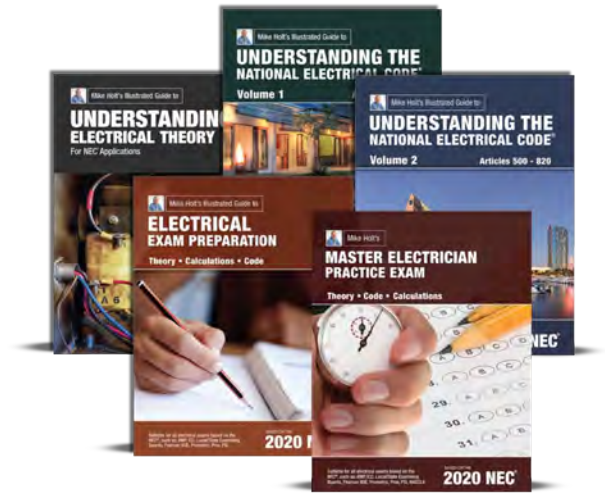


Mike Holt's Master Exam Prep Book Package



This document includes the Table of Contents from each book so you can see the full scope of this library.

Title	page #
Understanding Electrical Theory	3
Understanding the NEC, Volume 1, Art. 90—480	7
Understanding the NEC, Volume 2, Art. 500-820.....	17
Electrical Exam Preparation	25
Master Electrician Practice Exam.....	30



Mike Holt's Illustrated Guide to

Understanding Electrical Theory

for NEC Applications

TABLE OF CONTENTS

About This Textbook	ix	4.7	Secondary Distribution Voltage.....	23
Additional Products to Help You Learn	xii	4.8	Service Drop and Service Lateral.....	23
CHAPTER 1—ELECTRICAL FUNDAMENTALS	1	Chapter 1—Practice Questions		25
Unit 1—Atomic Structure	3	CHAPTER 2—USES AND DANGERS OF ELECTRICITY		33
1.1 Introduction.....	3	Unit 5—Uses of Electricity		35
1.2 Atomic Theory.....	3	5.1 Introduction.....		35
1.3 Electrostatic Field.....	4	5.2 Uses of Electricity.....		35
1.4 Atomic Charge of an Atom.....	5	5.3 Electrochemical Processes.....		35
1.5 Electrostatic Charge and Discharge.....	6	5.4 Electromagnetism.....		35
1.6 Lightning.....	7	5.5 Photoelectricity.....		36
1.7 Lightning Protection System.....	8	5.6 Electric Heating.....		37
Unit 2—Electron Theory and Chemical Bonding	9	5.7 Lighting.....		39
2.1 Introduction.....	9	Unit 6—Dangers of Electricity		41
2.2 Electron Orbitals.....	9	6.1 Introduction.....		41
2.3 Valence Electrons.....	9	6.2 <i>National Electrical Code (NEC)</i>		41
2.4 Freeing Valence Electron(s) from an Atom.....	10	6.3 Electrical Fire.....		41
2.5 Conductance.....	10	6.4 Electric Shock.....		42
2.6 Insulators.....	12	6.5 Electric Arc Flash and Arc Blast.....		43
2.7 Semiconductors.....	12	6.6 Arc Flash Incident Energy.....		44
2.8 Chemical Bonding.....	13	6.7 Electrically Safe Work Condition.....		45
Unit 3—Electrical Circuits and Power Sources	15	6.8 Personal Protective Equipment.....		46
3.1 Introduction.....	15	Chapter 2—Practice Questions		49
3.2 The Electrical Circuit.....	15	CHAPTER 3—MAGNETISM AND ELECTROMAGNETISM		55
3.3 Electric Current Flow (Electricity).....	15	Unit 7—Basics of Magnetism		57
3.4 Electrical Power Sources.....	16	7.1 Introduction.....		57
Unit 4—The Electrical System	21	7.2 The Natural Magnet.....		57
4.1 Introduction.....	21	7.3 Magnetic Polarities.....		57
4.2 Source of Electrical Generation.....	21	7.4 Theory of Magnetism.....		58
4.3 Step-Up Transmission Voltage.....	21	7.5 Permanent and Temporary Magnets.....		58
4.4 High-Voltage Transmission Lines.....	22	7.6 Magnetizing and Demagnetizing Magnets.....		58
4.5 Primary Distribution Voltage.....	22			
4.6 Primary Distribution Wires.....	22			

7.7	Magnetic Lines of Force.....	59
7.8	Law of Attraction and Repulsion of Magnets.....	59

Unit 8—Electromagnetism.....61

8.1	Introduction	61
8.2	Electromagnetism in a Wire.....	61
8.3	Electromagnet Field Interaction	62
8.4	Electromagnetic Field Interaction of Wire Loops.....	62
8.5	Electromagnetic Core	63

Unit 9—Uses of Electromagnetism.....65

9.1	Introduction	65
9.2	Motors	65
9.3	Generators.....	66
9.4	Relays.....	66
9.5	Transformers.....	66

Chapter 3—Practice Questions.....67

CHAPTER 4—MATHEMATICS.....71

Unit 10—Basic Math.....73

10.1	Introduction	73
10.2	Whole Numbers.....	73
10.3	Fractional Numbers	73
10.4	Decimal Numbers.....	73
10.5	Percentages.....	74
10.6	Parentheses.....	75
10.7	Squaring a Number	75
10.8	Square Root.....	75
10.9	Kilo.....	76
10.10	Rounding	76
10.11	Surface Area of a Rectangle or Square.....	76
10.12	Surface Area of a Circle.....	77
10.13	Volume	79
10.14	Reciprocal.....	79
10.15	Testing Your Answer.....	79

Unit 11—Trigonometry.....81

11.1	Introduction	81
11.2	Triangles.....	81
11.3	Right Triangle	81
11.4	Pythagorean Theorem.....	82
11.5	Practical Use of Trigonometry	83

Chapter 4—Practice Questions.....85

CHAPTER 5—OHM’S LAW AND WATT’S LAW.....91

Unit 12—Ohm’s Law.....93

12.1	Introduction	93
12.2	The Electrical Circuit.....	93
12.3	Electromotive Force (Pressure).....	93
12.4	Circuit Resistance	94
12.5	Circuit Intensity	95
12.6	Ohm’s Law	95
12.7	Ohm’s Law Formula Circle	96

Unit 13—Watt’s Law.....99

13.1	Introduction	99
13.2	Watt’s Law	99
13.3	Power Formula Circle.....	100
13.4	Power Changes with the Square of the Voltage.....	101

Chapter 5—Practice Questions.....103

CHAPTER 6—ELECTRICAL CIRCUIT TYPES.....107

Unit 14—Series Circuits.....109

14.1	Introduction	109
14.2	Series Circuits.....	109
14.3	Understanding Series Circuits.....	109
14.4	Series Circuit Summary.....	113
14.5	Series-Connected Power Supplies	113
14.6	Applications of Series Circuits.....	114

Unit 15—Parallel Circuits.....117

15.1	Introduction	117
15.2	Understanding Parallel Circuits.....	117
15.3	Parallel Circuit Resistance Calculations	119
15.4	Parallel Circuit Summary.....	122
15.5	Parallel-Connected Power Supplies	122
15.6	Practical Uses of Parallel Circuits.....	123

Unit 16—Series-Parallel Circuits.....125

16.1	Introduction	125
16.2	Understanding Series-Parallel Circuits	125
16.3	Calculating Resistance in Series-Parallel Circuits	126

Chapter 6—Practice Questions.....129

CHAPTER 7—ALTERNATING CURRENT 137

Unit 17—Alternating Current Fundamentals..... 139

17.1	Introduction	139
17.2	How Alternating Current is Produced	139
17.3	Waveforms	140
17.4	Frequency	143
17.5	In-Phase Waveforms	143
17.6	Out-of-Phase Waveforms	143
17.7	Alternating-Current Waveform Values	144

