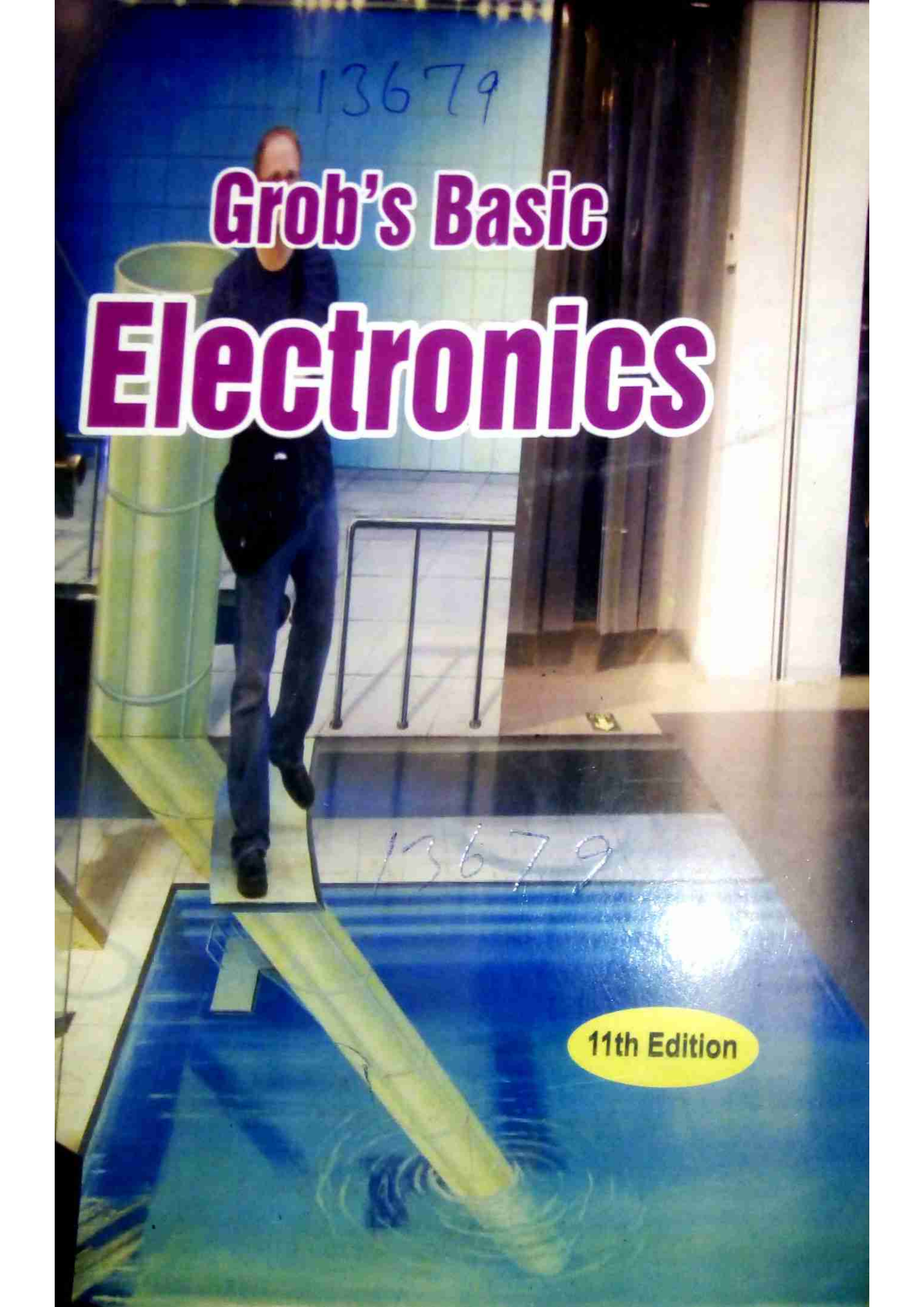


The background image shows a man in a dark shirt and jeans walking on a narrow tightrope that extends from a wall over a pool of water. On the wall behind him, the number '13679' is written in blue. On the floor of the pool, the same number '13679' is also written. The scene is brightly lit, possibly from a window on the right.

