.....	270
4.32	COMPARISON BETWEEN STAR & DELTA CONNECTIONS	271
4.33	COMPARISON BETWEEN 1-PHASE & 3-PHASE SUPPLY SYSTEMS..	272
4.34	SINGLE PHASE CIRCUITS WITH VARIABLE ELEMENTS - RESONANCE	272
4.35	RESONANCE IN A.C. CIRCUITS	273
4.35.1	Frequency Variation	273

4.35.2	Series Resonance	273
4.35.3	Series Resonance Frequency	275
4.35.4	Effects of Series Resonance	279
4.35.5	Selectivity & Bandwidth	281
4.35.6	Effect of Resistance in Series Resonance	286
4.35.7	Parallel Resonance	288
4.35.8	Parallel Resonant Frequency	289
4.35.9	Effects of Parallel Resonance	291
4.35.10	Quality Factor Of A Parallel Resonant Circuit	292
4.35.11	Comparison of Series And Parallel Resonant Circuits	295
4.36	SINGLE PHASE CIRCUITS WITH VARIABLE ELEMENTS - CURRENT	
	LOCUS DIAGRAMS	298
4.36.1	Series RL And RC Circuits with Variable R & Constant Reactance ...	299
	4.36.1.1 RL Circuit with variable resistance	300
	4.36.1.2 RC Circuit with variable resistance :	302
4.36.2	Locus of Voltage	305
	4.36.2.1 RL Circuit with variable resistance :	305
	4.36.2.2 RC Circuit with variable resistance :	306
4.36.3	Series RL And RC Circuits with Variable Reactance & Constant R ...	306
	4.36.3.1 RL Circuit with variable reactance :	307
	4.36.3.2 R.C. Circuit with variable reactance :	310
4.36.4	Properties of Constant Reactance, Variable Resistance	313
	4.36.4.1 Maximum Current	313
	4.36.4.2 Maximum Power Supplied To The Circuit	313
	4.36.4.3 Power Factor at Maximum Power Condition	314
4.36.5	Properties of Constant Resistance, Variable Reactance	315
	4.36.5.1 Maximum Current	315
	4.36.5.2 Maximum Power Supplied To The Circuit	315
	4.36.5.3 Power Factor at Maximum Power Condition	315
4.36.6	Points to be Considered in Locus Diagrams	315
	COMPREHENSION - 4	320
	EXERCISE - 4	326

CHAPTER 5

MAGNETIC CIRCUITS & ELECTRO - MAGNETIC INDUCTION

5.1	INTRODUCTION	337
5.2	MAGNETIC CIRCUITS	337
5.2.1	Magnetization or Magnetizing Force (H)	337
5.2.1.1	Right Hand Screw Rule	338
5.2.1.2	Right Hand Thumb Rule	338
5.2.1.3	Right Hand Grip Rule	338
5.2.2	Magnetic Flux Density	339
5.2.3	Magnetic Flux	339
5.2.4	Magnetic Circuits	339
5.2.5	Permeance	340
5.2.6	Reluctivity	340
5.2.7	Leakage Flux	340
5.2.7.1	Leakage Coefficient or Leakage Factor	341
5.2.7.2	Fringing	341
5.2.7.3	Ampere-Turns Calculations	344
5.2.8	Series Magnetic Circuit	345
5.2.9	Parallel Magnetic Circuit	352
5.3	MAGNETIZATION CURVE OR B-H CURVE	356
5.3.1	Magnetic Calculations from B-H Curves	358
5.4	MAGNETIC HYSTERESIS	359
5.4.1	Residual Magnetism and Retentivity	360
5.4.2	Coercive Force	361
5.4.3	Hysteresis Loss	361
5.4.4	Magnitude of Hysteresis Loss	362
5.4.5	Importance Of Hysteresis Loop	363
5.4.6	Methods of Reducing Hysteresis Loss	365
5.5	EDDY CURRENT LOSS	366
5.5.1	Method of Reducing Eddy Current Loss	367
5.5.2	Core Loss	367

