

Contents

Preface	x		
Part 1 Revision of Some Basic Mathematics	1		
1 Some mathematics revision	3	3.8 Electrical power and energy	60
1.1 Use of calculator and evaluating formulae	3	3.9 Summary of terms, units and their symbols	61
1.2 Fractions	6		
1.3 Percentages	8		
1.4 Ratio and proportion	10	4 An introduction to electric circuits	63
1.5 Laws of indices	13	4.1 Electrical/electronic system block diagrams	64
1.6 Brackets	15	4.2 Standard symbols for electrical components	65
1.7 Solving simple equations	16	4.3 Electric current and quantity of electricity	65
1.8 Transposing formulae	18	4.4 Potential difference and resistance	66
1.9 Solving simultaneous equations	20	4.5 Basic electrical measuring instruments	66
2 Further mathematics revision	22	4.6 Linear and non-linear devices	67
2.1 Radians and degrees	23	4.7 Ohm's law	67
2.2 Measurement of angles	24	4.8 Multiples and sub-multiples	67
2.3 Trigonometry revision	25	4.9 Conductors and insulators	69
2.4 Logarithms and exponentials	27	4.10 Electrical power and energy	69
2.5 Straight line graphs	32	4.11 Main effects of electric current	72
2.6 Gradients, intercepts and equation of a graph	34	4.12 Fuses	73
2.7 Practical straight line graphs	36	4.13 Insulation and the dangers of constant high current flow	73
2.8 Calculating areas of common shapes	38		
Formulae for revision of some basic mathematics	44	5 Resistance variation	76
Multiple choice questions on chapters 1 and 2	46	5.1 Resistor construction	76
Part 2 Basic Electrical and Electronic Engineering Principles	53	5.2 Resistance and resistivity	77
3 Units associated with basic electrical quantities	55	5.3 Temperature coefficient of resistance	79
3.1 SI units	55	5.4 Resistor colour coding and ohmic values	81
3.2 Charge	56		
3.3 Force	57	6 Batteries and alternative sources of energy	85
3.4 Work	57	6.1 Introduction to batteries	86
3.5 Power	58	6.2 Some chemical effects of electricity	86
3.6 Electrical potential and e.m.f.	59	6.3 The simple cell	87
3.7 Resistance and conductance	59	6.4 Corrosion	88
		6.5 E.m.f. and internal resistance of a cell	88
		6.6 Primary cells	90
		6.7 Secondary cells	91
		6.8 Lithium-ion batteries	93
		6.9 Cell capacity	96
		6.10 Safe disposal of batteries	96
		6.11 Fuel cells	96
		6.12 Alternative and renewable energy sources	97
		6.13 Solar energy	98
		Revision Test 1	103
		7 Series and parallel networks	104
		7.1 Series circuits	104
		7.2 Potential divider	106

7.3	Parallel networks	107	11.3	Rotation of a loop in a magnetic field	173
7.4	Current division	110	11.4	Inductance	174
7.5	Loading effect	114	11.5	Inductors	176
7.6	Potentiometers and rheostats	115	11.6	Energy stored	176
7.7	Relative and absolute voltages	117	11.7	Inductance of a coil	177
7.8	Earth potential and short circuits	119	11.8	Mutual inductance	179
7.9	Wiring lamps in series and in parallel	119			
8	Capacitors and capacitance	122	12	Electrical measuring instruments and measurements	183
8.1	Introduction to capacitors	123	12.1	Introduction	184
8.2	Electrostatic field	123	12.2	Analogue instruments	184
8.3	Electric field strength	124	12.3	Shunts and multipliers	184
8.4	Capacitance	124	12.4	Electronic instruments	186
8.5	Capacitors	125	12.5	The ohmmeter	186
8.6	Electric flux density	126	12.6	Multimeters	187
8.7	Permittivity	126	12.7	Wattmeters	187
8.8	The parallel plate capacitor	128	12.8	Instrument ‘loading’ effect	187
8.9	Capacitors connected in parallel and series	129	12.9	The oscilloscope	189
8.10	Dielectric strength	133	12.10	Virtual test and measuring instruments	194
8.11	Energy stored in capacitors	134	12.11	Virtual digital storage oscilloscopes	195
8.12	Practical types of capacitor	135	12.12	Waveform harmonics	198
8.13	Supercapacitors	137	12.13	Logarithmic ratios	199
8.14	Discharging capacitors	138	12.14	Null method of measurement	202
9	Magnetic circuits	141	12.15	Wheatstone bridge	202
9.1	Introduction to magnetism and magnetic circuits	142	12.16	D.c. potentiometer	203
9.2	Magnetic fields	143	12.17	A.c. bridges	204
9.3	Magnetic flux and flux density	144	12.18	Q-meter	205
9.4	Magnetomotive force and magnetic field strength	144	12.19	Measurement errors	206
9.5	Permeability and B–H curves	145			
9.6	Reluctance	148	13	Semiconductor diodes	211
9.7	Composite series magnetic circuits	149	13.1	Types of material	212
9.8	Comparison between electrical and magnetic quantities	152	13.2	Semiconductor materials	212
9.9	Hysteresis and hysteresis loss	153	13.3	Conduction in semiconductor materials	214
Revision Test 2		156	13.4	The p–n junction	214
			13.5	Forward and reverse bias	215
10	Electromagnetism	157	13.6	Semiconductor diodes	218
10.1	Magnetic field due to an electric current	158	13.7	Characteristics and maximum ratings	219
10.2	Electromagnets	159	13.8	Rectification	219
10.3	Force on a current-carrying conductor	161	13.9	Zener diodes	220
10.4	Principle of operation of a simple d.c. motor	164	13.10	Silicon controlled rectifiers	221
10.5	Principle of operation of a moving-coil instrument	164	13.11	Light emitting diodes	222
10.6	Force on a charge	165	13.12	Varactor diodes	222
13.13	Schottky diodes		13.13	Schottky diodes	222
11	Electromagnetic induction	168	14	Transistors	226
11.1	Introduction to electromagnetic induction	169	14.1	Transistor classification	227
11.2	Laws of electromagnetic induction	170	14.2	Bipolar junction transistors (BJTs)	227
			14.3	Transistor action	228
			14.4	Leakage current	229
			14.5	Bias and current flow	230
			14.6	Transistor operating configurations	230
			14.7	Bipolar transistor characteristics	230