Grob's Basic Electronics

11th Edition

Brief Contents

I	Introduction to Powers of 10	2
Chapter 1	Electricity	22
Chapter 2	Resistors	54
Chapter 3	Ohm's Law	76
Chapter 4	Series Circuits	106
Chapter 5	Parallel Circuits	138
Chapter 6	Series-Parallel Circuits	168
Chapter 7	Voltage Dividers and Current Dividers	202
Chapter 8	Analog and Digital Multimeters	226
Chapter 9	Kirchhoff's Laws	258
Chapter 10	Network Theorems	282
Chapter 11	Conductors and Insulators	314
Chapter 12	Batteries	342
Chapter 13	Magnetism	376
Chapter 14	Electromagnetism	396
Chapter 15	Alternating Voltage and Current	428
Chapter 16	Capacitance	470
Chapter 17	Capacitive Reactance	510
Chapter 18	Capacitive Circuits	532
Chapter 19	Inductance	558
Chapter 20	Inductive Reactance	602
Chapter 21	Inductive Circuits	624
Chapter 22	RC and LR Time Constants	652
Chapter 23	Alternating Current Circuits	686
Chapter 24	Complex Numbers for AC Circuits	714
Chapter 25	Resonance	744
Chapter 26	Filters	780
Chapter 27	Diodes and Diode Applications	824

Contents

Preface xviii

I Introduction to Powers of 10 2

1-1	Scientific Notation	4	1-6	Reciprocals with Powers of 10	13
1-2	Engineering Notation and Metric Prefixes	8	1-7	Squaring Numbers Expressed in Powers of 10 Notation	13
1-3	Converting between Metric Prefixes	10	1-8	Square Roots of Numbers Expressed in Powers of 10 Notation	14
1-4	Addition and Subtraction Involving Powers of 10 Notation	11	1-9	The Scientific Calculator	15
1-5	Multiplication and Division Involving Powers of 10 Notation	12		Summary	17

Chapter 1 Electricity 22

1-1	Negative and Positive Polarities	24	1-7	Resistance Is Opposition to Current	38
1-2	Electrons and Protons in the Atom	24	1-8	The Closed Circuit	40
1-3	Structure of the Atom	27	1-9	The Direction of Current	42
1-4	The Coulomb Unit of Electric Charge	30	1-10	Direct Current (DC) and Alternating Current (AC)	45
1-5	The Volt Unit of Potential Difference	33	1-11	Sources of Electricity	46
1-6	Charge in Motion Is Current	35	1-12	The Digital Multimeter	47
				Summary	49

Chapter 2 Resistors 54

2-1	Types of Resistors	56	2-5	Power Rating of Resistors	66
2-2	Resistor Color Coding	59	2-6	Resistor Troubles	68
2-3	Variable Resistors	63		Summary	70
2-4	Rheostats and Potentiometers	64			

Chapter 3 Ohm's Law 76

3-1	The Current $I = V/R$	78	3-5	Multiple and Submultiple Units	82
3-2	The Voltage $V = IR$	80	3-6	The Linear Proportion between V and I	83
3-3	The Resistance $R = V/I$	81			
3-4	Practical Units	82			

3-7	Electric Power	85
3-8	Power Dissipation in Resistance	89
3-9	Power Formulas	90
3-10	Choosing a Resistor for a Circuit	92

3-11	Electric Shock	94
3-12	Open-Circuit and Short-Circuit Troubles	95
	Summary	97

Chapter 4 Series Circuits 106

4-1	Why I Is the Same in All Parts of a Series Circuit	108	4-7	Series-Aiding and Series-Opposing Voltages	117
4-2	Total R Equals the Sum of All Series Resistances	110	4-8	Analyzing Series Circuits with Random Unknowns	118
4-3	Series IR Voltage Drops	112	4-9	Ground Connections in Electrical and Electronic Systems	120
4-4	Kirchhoff's Voltage Law (KVL)	113	4-10	Troubleshooting: Opens and Shorts in Series Circuits	122
4-5	Polarity of IR Voltage Drops	115		Summary	127
4-6	Total Power in a Series Circuit	116			