5.6	FARADAY'S LAWS OF ELECTROMAGNETIC INDUCTION	368
5.6.1	First Law	368
5.7	DIRECTION OF INDUCED E.M.F.	371
5.7.1	Fleming's Right Hand Rule	371
5.7.2	Lenz's Law	371
5.8	INDUCED E.M.F.	372
5.9	DYNAMICALLY INDUCED E.M.F.	373
5.10	STATICALLY INDUCED E.M.F.	376
5.10.1	Self Induced E.M.F.	376
5.10.2	Mutually Induced E.M.F.	378
5.10.3	Force on a Current Carrying Conductor in a Magnetic Field	379
5.10.4	Force Between Two Parallel Conductors in a Magnetic Field	380
5.11	LIFTING POWER OF MAGNET	384
	COMPREHENSION - 5	387
	EXERCISE - 5	389

CHAPTER 6

TRANSFORMERS

6.1	INTRODUCTION	393
6.2	USES OF TRANSFORMERS	394
6.3	PRINCIPLE OF OPERATION OF A TRANSFORMER	394
6.4.	IDEAL TRANSFORMER	395
6.5	TRANSFORMER CONSTRUCTION	395
6.6.	E.M.F EQUATION OF TRANSFORMER	397
6.7.	TRANSFORMER ON NO LOAD	400
6.8	TRANSFORMER ON LOAD	401
6.9.	REGULATION OF A TRANSFORMER	405
6.10.	OPEN CIRCUIT AND SHORT-CIRCUIT TESTS ON TRANSFORMER ..	405
6.11	OPEN CIRCUIT OR NO LOAD TEST	405
6.11.1	Short Circuit Tests :	406

6.12	EQUIVALENT CIRCUIT OF A TRANSFORMER.....	410
6.13	EFFICIENCY OF A TRANSFORMER	413
6.14	TRANSFORMER EFFICIENCY :.....	414
6.15	CONDITION FOR MAXIMUM EFFICIENCY :	414
6.16	ALL-DAY EFFICIENCY	418
6.17	AUTO TRANSFORMERS	419
	COMPREHENSION - 6	423
	EXERCISE - 6	424

CHAPTER 7

ROTATING MACHINES - I: D.C. MACHINES

7.1	INTRODUCTION.....	427
7.2	GENERATOR PRINCIPLE	427
7.3	PARTS OF A D.C. GENERATOR	428
7.4	PRINCIPLE OF OPERATION.....	431
7.5	E.M.F. INDUCED IN THE GENERATOR	434
7.6	NO LOAD MAGNETIZATION CURVE	436
7.7	THE VOLTAGE BUILD-UP PHENOMENON :	437
7.8	REASONS FOR A GENERATOR NOT BUILDING UP :	438
7.9	TYPES OF GENERATORS	439
7.10	LOAD CHARACTERISTICS	440
7.11	APPLICATIONS OF DC GENERATORS.....	447
7.12	ARMATURE REACTION	447
7.13	INTRODUCTION.....	448
7.14	PRINCIPLE OF OPERATION.....	448
7.15	BACK EM.....	449
7.16	TORQUE DEVELOPED:	450
7.17	SPEED EQUATION:	454
7.18	CHARACTERISTICS OF D.C. MOTORS:	455

7.19. COMPOUND MOTORS	457
7.20 APPLICATIONS OF D.C. MOTORS:	458
7.21 STARTERS FOR D.C. MOTORS:	459
7.22 CHANGING THE DIRECTION OF ROTATION:	461
7.23 SPEED CONTROL OF D.C. MOTORS:	461
7.24 EFFICIENCY OF D.C. MACHINES:	472
7.25 TESTING OF D.C. MACHINES:	476
COMPREHENSION - 7	482
EXERCISE - 7	484