14.8 Transistor parameters	232	17.3 Purely capacitive a.c. circuit	298	
14.9 Current gain	234	17.4 $R-L$ series a.c. circuit	299	
14.10 Typical BJT characteristics and maximum ratings	234	17.5 $R-C$ series a.c. circuit	303	
14.11 Field effect transistors	235	17.6 $R-L-C$ series a.c. circuit	304	
14.12 Field effect transistor characteristics	236	17.7 Series resonance	308	
14.13 Typical FET characteristics and maximum ratings	238	17.8 Q-factor	309	
14.14 Transistor amplifiers	238	17.9 Bandwidth and selectivity	310	
14.15 Load lines	240	17.10 Power in a.c. circuits	311	
Revision Test 3	247	17.11 Power triangle and power factor	312	
Formulae for basic electrical and electronic principles	248			
Part 3 Further Electrical and Electronic Principles	249	18 Single-phase parallel a.c. circuits	318	
15 D.c. circuit theory	251	18.1 Introduction	319	
15.1 Introduction	251	18.2 $R-L$ parallel a.c. circuit	319	
15.2 Kirchhoff's laws	252	18.3 $R-C$ parallel a.c. circuit	320	
15.3 The superposition theorem	256	18.4 $L-C$ parallel circuit	321	
15.4 General d.c. circuit theory	259	18.5 $LR-C$ parallel a.c. circuit	323	
15.5 Thévenin's theorem	261	18.6 Parallel resonance and Q -factor	326	
15.6 Constant-current source	266	18.7 Power factor improvement	330	
15.7 Norton's theorem	266			
15.8 Thévenin and Norton equivalent networks	269	19 Filter networks	337	
15.9 Maximum power transfer theorem	272	19.1 Introduction	337	
16 Alternating voltages and currents	278	19.2 Two-port networks and characteristic impedance	338	
16.1 Introduction	279	19.3 Low-pass filters	338	
16.2 The a.c. generator	279	19.4 High-pass filters	341	
16.3 Waveforms	280	19.5 Band-pass filters	345	
16.4 A.c. values	281	19.6 Band-stop filters	346	
16.5 Electrical safety – insulation and fuses	285			
16.6 The equation of a sinusoidal waveform	285	20 D.c. transients	349	
16.7 Combination of waveforms	287	20.1 Introduction	350	
16.8 Rectification	291	20.2 Charging a capacitor	350	
16.9 Smoothing of the rectified output waveform	292	20.3 Time constant for a $C-R$ circuit	351	
Revision Test 4	295	20.4 Transient curves for a $C-R$ circuit	351	
17 Single-phase series a.c. circuits	296	20.5 Discharging a capacitor	355	
17.1 Purely resistive a.c. circuit	297	20.6 Camera flash	357	
17.2 Purely inductive a.c. circuit	297	20.7 Current growth in an $L-R$ circuit	357	
		20.8 Time constant for an $L-R$ circuit	358	
		20.9 Transient curves for an $L-R$ circuit	358	
		20.10 Current decay in an $L-R$ circuit	360	
		20.11 Switching inductive circuits	362	
		20.12 The effects of time constant on a rectangular waveform	362	
		21 Operational amplifiers	366	
		21.1 Introduction to operational amplifiers	367	
		21.2 Some op amp parameters	368	
		21.3 Op amp inverting amplifier	369	
		21.4 Op amp non-inverting amplifier	372	
		21.5 Op amp voltage-follower	372	
		21.6 Op amp summing amplifier	373	
		21.7 Op amp voltage comparator	374	
		21.8 Op amp integrator	375	