Unit 18—Inductance 147

18.1	Introduction	147
18.2	How Inductance Works	147
18.3	Self-Inductance	147
18.4	Mutual Inductance	148
18.5	Inductive Reactance	149
18.6	Uses of Induction	150

Unit 19—Capacitance..... 151

19.1	Introduction	151
19.2	Capacitance in Capacitors	151
19.3	Capacitor Charge and Discharge.....	152
19.4	Capacitive Reactance	152
19.5	Uses of Capacitors	153

Unit 20—True Power, Power Factor, and Apparent Power 155

20.1	Introduction	155
20.2	True Power	155
20.3	Power Losses of Wires	156
20.4	Power Losses at Terminals	156
20.5	Equipment Efficiency	157
20.6	Cost of Power	158
20.7	Power Factor	159
20.8	Apparent Power.....	160
20.9	Apparent Power versus True Power.....	161
20.10	Effects of Power Factor on Circuits.....	162

Chapter 7—Practice Questions..... 165

CHAPTER 8—MOTORS, GENERATORS, RELAYS, AND TRANSFORMERS 177

Unit 21—Motors..... 179

21.1	Introduction	179
21.2	Alternating-Current Motor Principles.....	179
21.3	Motor Horsepower Rating.....	180
21.4	Motor Amperes.....	181
21.5	Motor Nameplate Amperes.....	182
21.6	Dual-Voltage Motors	184
21.7	Reversing the Rotation of Alternating-Current Motors	185
21.8	Alternating-Current Motor Types.....	186

Unit 22—Generators 187

22.1	Introduction	187
22.2	Generator Prime Mover	187
22.3	Alternating-Current Generators.....	187
22.4	Generator Output Current.....	188
22.5	Single-Phase and Three-Phase Generator Voltages.....	189
22.6	Electrical Industry Voltages	189

Unit 23—Relays..... 191

23.1	Introduction	191
23.2	How Relays Operate.....	191
23.3	Relay Contacts.....	192

Unit 24—Transformers 193

24.1	Introduction	193
24.2	Types of Transformers.....	193
24.3	Primary versus Secondary	193
24.4	Transformer Mutual Induction	194
24.5	Secondary Induced Voltage.....	194
24.6	Transformer Turns Ratios.....	194
24.7	Isolation Transformer (1:1).....	196
24.8	Autotransformer.....	197
24.9	Transformer kVA Rating	197
24.10	Transformer Current Flow	197
24.11	Transformer Current Rating	197
24.12	Transformer Configurations.....	200
24.13	Delta/Wye Transformers.....	201
24.14	Delta/Delta (High-Leg) Transformer	203

Chapter 8—Practice Questions..... 205

CHAPTER 9—PROTECTIVE DEVICES	215	Unit 28—Multiwire Circuits	249
Unit 25—Overcurrent Protection	217	28.1 Introduction	249
25.1 Introduction	217	28.2 Neutral Wire.....	249
25.2 Overcurrent Protection	217	28.3 Grounded Wire	250
25.3 Fuses	219	28.4 Current Flow on the Neutral Wire.....	250
25.4 Circuit Breakers.....	221	28.5 Multiwire Branch Circuits.....	251
25.5 Overcurrent Protective Devices, Time-Current Curves	222	28.6 Dangers of Multiwire Circuits	253
25.6 Available Short-Circuit Current	223	28.7 <i>NEC</i> Requirements.....	254
25.7 Overcurrent Protective Devices, Interrupting Rating.....	225	Unit 29—The Formula Wheel	255
25.8 Equipment Short-Circuit Current Rating (SCCR).....	225	29.1 Introduction	255
25.9 Coordination of Overcurrent Protective Devices.....	226	29.2 Formula Wheel Quadrants	255
UNIT 26—GFCIs, GFPEs, AFCIs, AND SPDs	229	29.3 Using the Formula Wheel	256
26.1 Introduction	229	Chapter 10—Practice Questions	259
26.2 Ground-Fault Circuit Interrupters (GFCIs).....	229	FINAL EXAM	267
26.3 Special Purpose Ground-Fault Circuit Interrupters (SPGFCIs).....	231	INDEX	279
26.4 Ground-Fault Protection of Equipment (GFPEs)	231	About the Author	283
26.5 Arc-Fault Circuit Interrupters (AFCIs).....	232	About the Illustrator	284
26.6 Clearing Arcing Faults	232	About the Mike Holt Team	285
26.7 Surge Protective Devices (SPDs)	233		
26.8 How Surge Protective Device Functions.....	234		
Chapter 9—Practice Questions	235		
CHAPTER 10—GENERAL KNOWLEDGE	241		
Unit 27—Wire Resistance and Voltage Drop	243		
27.1 Introduction	243		
27.2 Wire Sizes	243		
27.3 Direct-Current Wire Resistance.....	243		
27.4 <i>NEC</i> Wire Direct-Current Resistance.....	244		
27.5 Alternating-Current Wire Resistance	245		
27.6 Alternating-Current Resistance versus Direct-Current Resistance	246		
27.7 Wire Voltage Drop—Ohm's Law Method	246		

Understanding the National Electrical Code®

Volume 1

TABLE OF CONTENTS

About This Textbook	xv	110.25	Lockable Disconnecting Means	83
Additional Products to Help You Learn	xviii	Part II. 1,000V, Nominal, or Less		84
How to Use the <i>National Electrical Code</i>	1	110.26	Spaces About Electrical Equipment	84
		110.28	Enclosure Types	92
Article 90—Introduction to the <i>National Electrical Code</i>	7	Chapter 1—Practice Questions		95
90.1	Purpose of the <i>NEC</i>			
90.2	Scope of the <i>NEC</i>			
90.3	Code Arrangement			
90.4	Enforcement			
90.5	Mandatory Requirements and Explanatory Material			
90.7	Examination of Equipment for Product Safety			
Article 90—Practice Questions	15			
CHAPTER 1—GENERAL RULES	19	CHAPTER 2—WIRING AND PROTECTION		101
Article 100—Definitions	21	Article 200—Use and Identification of Grounded Conductors		103
100	Definitions	200.1	Scope	104
		200.2	General	104
		200.4	Neutral Conductor	104
		200.6	Identification of Grounded Conductors	105
		200.7	Use of White or Gray Color	107
		200.9	Means of Identification of Terminals	108
		200.10	Identification of Terminals	108
Article 110—Requirements for Electrical Installations	65	Article 210—Branch Circuits		109
Part I. General Requirements	65	Part I. General Provisions		109
110.1	Scope	210.1	Scope	109
110.2	Approval of Conductors and Equipment	210.3	Other Articles	110
110.3	Use and Product Listing (Certification) of Equipment	210.4	Multiwire Branch Circuits	110
110.4	Voltage Rating of Electrical Equipment	210.5	Identification for Branch Circuits	112
110.5	Conductor Material	210.7	Multiple Branch Circuits	114
110.6	Conductor Sizes	210.8	GFCI Protection	114
110.7	Wiring Integrity	210.11	Branch Circuits Required	121
110.8	Suitable Wiring Methods	210.12	Arc-Fault Circuit-Interrupter Protection	123
110.9	Interrupting Rating (Overcurrent Protective Devices)	Part II. Branch-Circuit Ratings		124
110.10	Equipment Short-Circuit Current Rating	210.18	Branch-Circuit Rating	124
110.11	Deteriorating Agents	210.19	Conductor Sizing	125
110.12	Mechanical Execution of Work	210.20	Overcurrent Protection	128
110.13	Mounting and Cooling of Equipment	210.21	Receptacle Rating	129
110.14	Conductor Termination and Splicing	210.23	Permissible Loads, Multiple-Outlet Branch Circuits	130
110.15	High-Leg Conductor Identification	Part III. Required Outlets		130
110.16	Arc Flash Hazard Warning	210.50	Receptacle Outlets	130
110.21	Markings	210.52	Dwelling Unit Receptacle Outlet Requirements	131
110.22	Identification of Disconnecting Means	210.60	Receptacles in Guest Rooms, Guest Suites, Dormitory Units, and Similar Occupancies	138
110.24	Available Fault Current	210.63	Equipment Requiring Servicing	139