Chapter 5 Parallel Circuits 138

5-1	The Applied Voltage V_A Is the Same across Parallel Branches	140	5-6	Total Power in Parallel Circuits	151
5-2	Each Branch I Equals V_A/R	141	5-7	Analyzing Parallel Circuits with Random Unknowns	152
5-3	Kirchhoff's Current Law (KCL)	142	5-8	Troubleshooting: Opens and Shorts in Parallel Circuits	152
5-4	Resistances in Parallel	144		Summary	159
5-5	Conductances in Parallel	150			

Chapter 6 Series-Parallel Circuits 168

6-1	Finding R_T for Series-Parallel Resistances	170	6-5	Analyzing Series-Parallel Circuits with Random Unknowns	175
6-2	Resistance Strings in Parallel	171	6-6	The Wheatstone Bridge	178
6-3	Resistance Banks in Series	173	6-7	Troubleshooting: Opens and Shorts in Series-Parallel Circuits	182
6-4	Resistance Banks and Strings in Series-Parallel	174		Summary	188

Cumulative Review Summary Chapters 1 to 6 200

Chapter 7 Voltage Dividers and Current Dividers 202

7-1	Series Voltage Dividers	204	7-3	Current Division by Parallel Conductances	209
7-2	Current Divider with Two Parallel Resistances	205			

Chapter 8 Analog and Digital Multimeters 226

8-1 Moving-Coil Meter 228	8-7 Digital Multimeter DMM 241
8-2 Meter Shunts 230	8-8 Meter Applications 245
8-3 Voltmeters 230	8-9 Checking Continuity with the Ohmmeter 247
8-4 Loading Effect on a Voltmeter 238	Summary 248
8-5 Ohmmeters 238	
8-6 Wattmeters 241	

Cumulative Review Summary Chapters 7 and 8 257

Chapter 9 Kirchhoff's Laws 258

9-1 Kirchhoff's Current Law KCL 260	9-4 Node-Voltage Analysis 269
9-2 Kirchhoff's Voltage Law KVL 262	9-5 Method of Mesh Currents 271
9-3 Method of Branch Currents 265	Summary 275

Chapter 10 Network Theorems 282

10-1 Superposition Theorem 284	10-6 Thevenin-Norton Conversions 294
10-2 Thevenin's Theorem 285	10-7 Conversion of Voltage and Current Sources 296
10-3 Thevenizing a Circuit with Two Voltage Sources 288	10-8 Millman's Theorem 298
10-4 Thevenizing a Bridge Circuit 289	10-9 T or Y and π or Δ Connections 300
10-5 Norton's Theorem 291	Summary 305

Cumulative Review Summary Chapters 9 and 10 313

Chapter 11 Conductors and Insulators 314

11-1 Function of the Conductor 316	11-8 Wire Resistance 327
11-2 Standard Wire Gage Sizes 317	11-9 Temperature Coefficient of Resistance 330
11-3 Types of Wire Conductors 319	11-10 Ion Current in Liquids and Gases 332
11-4 Connectors 321	11-11 Insulators 334
11-5 Printed Wiring 322	11-12 Troubleshooting Hints for Wires and Connectors 336
11-6 Switches 323	Summary 337
11-7 Fuses 325	

Chapter 12 Batteries 342

- | | | | | | |
|------|---|-----|-------|---|-----|
| 12-1 | Introduction to Batteries | 344 | 12-7 | Current Drain Depends on Load Resistance | 360 |
| 12-2 | The Voltaic Cell | 346 | 12-8 | Internal Resistance of a Generator | 361 |
| 12-3 | Common Types of Primary Cells | 348 | 12-9 | Constant-Voltage and Constant-Current Sources | 364 |
| 12-4 | Lead-Acid Wet Cells | 352 | 12-10 | Matching a Load Resistance to the Generator r_i | 366 |
| 12-5 | Additional Types of Secondary Cells | 355 | | Summary | 368 |
| 12-6 | Series-Connected and Parallel-Connected Cells | 358 | | | |