viii Contents

21.9 Op amp differential amplifier	375	24.5 Transformer on-load phasor diagram	424
21.10 Digital to analogue (D/A) conversion	377	24.6 Transformer construction	425
21.11 Analogue to digital (A/D) conversion	379	24.7 Equivalent circuit of a transformer	426
Revision Test 5	382	24.8 Regulation of a transformer	428
Formulae for further electrical and electronic principles	383	24.9 Transformer losses and efficiency	428
Part 4 Electrical Power Technology	385	24.10 Resistance matching	431
Revision Test 6	441	24.11 Auto transformers	433
22 Ways of generating electricity – the present and the future	387	24.12 Isolating transformers	435
22.1 Introduction	388	24.13 Three-phase transformers	435
22.2 Generating electrical power using coal	388	24.14 Current transformers	437
22.3 Generating electrical power using oil	390	24.15 Voltage transformers	438
22.4 Generating electrical power using natural gas	391		
22.5 Generating electrical power using nuclear energy	392		
22.6 Generating electrical power using hydro power	393		
22.7 Generating electrical power using pumped storage	394		
22.8 Generating electrical power using wind	395		
22.9 Generating electrical power using tidal power	395		
22.10 Generating electrical power using biomass	397		
22.11 Generating electrical power using solar energy	397		
22.12 Harnessing the power of wind, tide and sun on an ‘energy island’ – a future possibility?	398		
23 Three-phase systems	401	25 D.c. machines	442
23.1 Introduction	402	25.1 Introduction	443
23.2 Three-phase supply	402	25.2 The action of a commutator	443
23.3 Star connection	402	25.3 D.c. machine construction	444
23.4 Delta connection	406	25.4 Shunt, series and compound windings	444
23.5 Power in three-phase systems	407	25.5 E.m.f. generated in an armature winding	445
23.6 Measurement of power in three-phase systems	409	25.6 D.c. generators	447
23.7 Comparison of star and delta connections	414	25.7 Types of d.c. generator and their characteristics	447
23.8 Advantages of three-phase systems	414	25.8 D.c. machine losses	451
24 Transformers	417	25.9 Efficiency of a d.c. generator	451
24.1 Introduction	418	25.10 D.c. motors	452
24.2 Transformer principle of operation	418	25.11 Torque of a d.c. motor	453
24.3 Transformer no-load phasor diagram	421	25.12 Types of d.c. motor and their characteristics	455
24.4 E.m.f. equation of a transformer	422	25.13 The efficiency of a d.c. motor	458
		25.14 D.c. motor starter	461
		25.15 Speed control of d.c. motors	461
		25.16 Motor cooling	464
		26 Three-phase induction motors	467
		26.1 Introduction	468
		26.2 Production of a rotating magnetic field	468
		26.3 Synchronous speed	470
		26.4 Construction of a three-phase induction motor	471
		26.5 Principle of operation of a three-phase induction motor	471
		26.6 Slip	472
		26.7 Rotor e.m.f. and frequency	473
		26.8 Rotor impedance and current	474
		26.9 Rotor copper loss	474
		26.10 Induction motor losses and efficiency	475
		26.11 Torque equation for an induction motor	476
		26.12 Induction motor torque–speed characteristics	479

26.13 Starting methods for induction motors	480	27.6 Use of an oscilloscope with a bridge rectifier	497
26.14 Advantages of squirrel-cage induction motors	480	27.7 Measurement of the inductance of a coil	498
26.15 Advantages of wound rotor induction motors	481	27.8 Series a.c. circuit and resonance	499
26.16 Double cage induction motor	481	27.9 Parallel a.c. circuit and resonance	501
26.17 Uses of three-phase induction motors	482	27.10 Charging and discharging a capacitor	503
Revision Test 7	485	Answers to Practice Exercises	504
Formulae for electrical power technology	486	Index	521

Part 5 Laboratory Experiments **487**

27 Some practical laboratory experiments	489
27.1 Ohm's law	490
27.2 Series-parallel d.c. circuit	491
27.3 Superposition theorem	492
27.4 Thévenin's theorem	494
27.5 Use of an oscilloscope to measure voltage, frequency and phase	496