CHAPTER 8

ROTATING MACHINES - II : SYNCHRONOUS MACHINES

8.1 INTRODUCTION	491
8.2 PRINCIPLE OF OPERATION OF AN ALTERNATOR	492
8.3 ARRANGEMENT OF WINDINGS	492
8.4 CONSTRUCTIONAL DETAILS	493
8.5 EMF EQUATION OF AN ALTERNATOR	493
8.6 VOLTAGE DROP IN AN ALTERNATOR	496
8.7 VOLTAGE REGULATION	497
SYNCHRONOUS MOTORS	500
8.8 INTRODUCTION	500
8.9 ROTATING MAGNETIC FIELD	500
8.10. THE SYNCHRONOUS MOTOR ON LOAD	502
8.11 SYNCHRONOUS MOTOR CHARACTERISTICS	502
8.12 APPLICATIONS OF SYNCHRONOUS MOTORS	503
COMPREHENSION - 8	504
EXERCISE - 8	505

CHAPTER 9

ROTATING MACHINES-III : INDUCTION MOTORS AND SPECIAL MOTORS

9.1	INTRODUCTION	507
9.2	CONSTRUCTION	507
9.3	PRODUCTION OF ROTATING MAGNETIC FIELD	508
9.4	MATHEMATICAL PROOF	512
9.5	PRINCIPLE OF OPERATION	512
9.6	FREQUENCY OF ROTOR E.M.F. AND CURRENT	513
9.7	TORQUE OF AN INDUCTION MOTOR	515
9.8	TORQUE SLIP CURVE.....	516
9.9	STARTING OF THREE-PHASE INDUCTION MOTORS	517
9.10	COMPARISON OF INDUCTION MOTORS AND SYNCHRONOUS MOTORS	518
9.11	SINGLE-PHASE INDUCTION MOTORS	518
9.12	SPLIT-PHASE MOTOR.....	519
9.13	CAPACITOR START MOTORS	519
9.14	CAPACITOR START AND RUN MOTOR	520
9.15	SHADED-POLE MOTORS	520
9.16	SPECIAL MOTORS - STEPPER MOTORS :	520
9.16.1	Introduction to Stepper Motors and Drives :	520
9.16.2	Advantages of Stepper Motors:	521
9.16.3	Disadvantages of Stepper Motors:	521
9.16.4	Open Loop Operation :	521
9.16.5	Stepper Motor Types	521
9.16.6	Size and Power	523
9.16.7	When to Use a Stepper Motor :	524
9.16.8	The Rotating Magnetic Field.....	524
9.16.9	Torque Generation	525
9.16.10	Phases, Poles and Stepping Angles :	525
9.17	STEPPING MODES :	526

9.18 TORQUE VS, ANGLE CHARACTERISTICS :	526
9.19 SINGLE STEP RESPONSE AND RESONANCES :	527
9.20 SERIES AND PARALLEL CONNECTION :	528
9.21 UNIVERSAL MOTORS	529
9.21.1 Types	529
9.21.2 Non-Compensated motor :	529
9.21.3 Compensated type motor	530
9.21.4 Direction of rotation:	530
9.21.5 Speed/Load characteristics :	530
9.21.6 Speed control:	531
9.21.7 Applications of Universal Motors :	531
COMPREHENSION - 9	532
EXERCISE - 9	533

CHAPTER 10

ELECTRICAL MEASURING INSTRUMENTS

10.1 INTRODUCTION	537
10.2 TYPES OF INSTRUMENTS	538
10.2.1 Absolute Instruments	538
10.2.2 Secondary Instruments	538
10.2.3 Effects Used in the Secondary Instruments :	538
10.3 CLASSIFICATION OF INSTRUMENTS	539
10.4 ESSENTIAL FEATURES OF INDICATING INSTRUMENTS	539
10.5 DEFLECTING MECHANISM	539
10.6 CONTROLLING MECHANISM	540
10.7 DAMPING MECHANISM	541
10.8 MOVING-COIL AMMETERS AND VOLTMETERS	542
10.9 MOVING-IRON AMMETERS AND VOLTMETERS	547

10.10	DYNAMOMETER TYPE WATTMETER	548
10.11	INDUCTION TYPE ENERGY METER (WATT-HOUR METER)	549
10.12	THE MEGGER	550
	COMPREHENSION - 10	551
	EXERCISE - 10	552
	REFERENCES	553