210.65	Meeting Rooms	140	225.19	Clearances from Buildings	178
210.70	Lighting Outlet Requirements	141	225.22	Raceways on Exterior Surfaces of Buildings or Other Structures	179
Article 215—Feeders		145	225.26	Trees for Conductor Support	179
215.1	Scope	145	225.27	Raceway Seals	180
215.2	Conductor Sizing	145	Part II. Buildings or Other Structures Supplied by a Feeder		180
215.3	Overcurrent Protection Sizing	150	225.30	Number of Supplies	180
215.10	Ground-Fault Protection of Equipment	151	225.31	Disconnecting Means	181
215.12	Conductor Identification	151	225.32	Disconnecting Means Location	181
Article 220—Branch-Circuit, Feeder, and Service Load Calculations		153	225.33	Maximum Number of Disconnects	181
Part I. General		153	225.34	Grouping of Disconnects	182
220.1	Scope	153	225.37	Identification of Multiple Supplies	182
220.3	Application of Other Articles	153	225.39	Rating of Disconnecting Means	182
220.5	Calculations	154	Article 230—Services		183
220.11	Floor Area	154	Part I. General		183
Part II. Branch-Circuit Load Calculations		155	230.1	Scope	183
220.12	Lighting Load for Non-Dwelling Occupancies	155	230.2	Number of Services	183
220.14	Other Loads—Occupancies	156	230.3	Not to Pass Through a Building	185
220.18	Motor-Operated Loads	160	230.6	Conductors Considered Outside a Building	185
Part III. Feeder and Service Calculations		160	230.7	Service Conductors Separate from Other Conductors	185
220.42	General Lighting Demand Factors	160	230.8	Raceway Seals	186
220.43	Show-Window and Track Lighting Loads, Commercial	161	230.9	Clearances on Buildings	186
220.44	Receptacle Load, Other Than Dwelling Units	162	230.10	Vegetation as Support	187
220.50	Motor Type Loads	162	Part II. Overhead Service Conductors		187
220.51	Fixed Electric Space-Heating Load	162	230.23	Overhead Service Conductor Size and Rating	187
220.52	Small-Appliance and Laundry Loads, Dwelling	162	230.24	Vertical Clearance for Overhead Service Conductors	188
220.53	Appliance Load, Dwelling	163	230.26	Point of Attachment	189
220.54	Clothes Dryer Demand Load, Dwelling	164	230.27	Means of Attachment	189
220.55	Cooking Appliances in Dwelling Units	165	230.28	Service Masts as Support	189
220.56	Kitchen Equipment Load, Commercial	167	Part III. Underground Service Conductors		190
220.60	Noncoincident Loads	168	230.30	Installation	190
220.61	Neutral Load	168	230.31	Underground Service Conductor Size and Rating	190
Part IV. Optional Calculations for Computing Feeder and Service Loads		170	230.32	Protection Against Damage	190
220.82	Optional Load Calculations, Dwellings	170	Part IV. Service-Entrance Conductors		191
220.84	Optional Load Calculations, Multifamily	171	230.40	Number of Service-Entrance Conductor Sets	191
220.85	Optional Load Calculations, Two Dwelling Units	172	230.42	Conductor Sizing	191
220.87	Determining Existing Loads	172	230.43	Wiring Methods	195
Article 225—Outside Branch Circuits and Feeders		175	230.46	Spliced Conductors	195
Part I. General		175	230.50	Protection Against Physical Damage	196
225.1	Scope	175	230.51	Cable Supports	197
225.6	Minimum Conductor Size and Support	175	230.53	Raceways to Drain	197
225.16	Attachment of Overhead Conductors	176	230.54	Overhead Service Locations	197
225.17	Masts as Supports	176	230.56	High-Leg Conductor Identification	198
225.18	Clearance for Overhead Conductors	177	Part V. Service Disconnect—General		199
			230.62	Service Equipment—Enclosed or Guarded	199
			230.66	Marking for Service Disconnect	199
			230.67	Surge Protection	199

Part VI. Service Disconnect—Disconnecting Means	200	Part II. Surge Protective Devices (SPDs), 1,000V or Less	232
230.70 Service Disconnect Requirements.....	200	242.6 Uses Not Permitted.....	232
230.71 Number of Service Disconnects.....	201	242.8 Listing.....	232
230.72 Grouping of Disconnects.....	202	242.10 Short-Circuit Current Rating.....	233
230.76 Manually or Power Operated.....	202	242.12 Type 1 SPDs—Line Side of Service Disconnect.....	233
230.79 Rating of Disconnect.....	202	242.14 Type 2 SPDs—Feeder Circuits.....	233
230.82 Connected on Supply Side of the Service Disconnect.....	203	242.20 Number Required.....	234
230.85 Emergency Disconnects.....	204	242.24 Routing of Surge Protection Device Conductors.....	234
Part VII. Service Disconnect Overcurrent Protection	204	Article 250—Grounding and Bonding	235
230.90 Overload Protection—Where Required.....	204	Part I. General	235
230.91 Location.....	205	250.1 Scope.....	235
230.95 Ground-Fault Protection of Equipment.....	206	250.4 Performance Requirements for Grounding and Bonding.....	236
Article 240—Overcurrent Protection	207	250.6 Objectionable Current.....	242
Part I. General	208	250.8 Connection of Grounding and Bonding Connectors.....	246
240.1 Scope.....	208	250.10 Protection of Ground Clamps and Fittings.....	246
240.2 Definitions.....	208	250.12 Clean Surfaces.....	246
240.3 Other Articles (Overcurrent Protection of Equipment).....	209	Part II. System Grounding and Bonding	247
240.4 Overcurrent Protection of Conductors.....	209	250.20 Systems Required to be Grounded.....	247
240.5 Protection of Flexible Cords, Flexible Cables, and Fixture Wires.....	213	250.21 Ungrounded Systems.....	248
240.6 Standard Ampere Ratings.....	213	250.24 Grounding.....	248
240.10 Supplementary Overcurrent Protection.....	214	250.25 Grounding for Supply Side of the Service Disconnect.....	252
240.13 Ground-Fault Protection of Equipment.....	214	250.28 Main Bonding Jumper and System Bonding Jumper.....	253
240.15 Phase Conductor Overcurrent Device.....	215	250.30 Separately Derived Systems.....	254
Part II. Location	215	250.32 Buildings Supplied by a Feeder.....	263
240.21 Location in Circuit.....	215	250.34 Generators—Portable and Vehicle- or Trailer-Mounted.....	265
240.24 Location of Overcurrent Protective Devices at Premises.....	221	250.36 High-Impedance Grounded Systems.....	266
Part III. Enclosures	223	Part III. Grounding Electrode System and Grounding Electrode Conductor	267
240.33 Vertical Position.....	223	250.50 Grounding Electrode System.....	267
Part IV. Disconnecting and Guarding	223	250.52 Grounding Electrode Types.....	267
240.40 Disconnecting Means for Fuses.....	223	250.53 Grounding Electrode Installation Requirements.....	270
Part V. Plug Fuses, Fuseholders, and Adapters	224	250.54 Auxiliary Grounding Electrodes.....	275
240.51 Edison-Base Fuses.....	224	250.58 Common Grounding Electrode.....	276
Part VI. Cartridge Fuses and Fuseholders	224	250.62 Grounding Electrode Conductor.....	277
240.60 General.....	224	250.64 Grounding Electrode Conductor Installation.....	277
240.67 Arc Energy Reduction—Fuses.....	225	250.66 Sizing Grounding Electrode Conductor.....	281
Part VII. Circuit Breakers	226	250.68 Grounding Electrode Conductor and Bonding Jumper Connection to Grounding Electrodes.....	282
240.81 Indicating.....	226	250.70 Grounding Electrode Conductor Termination Fittings.....	284
240.83 Markings.....	226	Part IV. Enclosure, Raceway, and Service Cable Connections	285
240.85 Applications.....	227	250.80 Service Raceways and Enclosures.....	285
240.86 Series Ratings.....	228	250.86 Other Enclosures.....	285
240.87 Arc Energy Reduction—Circuit Breakers.....	228	Part V. Bonding for Fault Current	285
240.88 Reconditioned Equipment.....	229	250.90 General.....	285
Article 242—Overvoltage Protection	231	250.92 Bonding Equipment Containing Service Conductors.....	285
Part I. General	232	250.94 Bonding Communications Systems.....	288
242.1 Scope.....	232	250.96 Bonding Other Enclosures.....	289
		250.97 Bonding Metal Parts Containing 277V and 480V Circuits.....	290