Cumulative Review Summary Chapters 11 and 12 373

Chapter 13 Magnetism 376

- | | | | | | |
|------|---------------------------------|-----|------|--------------------|-----|
| 13-1 | The Magnetic Field | 378 | 13-6 | Types of Magnets | 387 |
| 13-2 | Magnetic Flux (ϕ) | 380 | 13-7 | Ferrites | 388 |
| 13-3 | Flux Density (B) | 382 | 13-8 | Magnetic Shielding | 389 |
| 13-4 | Induction by the Magnetic Field | 384 | 13-9 | The Hall Effect | 389 |
| 13-5 | Air Gap of a Magnet | 386 | | Summary | 391 |

Chapter 14 Electromagnetism 396

- | | | | | | |
|------|---|-----|-------|--|-----|
| 14-1 | Ampere-Turns of Magnetomotive Force (mmf) | 398 | 14-6 | Magnetic Polarity of a Coil | 408 |
| 14-2 | Field Intensity (H) | 399 | 14-7 | Motor Action between Two Magnetic Fields | 409 |
| 14-3 | B - H Magnetization Curve | 402 | 14-8 | Induced Current | 411 |
| 14-4 | Magnetic Hysteresis | 404 | 14-9 | Generating an Induced Voltage | 413 |
| 14-5 | Magnetic Field around an Electric Current | 406 | 14-10 | Relays | 417 |
| | | | | Summary | 421 |

Chapter 15 Alternating Voltage and Current 428

- | | | | | | |
|------|--|-----|-------|--|-----|
| 15-1 | Alternating Current Applications | 430 | 15-10 | The Time Factor in Frequency and Phase | 448 |
| 15-2 | Alternating-Voltage Generator | 431 | 15-11 | Alternating Current Circuits with Resistance | 449 |
| 15-3 | The Sine Wave | 434 | 15-12 | Nonsinusoidal AC Waveforms | 451 |
| 15-4 | Alternating Current | 435 | 15-13 | Harmonic Frequencies | 453 |
| 15-5 | Voltage and Current Values for a Sine Wave | 436 | 15-14 | The 60-Hz AC Power Line | 453 |
| 15-6 | Frequency | 439 | 15-15 | Motors and Generators | 456 |
| 15-7 | Period | 441 | 15-16 | Three-Phase AC Power | 458 |
| 15-8 | Wavelength | 442 | | Summary | 460 |
| 15-9 | Phase Angle | 445 | | | |

Cumulative Review Summary Chapters 13 to 15 468

Chapter 16 Capacitance 470

- | | | | |
|------|--|-------|---|
| 16-1 | How Charge Is Stored in a Dielectric 472 | 16-7 | Parallel Capacitances 492 |
| 16-2 | Charging and Discharging a Capacitor 473 | 16-8 | Series Capacitances 492 |
| 16-3 | The Farad Unit of Capacitance 475 | 16-9 | Energy Stored in Electrostatic Field of Capacitance 494 |
| 16-4 | Typical Capacitors 479 | 16-10 | Measuring and Testing Capacitors 495 |
| 16-5 | Electrolytic Capacitors 484 | 16-11 | Troubles in Capacitors 498 |
| 16-6 | Capacitor Coding 486 | | Summary 501 |

Chapter 17 Capacitive Reactance 510

- | | | | |
|------|---|------|--|
| 17-1 | Alternating Current in a Capacitive Circuit 512 | 17-4 | Ohm's Law Applied to X_C 518 |
| 17-2 | The Amount of X_C Equals $1/(2\pi fC)$ 513 | 17-5 | Applications of Capacitive Reactance 518 |
| 17-3 | Series or Parallel Capacitive Reactances 517 | 17-6 | Sine-Wave Charge and Discharge Current 519 |
| | | | Summary 524 |

Chapter 18 Capacitive Circuits 532

- | | | | |
|------|--|------|--|
| 18-1 | Sine Wave v_C Lags i_C by 90° 534 | 18-6 | RF and AF Coupling Capacitors 544 |
| 18-2 | X_C and R in Series 535 | 18-7 | Capacitive Voltage Dividers 545 |
| 18-3 | Impedance Z Triangle 537 | 18-8 | The General Case of Capacitive Current i_C 547 |
| 18-4 | RC Phase-Shifters Circuit 539 | | Summary 548 |
| 18-5 | X_C and R in Parallel 540 | | |