250.98	Bonding Loosely Jointed Metal Raceways.....	291
250.102	Neutral Conductor, Bonding Conductors, and Bonding Jumpers	291
250.104	Bonding of Piping Systems and Exposed Structural Metal.....	293
250.106	Lightning Protection Systems.....	297
Part VI. Equipment Grounding and Equipment Grounding Conductors.....		
250.109	Metal Enclosures.....	298
250.114	Equipment Connected by Cord and Plug.....	298
250.118	Types of Equipment Grounding Conductors.....	299
250.119	Identification of Equipment Grounding Conductors	303
250.120	Equipment Grounding Conductor Installation.....	304
250.121	Restricted Use of Equipment Grounding Conductors	304
250.122	Sizing Equipment Grounding Conductors.....	304
Part VII. Methods of Equipment Grounding Conductor Connections		
250.134	Equipment Connected by Permanent Wiring Methods.....	308
250.136	Equipment Secured to Grounded Metal Supports	309
250.138	Cord-and-Plug-Connected	309
250.140	Frames of Ranges, Ovens, and Clothes Dryers.....	309
250.142	Neutral Conductor for Effective Ground-Fault Current Path.....	310
250.146	Connecting Receptacle Grounding Terminal to an Equipment Grounding Conductor.....	311
250.148	Continuity and Attachment of Equipment Grounding Conductors in Boxes.....	314
Chapter 2—Practice Questions.....		317

CHAPTER 3—WIRING METHODS AND MATERIALS

Article 300—General Requirements for Wiring Methods and Materials.....

Part I. General Requirements.....		327
300.1	Scope	327
300.3	Conductors	328
300.4	Protection Against Physical Damage.....	331
300.5	Underground Installations.....	334
300.6	Protection Against Corrosion and Deterioration.....	338
300.7	Raceways Exposed to Different Temperatures.....	339
300.9	Raceways in Wet Locations Above Grade	340
300.10	Electrical Continuity.....	340
300.11	Securing and Supporting	341
300.12	Mechanical Continuity.....	342
300.13	Mechanical and Electrical Continuity of Conductors-Splices and Pigtails.....	343
300.14	Length of Free Conductors	344
300.15	Boxes or Fittings	345
300.17	Number and Size of Conductors in a Raceway.....	347
300.18	Inserting Conductors in Raceways	349

300.19	Supporting Conductors in Vertical Raceways.....	350
300.20	Induced Alternating Currents in Ferrous Metal Parts	350
300.21	Spread of Fire or Products of Combustion	352
300.22	Wiring in Ducts and Plenum Spaces	353
300.23	Panels Designed to Allow Access	355
300.25	Exit Enclosures (Stair Towers).....	355

Article 310—Conductors for General Wiring.....

Part I. General		357
310.1	Scope	357
310.3	Conductors	357
Part II. Construction Specifications.....		358
310.4	Conductor Construction and Application	358
310.6	Conductor Identification.....	361
Part III. Installation		361
310.10	Uses Permitted.....	361
310.12	Single-Phase Dwelling Services and Feeders.....	364
310.14	Ampacities for Conductors Rated 0V to 2,000V	367
310.15	Ampacity Tables.....	368
310.16	Ampacities of Insulated Conductors in Raceways, Cables, or Buried	375

Article 312—Cabinets.....

Part I. Scope and Installation		377
312.1	Scope	377
312.2	Damp or Wet Locations.....	377
312.3	Position in Walls	378
312.4	Repairing Gaps in Noncombustible Surfaces	378
312.5	Enclosures	378
312.6	Deflection of Conductors.....	380
312.8	Overcurrent Device Enclosures	380
Part II. Construction Specifications.....		382
312.10	Material	382

Article 314—Outlet, Pull, and Junction Boxes; Conduit Bodies; and Handhole Enclosures

Part I. Scope and General		383
314.1	Scope	383
314.3	Nonmetallic Boxes	383
314.4	Metal Boxes	384
Part II. Installation		384
314.15	Damp or Wet Locations.....	384
314.16	Sizing Outlet Boxes	384
314.17	Conductors That Enter Boxes or Conduit Bodies	392
314.20	Flush-Mounted Box Installations	393
314.21	Repairing Noncombustible Surfaces.....	393
314.22	Surface Extensions	394
314.23	Support of Boxes.....	394

314.25	Covers and Canopies	397
314.27	Outlet Box Requirements	398
314.28	Sizing Pull and Junction Boxes	399
314.29	Wiring to be Accessible	403
314.30	Handhole Enclosures	403

Article 320—Armored Cable (Type AC).....405

Part I. General	405
320.1 Scope	405
320.2 Definition	405
320.6 Listing Requirements	406
Part II. Installation	406
320.10 Uses Permitted	406
320.12 Uses Not Permitted	406
320.15 Exposed Work	406
320.17 Through or Parallel to Framing Members	406
320.23 In Accessible Attics or Roof Spaces	407
320.24 Bending Radius	407
320.30 Securing and Supporting	408
320.40 Boxes and Fittings	409
320.80 Conductor Ampacity	409
Part III. Construction Specifications	410
320.100 Construction	410
320.108 Equipment Grounding Conductor	410

Article 330—Metal-Clad Cable (Type MC).....411

Part I. General	411
330.1 Scope	411
330.2 Definition	411
330.6 Listing Requirements	412
Part II. Installation	412
330.10 Uses Permitted	412
330.12 Uses Not Permitted	413
330.15 Exposed Work	413
330.17 Through or Parallel to Framing Members	413
330.23 In Accessible Attics or Roof Spaces	413
330.24 Bending Radius	414
330.30 Securing and Supporting	414
330.80 Conductor Ampacities	416
Part III. Construction Specifications	417
330.108 Equipment Grounding Conductor	417

Article 334—Nonmetallic-Sheathed Cable (Type NM) ...419

Part I. General	419
334.1 Scope	419
334.2 Definition	419
334.6 Listing Requirements	419

Part II. Installation	420
334.10 Uses Permitted	420
334.12 Uses Not Permitted	420
334.15 Exposed Work	421
334.17 Through or Parallel to Framing Members	422
334.23 Accessible Attics and Roof Spaces	423
334.24 Bending Radius	423
334.30 Securing and Supporting	424
334.40 Boxes and Fittings	424
334.80 Conductor Ampacity	425
Part III. Construction Specifications	426
334.108 Equipment Grounding Conductor	426

Article 336—Power and Control Tray Cable (Type TC) ..427

Part I. General	427
336.1 Scope	427
336.2 Definition	427
336.6 Listing Requirements	427
Part II. Installation	427
336.10 Uses Permitted	427
336.12 Uses Not Permitted	428
336.24 Bending Radius	428

Article 338—Service-Entrance Cable (Types SE and USE).....429

Part I. General	429
338.1 Scope	429
338.2 Definitions	429
338.6 Listing Requirements	430
Part II. Installation	430
338.10 Uses Permitted	430
338.12 Uses Not Permitted	431
338.24 Bending Radius	431

Article 340—Underground Feeder and Branch-Circuit Cable (Type UF).....433

Part I. General	433
340.1 Scope	433
340.2 Definition	433
340.6 Listing Requirements	433
Part II. Installation	433
340.10 Uses Permitted	433
340.12 Uses Not Permitted	434
340.24 Bends	434
340.80 Ampacity	434
Part III. Construction Specifications	434
340.108 Equipment Grounding Conductor	434
340.112 Insulation	434

Article 342—Intermediate Metal Conduit (Type IMC)	435	348.28	Trimming.....	449
Part I. General	435	348.30	Securing and Supporting	449
342.1 Scope	435	348.60	Equipment Grounding and Bonding Conductors.....	450
342.2 Definition.....	435			
342.6 Listing Requirements	436			
Part II. Installation	436			
342.10 Uses Permitted.....	436			
342.14 Dissimilar Metals.....	436			
342.20 Trade Size	436			
342.22 Number of Conductors	436			
342.24 Bends	436			
342.26 Number of Bends (360°).....	436			
342.28 Reaming.....	436			
342.30 Securing and Supporting	437			
342.42 Couplings and Connectors.....	438			
342.46 Bushings	438			
342.60 Equipment Grounding Conductor.....	439			
Article 344—Rigid Metal Conduit (Type RMC)	441			
Part I. General	441			
344.1 Scope	441			
344.2 Definition.....	441			
344.6 Listing Requirements	442			
Part II. Installation	442			
344.10 Uses Permitted.....	442			
344.14 Dissimilar Metals.....	442			
344.20 Trade Size	442			
344.22 Number of Conductors	442			
344.24 Bends	443			
344.26 Number of Bends (360°).....	443			
344.28 Reaming.....	443			
344.30 Securing and Supporting	443			
344.42 Couplings and Connectors.....	445			
344.46 Bushings	446			
344.60 Equipment Grounding Conductor.....	446			
Article 348—Flexible Metal Conduit (Type FMC)	447			
Part I. General	447			
348.1 Scope	447			
348.2 Definition.....	447			
348.6 Listing Requirements	447			
Part II. Installation	447			
348.10 Uses Permitted.....	447			
348.12 Uses Not Permitted.....	447			
348.20 Trade Size	448			
348.22 Number of Conductors	448			
348.24 Bends	449			
348.26 Number of Bends (360°).....	449			
Article 350—Liquidtight Flexible Metal Conduit (Type LFMC)	451			
Part I. General	451			
350.1 Scope	451			
350.2 Definition.....	451			
350.6 Listing Requirements	451			
Part II. Installation	452			
350.10 Uses Permitted.....	452			
350.12 Uses Not Permitted.....	452			
350.20 Trade Size	452			
350.22 Number of Conductors	452			
350.24 Bends	453			
350.26 Number of Bends (360°).....	453			
350.28 Trimming.....	453			
350.30 Securing and Supporting	453			
350.60 Equipment Grounding and Bonding Conductors.....	454			
Article 352—Rigid Polyvinyl Chloride Conduit (Type PVC)	457			
Part I. General	457			
352.1 Scope	457			
352.2 Definition.....	457			
Part II. Installation	457			
352.10 Uses Permitted.....	457			
352.12 Uses Not Permitted.....	458			
352.20 Trade Size	459			
352.22 Number of Conductors	459			
352.24 Bends	460			
352.26 Number of Bends (360°).....	460			
352.28 Trimming.....	460			
352.30 Securing and Supporting	460			
352.44 Expansion Fittings.....	461			
352.46 Bushings	462			
352.48 Joints.....	462			
352.60 Equipment Grounding Conductor.....	462			
Article 356—Liquidtight Flexible Nonmetallic Conduit (Type LFNC)	465			
Part I. General	465			
356.1 Scope	465			
356.2 Definition.....	465			
356.6 Listing Requirements	465			
Part II. Installation	465			
356.10 Uses Permitted.....	465			
356.12 Uses Not Permitted.....	466			

356.20	Trade Size	466	376.12	Uses Not Permitted	482
356.22	Number of Conductors	466	376.20	Conductors Connected in Parallel	482
356.24	Bends	467	376.22	Number of Conductors and Ampacity	482
356.26	Number of Bends (360°)	467	376.23	Wireway Sizing	484
356.30	Securing and Supporting	467	376.30	Supports	485
356.42	Fittings	467	376.56	Splices, Taps, and Power Distribution Blocks	485
356.60	Equipment Grounding Conductor	468	Part III. Construction Specifications	486	
Article 358—Electrical Metallic Tubing (Type EMT)			376.100	Construction	486
Part I. General			Article 380—Multioutlet Assemblies		487
358.1	Scope	469	Part I. General		487
358.2	Definition	469	380.1	Scope	487
358.6	Listing Requirements	470	Part II. Installation		487
Part II. Installation			380.10	Uses Permitted	487
358.10	Uses Permitted	470	380.12	Uses Not Permitted	487
358.12	Uses Not Permitted	470	380.76	Through Partitions	487
358.20	Trade Size	471	Article 386—Surface Metal Raceways		
358.22	Number of Conductors	471	Part I. General		
358.24	Bends	471	386.1	Scope	489
358.26	Number of Bends (360°)	471	386.2	Definition	489
358.28	Reaming	471	386.6	Listing Requirements	490
358.30	Securing and Supporting	472	Part II. Installation		
358.42	Couplings and Connectors	473	386.10	Uses Permitted	490
358.60	Equipment Grounding Conductor	473	386.12	Uses Not Permitted	490
Article 362—Electrical Nonmetallic Tubing (Type ENT)			386.21	Size of Conductors	490
Part I. General			386.22	Number of Conductors	490
362.1	Scope	475	386.30	Securing and Supporting	491
362.2	Definition	475	386.56	Splices and Taps	491
362.6	Listing	475	386.60	Equipment Grounding Conductor	491
Part II. Installation			386.70	Separate Compartments	491
362.10	Uses Permitted	475	Article 392—Cable Trays		
362.12	Uses Not Permitted	477	Part I. General		
362.20	Trade Sizes	477	392.1	Scope	493
362.22	Number of Conductors	477	392.2	Definition	493
362.24	Bends	478	Part II. Installation		
362.26	Number of Bends (360°)	478	392.10	Uses Permitted	493
362.28	Trimming	478	392.12	Uses Not Permitted	495
362.30	Securing and Supporting	478	392.18	Cable Tray Installations	495
362.46	Bushings	479	392.20	Cable and Conductor Installation	496
362.48	Joints	479	392.30	Securing and Supporting	496
362.60	Equipment Grounding Conductor	479	392.44	Expansion Splice Plates	496
Article 376—Metal Wireways			392.46	Bushed Conduit and Tubing	496
Part I. General			392.56	Cable Splices	496
376.1	Scope	481	392.60	Equipment Grounding Conductor	497
376.2	Definition	481	Chapter 3—Practice Questions		
Part II. Installation			499		
376.10	Uses Permitted	482			