Cumulative Review Summary Chapters 16 to 18 556

Chapter 19 Inductance 558

- | | | | |
|------|---|-------|--|
| 19-1 | Induction by Alternating Current 560 | 19-10 | Types of Cores 583 |
| 19-2 | Self-Inductance L 561 | 19-11 | Variable Inductance 584 |
| 19-3 | Self-Induced Voltage v_L 564 | 19-12 | Inductances in Series or Parallel 585 |
| 19-4 | How v_L Opposes a Change in Current 565 | 19-13 | Energy in a Magnetic Field of Inductance 587 |
| 19-5 | Mutual Inductance L_M 566 | 19-14 | Stray Capacitive and Inductive Effects 588 |
| 19-6 | Transformers 569 | 19-15 | Measuring and Testing Inductors 590 |
| 19-7 | Transformer Ratings 575 | | Summary 593 |
| 19-8 | Impedance Transformation 578 | | |
| 19-9 | Core Losses 582 | | |

Chapter 20 Inductive Reactance 602

- | | | | |
|------|---|---------|---|
| 20-1 | How X_L Reduces the Amount of I 604 | 20-5 | Applications of X_L for Different Frequencies 610 |
| 20-2 | $X_L = 2\pi fL$ 605 | 20-6 | Waveshape of v_L Induced by Sine-Wave Current 611 |
| 20-3 | Series or Parallel Inductive Reactances 609 | Summary | 616 |
| 20-4 | Ohm's Law Applied to X_L 609 | | |

Chapter 21 Inductive Circuits 624

- | | | | |
|------|--|---------|---|
| 21-1 | Sine Wave i Lags v_L by 90° 626 | 21-5 | Q of a Coil 635 |
| 21-2 | X_L and R in Series 627 | 21-6 | AF and RF Chokes 638 |
| 21-3 | Impedance Z Triangle 629 | 21-7 | The General Case of Inductive Voltage 640 |
| 21-4 | X_L and R in Parallel 632 | Summary | 642 |

Chapter 22 RC and L/R Time Constants 652

- | | | | |
|------|---|---------|--|
| 22-1 | Response of Resistance Alone 654 | 22-8 | Long and Short Time Constants 665 |
| 22-2 | L/R Time Constant 654 | 22-9 | Charge and Discharge with a Short RC Time Constant 668 |
| 22-3 | High Voltage Produced by Opening an RL Circuit 656 | 22-10 | Long Time Constant for an RC Coupling Circuit 667 |
| 22-4 | RC Time Constant 658 | 22-11 | Advanced Time Constant Analysis 669 |
| 22-5 | RC Charge and Discharge Curves 661 | 22-12 | Comparison of Reactance and Time Constant 672 |
| 22-6 | High Current Produced by Short-Circuiting an RC Circuit 662 | Summary | 675 |
| 22-7 | RC Waveshapes 663 | | |

Cumulative Review Summary Chapters 19 to 22 684

Chapter 23 Alternating Current Circuits 686

- | | | | |
|------|--|---------|--|
| 23-1 | AC Circuits with Resistance but No Reactance 688 | 23-7 | Series-Parallel Reactance and Resistance 697 |
| 23-2 | Circuits with X_L Alone 689 | 23-8 | Real Power 698 |
| 23-3 | Circuits with X_C Alone 690 | 23-9 | AC Meters 700 |
| 23-4 | Opposite Reactances Cancel 691 | 23-10 | Wattmeters 701 |
| 23-5 | Series Reactance and Resistance 693 | 23-11 | Summary of Types of Ohms in AC Circuits 701 |
| 23-6 | Parallel Reactance and Resistance 695 | 23-12 | Summary of Types of Phasors in AC Circuits 702 |
| | | Summary | 705 |