CHAPTER 4—EQUIPMENT FOR GENERAL USE.....505

Article 400—Flexible Cords and Flexible Cables.....507

400.1	Scope	507
400.3	Suitability	507
400.4	Types of Flexible Cords and Flexible Cables.....	508
400.5	Ampacity of Flexible Cords and Flexible Cables	508
400.10	Uses Permitted.....	508
400.12	Uses Not Permitted.....	509
400.14	Pull at Joints and Terminals.....	510
400.17	Protection from Damage	510

Article 402—Fixture Wires.....513

402.1	Scope	513
402.2	Other Articles.....	513
402.3	Types	513
402.5	Ampacity of Fixture Wires	513
402.6	Minimum Size	513
402.7	Raceway Size.....	514
402.8	Neutral Conductor.....	514
402.10	Uses Permitted.....	514
402.12	Uses Not Permitted.....	515

Article 404—Switches.....517

Part I. Installation.....517

404.1	Scope	517
404.2	Switch Connections.....	517
404.3	Switch Enclosures.....	519
404.4	Damp or Wet Locations.....	519
404.7	Indicating	520
404.8	Accessibility and Grouping	521
404.9	General-Use Snap Switches, Dimmers, and Control Switches	523
404.10	Mounting of Snap Switches, Dimmers, and Control Switches	524
404.12	Grounding of Enclosures	525
404.14	Rating and Use of Snap Switches	525

Part II. Construction Specifications.....525

404.20	Switch Marking	525
404.22	Electronic Control Switches.....	526

Article 406—Receptacles, Attachment Plugs, and Cord Connectors.....527

406.1	Scope	527
406.2	Definitions	527
406.3	Receptacle Rating and Type	527
406.4	General Installation Requirements.....	528
406.5	Receptacle Mounting.....	531
406.6	Receptacle Faceplates	533

406.7	Attachment Plugs and Flanged Surface Devices	534
406.9	Receptacles in Damp or Wet Locations.....	534
406.11	Connecting Receptacle Grounding Terminal to Equipment Grounding Conductor	537
406.12	Tamper-Resistant Receptacles.....	537

Article 408—Switchboards and Panelboards.....539

Part I. General.....539

408.1	Scope	539
408.3	Arrangement of Busbars and Conductors.....	539
408.4	Field Identification.....	540
408.5	Clearance for Conductors Entering Bus Enclosures	541
408.6	Short-Circuit Current Rating.....	542
408.7	Unused Openings	542
408.8	Reconditioning of Equipment	542

Part II. Switchboards and Switchgear.....542

408.18	Clearances	542
--------	------------------	-----

Part III. Panelboards.....543

408.36	Overcurrent Protection	543
408.37	Panelboards in Damp or Wet Locations	543
408.40	Equipment Grounding Conductor.....	543
408.41	Neutral Conductor Terminations	544
408.43	Panelboard Orientation.....	544

Article 410—Luminaires, Lampholders, and Lamps.....545

Part I. General.....545

410.1	Scope	545
410.2	Definitions	546
410.6	Listing Required	546
410.7	Reconditioned Equipment.....	546

Part II. Luminaire Locations.....546

410.10	Luminaires in Specific Locations	546
410.16	Luminaires in Clothes Closets	548

Part III. Luminaire Outlet Boxes and Covers.....549

410.22	Outlet Boxes to be Covered.....	549
410.24	Connection of Electric-Discharge and LED Luminaires	549

Part IV. Luminaire Supports.....550

410.30	Supports	550
410.36	Means of Support	551

Part V. Grounding (Bonding).....552

410.44	Equipment Grounding Conductor.....	552
410.46	Equipment Grounding Conductor Attachment	552

Part VI. Wiring of Luminaires.....552

410.62	Cord-Connected Luminaires	552
--------	---------------------------------	-----

Part X. Special Provisions for Flush and Recessed Luminaires.....553

410.115	Temperature	553
410.116	Clearance and Installation.....	553
410.118	Access to Other Boxes.....	554

Part XII. Electric-Discharge Lighting	554	424.4	Branch Circuits	567
410.130 General	554	Part III. Electric Space-Heating Equipment		568
Part XIV. Track Lighting	554	424.19	Disconnecting Means	568
410.151 Installation	554	Part V. Electric Space-Heating Cables		569
410.154 Fastening	555	424.44	Electric Heating Cables in Concrete or Masonry Floors	569
Part XVI. Special Provisions for Horticultural Lighting Equipment	555	Part VI. Duct Heaters		569
410.170 General	555	424.65	Location of Disconnecting Means for Electric Duct Heater	
410.172 Listing	555		Controllers	569
410.174 Installation and Use	555	Article 430—Motors, Motor Circuits, and Controllers		571
410.176 Locations Not Permitted	555	Part I. General		571
410.178 Flexible Cord	555	430.1	Scope	571
410.180 Fittings and Connectors	555	430.2	Definitions	572
410.182 Grounding	556	430.6	Table FLC versus Motor Nameplate Current Rating	572
410.184 Ground-Fault Circuit-Interrupter Protection	556	430.14	Location of Motors	573
410.186 Support	556	430.17	Highest Rated Motor	573
Article 411—Low-Voltage Lighting	557	Part II. Conductor Size		574
411.1	Scope	430.22	Single Motor Conductor Size	574
411.3	Low-Voltage Lighting Systems	430.24	Several Motors—Conductor Size	576
411.4	Listing Required	Part III. Motor and Branch-Circuit Overload Protection		576
411.5	Specific Location Requirements	430.31	Overload	576
		430.32	Overload Sizing for Continuous-Duty Motors	577
Article 422—Appliances	559	Part IV. Branch-Circuit Short-Circuit and Ground-Fault Protection		579
Part I. General	559	430.51	General	579
422.1	Scope	430.52	Branch-Circuit Short-Circuit and Ground-Fault Protection	580
422.3	Other Articles	430.55	Combined Overcurrent Protective Device	581
422.5	GFCI Protection	Part V. Feeder Short-Circuit and Ground-Fault Protection		582
422.6	Listing Required	430.62	Motor Feeder Protection	582
Part II. Branch-Circuit Requirements	561	Part VI. Motor Control Circuits		584
422.10	Branch Circuits	430.72	Overcurrent Protection for Control Circuits	584
422.11	Overcurrent Protection	430.75	Disconnect for Control Circuits	584
422.12	Central Heating Equipment	Part VII. Motor Controllers		584
422.13	Storage Water Heaters	430.83	Motor Controller Horsepower Rating	584
422.15	Central Vacuums	Part IX. Disconnecting Means		585
422.16	Flexible Cords	430.102	Disconnect Location	585
422.18	Support of Ceiling-Suspended (Paddle) Fans	430.107	Readily Accessible	586
422.19	Space for Conductors	430.109	Type of Disconnecting Means	586
422.20	Outlet Boxes to be Covered	Part X. Adjustable-Speed Drive Systems		586
Part III. Disconnecting Means	565	430.120	General	586
422.30	Disconnection—General	430.122	Conductor Sizing	586
422.31	Permanently Connected Appliance Disconnects	430.124	Overload Protection	588
422.33	Disconnection of Cord-and-Plug-Connected or Attachment Fitting-Connected Appliances	430.128	Disconnecting Means	588
		430.130	Branch-Circuit Short-Circuit and Ground-Fault Protection	588
Article 424—Fixed Electric Space-Heating Equipment	567	Part XIV. Tables		588
Part I. General	567			
424.1	Scope			
424.3	Other Articles			

Article 440—Air-Conditioning and Refrigeration Equipment.....591

Part I. General591	
440.1 Scope.....591	
440.2 Definitions.....591	
440.3 Other Articles.....591	
440.4 Marking on Hermetic Refrigerant Motor-Compressors and Equipment.....592	
440.9 Grounding and Bonding.....593	
Part II. Disconnecting Means593	
440.14 Location.....593	
Part III. Overcurrent Protection594	
440.21 General.....594	
440.22 Short-Circuit and Ground-Fault Overcurrent Device Size.....594	
Part IV. Conductor Sizing595	
440.33 Motor-Compressor(s) With or Without Additional Motor Loads.....595	

Article 445—Generators599	
445.1 Scope.....599	
445.6 Listing.....599	
445.11 Marking.....599	
445.13 Ampacity of Conductors.....600	
445.18 Disconnecting Means and Emergency Shutdown.....600	

Article 450—Transformers603	
450.1 Scope.....603	
450.3 Overcurrent Protection.....603	
450.9 Ventilation.....604	
450.10 Grounding and Bonding.....604	
450.13 Transformer Accessibility.....605	
450.14 Disconnecting Means.....605	

Article 480—Storage Batteries607	
480.1 Scope.....607	
480.2 Definitions.....607	
480.4 Battery and Cell Terminations.....608	
480.5 Wiring and Equipment Supplied from Batteries.....609	
480.7 Direct-Current Disconnect Methods.....609	
480.8 Insulation of Batteries.....609	
480.9 Battery Support Systems.....609	
480.10 Battery Locations.....610	
480.12 Battery Interconnections.....610	
480.13 Ground-Fault Detection.....610	

Chapter 4—Practice Questions611	
--	--

Final Exam A—Straight Order617	
---	--

Final Exam B—Random Order627	
---	--

INDEX637	
-----------------------	--

About the Author645	
----------------------------------	--

About the Illustrator646	
---------------------------------------	--

About the Mike Holt Team647	
--	--

Understanding the National Electrical Code®

Volume 2

TABLE OF CONTENTS

About This Textbook	xiii	110.15	High-Leg Conductor Identification.....	84
Additional Products to Help You Learn	xvi	110.16	Arc Flash Hazard Warning.....	85
How to Use the <i>National Electrical Code</i>	1	110.21	Markings.....	87
Article 90—Introduction to the <i>National Electrical Code</i>	7	110.22	Identification of Disconnecting Means.....	88
90.1 Purpose of the <i>NEC</i>	7	110.24	Available Fault Current.....	88
90.2 Scope of the <i>NEC</i>	8	110.25	Lockable Disconnecting Means.....	89
90.3 Code Arrangement.....	10	Part II. 1,000V, Nominal, or Less		89
90.4 Enforcement.....	11	110.26	Spaces About Electrical Equipment.....	89
90.5 Mandatory Requirements and Explanatory Material.....	13	110.27	Guarding of Live Parts.....	98
90.7 Examination of Equipment for Product Safety.....	13	110.28	Enclosure Types.....	98
90.8 Wiring Planning.....	14	Chapter 1—Practice Questions		101
Article 90—Practice Questions	15	CHAPTER 5—SPECIAL OCCUPANCIES		107
CHAPTER 1—GENERAL RULES	19	Article 500—Hazardous (Classified) Locations		109
Article 100—Definitions	21	500.1 Scope—Articles 500 Through 503.....		110
100 Definitions.....	21	500.3 Other Articles.....		110
Part I. General	21	500.4 Documentation.....		110
Part III. Hazardous (Classified) Locations	66	500.5 Classifications of Hazardous Locations.....		111
Article 110—Requirements for Electrical Installations	69	500.6 Material Groups.....		113
Part I. General Requirements	69	500.7 Protection Techniques.....		113
110.1 Scope.....	69	500.8 Equipment.....		115
110.2 Approval of Conductors and Equipment.....	69	Article 501—Class I Hazardous (Classified) Locations		117
110.3 Use and Product Listing (Certification) of Equipment.....	70	Part I. General		117
110.4 Voltage Rating of Electrical Equipment.....	70	501.1 Scope.....		117
110.5 Conductor Material.....	70	Part II. Wiring		117
110.6 Conductor Sizes.....	71	501.10 Wiring Methods.....		117
110.7 Wiring Integrity.....	71	501.15 Raceway and Cable Seals.....		119
110.8 Suitable Wiring Methods.....	71	501.30 Grounding and Bonding.....		125
110.9 Interrupting Rating (Overcurrent Protective Devices).....	72	Part III. Equipment		126
110.10 Equipment Short-Circuit Current Rating.....	72	501.115 Enclosures Containing Make-and-Break Contact Devices.....		126
110.11 Deteriorating Agents.....	74	501.125 Motors and Generators.....		127
110.12 Mechanical Execution of Work.....	74	501.130 Luminaires.....		127
110.13 Mounting and Cooling of Equipment.....	76	501.135 Utilization Equipment.....		128
110.14 Conductor Termination and Splicing.....	77	501.140 Flexible Cords, Class I, Divisions 1 and 2.....		128
		501.145 Receptacles and Attachment Plugs.....		129
		501.150 Limited-Energy and Communications Systems.....		129

Article 502—Class II Hazardous (Classified)

Locations	131
Part I. General	131
502.1 Scope	131
502.5 Explosionproof Equipment	131
Part II. Wiring	132
502.10 Wiring Methods	132
502.15 Sealing	134
502.30 Grounding and Bonding	134
Part III. Equipment	136
502.115 Enclosures Containing Make-and-Break Contacts	136
502.125 Motors and Generators	136
502.130 Luminaires	136
502.140 Flexible Cords	137
502.145 Receptacles and Attachment Plugs	138
502.150 Limited-Energy and Communications Systems	138

Article 503—Class III Hazardous (Classified)

Locations	139
Part I. General	139
503.1 Scope	139
Part II. Wiring	139
503.10 Wiring Methods	139
503.30 Grounding and Bonding	140
Part III. Equipment	141
503.115 Enclosures Containing Make-and-Break Contacts	141
503.125 Motors and Generators	141
503.130 Luminaires	141
503.140 Flexible Cords	142
503.145 Receptacles and Attachment plugs	142
503.150 Limited-Energy and Communications Systems	142

Article 511—Commercial Garages, Repair and Storage

511.1 Scope	143
511.3 Classification of Hazardous Areas	143
511.7 Wiring and Equipment Above Hazardous (Classified) Locations	144
511.8 Underground Wiring Below Class I Locations	145
511.9 Seals	145
511.10 Special Equipment	146
511.12 GFCI-Protected Receptacles	146

Article 514—Motor Fuel Dispensing Facilities

514.1 Scope	147
514.3 Classification of Locations	147
514.4 Wiring and Equipment Within Class I Locations	148
514.7 Wiring and Equipment Above Class I Locations	148

514.8 Underground Wiring	148
514.9 Conduit Seal	149
514.16 Grounding and Bonding	150

Article 517—Health Care Facilities

Part I. General	151
517.1 Scope	151
517.2 Definitions	152
Part II. Wiring and Protection	153
517.10 Applicability	153
517.12 Wiring Methods	153
517.13 Equipment Grounding Conductor for Receptacles and Fixed Electrical Equipment in Patient Care Spaces	153
517.16 Isolated Ground Receptacles	156
517.18 General Care Spaces	157

Article 518—Assembly Occupancies

518.1 Scope	159
518.2 General Classifications	159
518.3 Other Articles	160
518.4 Wiring Methods	160
518.6 Illumination	161