Chapter 24 Complex Numbers for AC Circuits 714

24-1	Positive and Negative Numbers	716	24-9	Converting Polar to Rectangular Form	725
24-2	The j Operator	716	24-10	Complex Numbers in Series AC Circuits	727
24-3	Definition of a Complex Number	718	24-11	Complex Numbers in Parallel AC Circuits	729
24-4	How Complex Numbers Are Applied to AC Circuits	718	24-12	Combining Two Complex Branch Impedances	731
24-5	Impedance in Complex Form	719	24-13	Combining Complex Branch Currents	732
24-6	Operations with Complex Numbers	721	24-14	Parallel Circuit with Three Complex Branches	733
24-7	Magnitude and Angle of a Complex Number	722		Summary	735
24-8	Polar Form of Complex Numbers	724			

Cumulative Review Summary Chapters 23 and 24 742

Chapter 25 Resonance 744

25-1	The Resonance Effect	746	25-7	Tuning	765
25-2	Series Resonance	746	25-8	Mistuning	767
25-3	Parallel Resonance	750	25-9	Analysis of Parallel Resonant Circuits	768
25-4	Resonant Frequency $f_r = 1/(2\pi\sqrt{LC})$	753	25-10	Damping of Parallel Resonant Circuits	769
25-5	Q Magnification Factor of a Resonant Circuit	757	25-11	Choosing L and C for a Resonant Circuit	771
25-6	Bandwidth of a Resonant Circuit	761		Summary	772

Chapter 26 Filters 780

26-1	Examples of Filtering	782	26-8	High-Pass Filters	793
26-2	Direct Current Combined with Alternating Current	782	26-9	Analyzing Filter Circuits	794
26-3	Transformer Coupling	785	26-10	Decibels and Frequency Response Curves	803
26-4	Capacitive Coupling	786	26-11	Resonant Filters	810
26-5	Bypass Capacitors	789	26-12	Interference Filters	812
26-6	Filter Circuits	791		Summary	814
26-7	Low-Pass Filters	792			

Cumulative Review Summary Chapters 25 and 26 822

Chapter 27 Diodes and Diode Applications 824

27-1	Semiconductor Materials	826	27-3	Volt-Ampere Characteristic Curve	831
27-2	The p - n Junction Diode	828	27-4	Diode Approximations	834

- 27-5 Diode Ratings 837
27-6 Rectifier Circuits 838

- 27-7 Special Diodes 858
Summary 864

Chapter 28 Bipolar Junction Transistors 872

- 28-1 Transistor Construction 874
28-2 Proper Transistor Biasing 876
28-3 Transistor Operating Regions 880
28-4 Transistor Ratings 882
28-5 Checking a Transistor with an Ohmmeter 885
28-6 Transistor Biasing Techniques 887
Summary 899

Chapter 29 Transistor Amplifiers 906

- 29-1 AC Resistance of a Diode 908
29-2 Small Signal Amplifier Operation 910
29-3 AC Equivalent Circuit of a CE Amplifier 914
29-4 Calculating the Voltage Gain, A_v of a CE Amplifier 914
29-5 Calculating the Input and Output Impedances in a CE Amplifier 919
29-6 Common-Collector Amplifier 921
29-7 AC Analysis of an Emitter Follower 923
29-8 Emitter Follower Applications 928
29-9 Common-Base Amplifier 931
29-10 AC Analysis of a Common-Base Amplifier 932
Summary 938

Chapter 30 Field Effect Transistors 948

- 30-1 JFETs and Their Characteristics 950
30-2 JFET Biasing Techniques 955
30-3 JFET Amplifiers 961
30-4 MOSFETs and Their Characteristics 969
30-5 MOSFET Biasing Techniques 975
30-6 Handling MOSFETs 977
Summary 979

Chapter 31 Power Amplifiers 988

- 31-1 Classes of Operation 990
31-2 Class A Amplifiers 991
31-3 Class B Push-Pull Amplifiers 1000
31-4 Class C Amplifiers 1007
Summary 1013

Chapter 32 Thyristors 1020

- 32-1 Diacs 1022
32-2 SCRs and Their Characteristics 1022
32-3 Triacs 1027
32-4 Unijunction Transistors 1029
Summary 1033