Article 525—Carnivals, Circuses, Fairs, and Similar Events

Part I. General Requirements	163
525.1 Scope	163
525.2 Definitions	163
525.5 Overhead Conductor Clearances	163
525.6 Protection of Electrical Equipment	164
Part III. Wiring Methods	164
525.20 Wiring Methods	164
525.21 Rides, Tents, and Concessions	165
525.22 Outdoor Portable Distribution or Termination Boxes	165
525.23 GFCI-Protected Receptacles and Equipment	166
Part IV. Grounding and Bonding	166
525.31 Equipment Grounding	166
525.32 Portable Equipment Grounding Conductor Continuity	166

Article 547—Agricultural Buildings

547.1 Scope	167
547.2 Definitions	167
547.5 Wiring Methods	168
547.8 Luminaires	169
547.10 Equipotential Planes	169

Article 550—Mobile Homes, Manufactured Homes, and Mobile Home Parks	171
Part I. General	171
550.1 Scope	171
550.2 Definitions	171
550.4 General Requirements	172
Part II. Mobile and Manufactured Homes	172
550.13 Receptacle Outlets	172
550.15 Wiring Methods and Materials	172
550.25 AFCI Protection	172
Part III. Services and Feeders	173
550.32 Mobile and Manufactured Home Service Disconnect	173
550.33 Feeder	173
 Article 555—Marinas, Boatyards, and Docking Facilities	175
Part I. General	175
555.1 Scope	175
555.2 Definitions	175
555.3 Electrical Datum Plane Distances	177
555.4 Location of Service Equipment	177
555.5 Maximum Voltage	178
555.6 Load Calculations for Service and Feeder Conductors	178
555.7 Transformers	178
555.9 Boat Hoists	179
555.10 Electric Shock Hazard Signage	179
555.11 Motor Fuel Dispensing Stations—Hazardous (Classified) Locations	179
555.12 Repair Facilities—Hazardous (Classified) Locations	180
555.13 Bonding of Noncurrent-Carrying Metal Parts	180
Part II. Marinas, Boatyards, and Docking Facilities	180
555.30 Electrical Connections	180
555.33 Receptacles	181
555.34 Wiring Methods and Installation	182
555.35 Ground-Fault Protection of Equipment (GFPE) and Ground-Fault Circuit-Interrupter (GFCI) Protection	182
555.36 Boat Receptacle Disconnecting Means	183
555.37 Equipment Grounding Conductor	183
 Article 590—Temporary Installations	185
590.1 Scope	185
590.2 All Wiring Installations	185
590.3 Time Constraints	186
590.4 General	186
590.5 Listing of Decorative Lighting	188
590.6 GFCI Protection for Personnel	189
590.8 Overcurrent Protective Devices	189
 Chapter 5—Practice Questions	191

CHAPTER 6—SPECIAL EQUIPMENT	215
Article 600—Electric Signs and Outline Lighting	217
Part I. General	217
600.1 Scope	217
600.2 Definitions	218
600.3 Listing	218
600.4 Markings	219
600.5 Branch Circuits	219
600.6 Disconnecting Means	220
600.7 Grounding and Bonding	222
600.9 Location	224
600.21 Ballasts, Transformers, Class 2 Power Sources, and Electronic Power Supplies	224
600.24 Class 2 Power Sources	224
Part II. Field-Installed Skeleton Tubing, Outline Lightning, and Secondary Wiring	225
600.34 Photovoltaic (PV) Powered Sign	225
600.35 Retrofit Kits	225
 Article 604—Manufactured Wiring Systems	227
604.1 Scope	227
604.2 Definition	227
604.6 Listing Requirements	227
604.7 Installation—Securing and Supporting	228
604.10 Uses Permitted	228
 Article 620—Elevators, Escalators, and Moving Walks	229
Part I. General	229
620.1 Scope	229
620.6 GFCI-Protected Receptacles	229
Part II. Conductors	230
620.13 Feeder and Branch-Circuit Conductors	230
620.16 Short-Circuit Current Rating	230
Part III. Wiring	230
620.22 Branch Circuits for Elevator Car(s)	230
620.23 Branch Circuits for Machine Room/Machinery Space	231
620.24 Branch Circuit for Hoistway Pit Lighting and Receptacles	231
Part IV. Installation of Conductors	231
620.37 Wiring in Elevator Hoistways, Control, and Machine Rooms/Spaces	231
Part VI. Disconnecting Means and Control	232
620.51 Disconnecting Means	232
 Article 625—Electric Vehicle Power Transfer System	233
Part I. General	233
625.1 Scope	233
625.2 Definitions	233

625.5	Listed.....	234
Part III. Installation		
625.40	Electric Vehicle Branch Circuit.....	234
625.41	Overcurrent Protection	234
625.42	Rating.....	235
625.43	Disconnecting Means	235
625.48	Interactive Systems	235
625.50	Location	235
625.52	Ventilation	236
625.54	Ground-Fault Circuit-Interrupter Protection for Personnel.....	236
625.60	Alternating-Current Electric Vehicle Power Export (EVPE) Receptacles	236

Article 630—Electric Welders.....237

Part I. General

630.1	Scope	237
630.6	Listing.....	237

Part II. Arc Welders

630.11	Ampacity of Supply Conductors	237
630.12	Overcurrent Protection	240
630.13	Disconnecting Means	240

Part III. Resistance Welders.....240

630.31	Ampacity of Supply Conductor	240
630.32	Overcurrent Protection	242
630.33	Disconnecting Means	242

Article 640—Audio Signal Amplification and Reproduction Equipment.....243

Part I. General

640.1	Scope	243
640.2	Definitions	243
640.3	Locations and Other Articles	244
640.4	Protection of Electrical Equipment.....	244
640.6	Mechanical Execution of Work	244
640.9	Wiring Methods	245
640.10	Audio Systems Near Bodies of Water	245

Part II. Permanent Audio System Installations

640.21	Use of Flexible Cords and Flexible Cables	245
640.23	Conduit or Tubing	246

Article 645—Information Technology Equipment (ITE).....247

645.1	Scope	247
645.2	Definitions	247
645.3	Other Articles.....	247
645.4	Special Requirements	248
645.5	Supply Circuits and Interconnecting Cables	248
645.10	Disconnecting Means	251
645.15	Equipment Grounding and Bonding	251

Article 680—Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations.....253

Part I. General Requirements for Pools, Spas, Hot Tubs, and Fountains.....253

680.1	Scope	253
680.2	Definitions	254
680.3	Approval of Equipment	257
680.4	Inspections After Installation.....	257
680.5	Ground-Fault Circuit Interrupters.....	257
680.6	Bonding and Equipment Grounding	257
680.7	Bonding and Equipment Grounding Terminals	257
680.9	Overhead Conductor Clearance	257
680.10	Electric Water Heaters.....	258
680.11	Underground Wiring.....	259
680.12	Equipment Rooms and Pits.....	259
680.13	Maintenance Disconnecting Means.....	259
680.14	Wiring Methods in Corrosive Environment.....	260

Part II. Permanently Installed Pools

680.20	General.....	260
680.21	Pool Motors.....	260
680.22	Receptacles, Luminaires, and Switches.....	261
680.23	Underwater Pool Luminaires	264
680.24	Junction Box, Transformer, or GFCI Enclosure	267
680.25	Feeders	268
680.26	Equipotential Bonding	268
680.27	Specialized Equipment	273
680.28	Gas-Fired Water Heaters	273

Part III. Storable Pools, Spas, Hot Tubs, and Immersion Pools.....273

680.30	General.....	273
680.31	Pumps	273
680.32	GFCI Protection.....	273
680.34	Receptacle Locations	274
680.35	Storable and Portable Immersion Pools	274

Part IV. Spas and Hot Tubs, and Permanently Installed Immersion Pools.....274

680.40	General.....	274
680.41	Emergency Switch for Spas and Hot Tubs	274
680.42	Outdoor Installations.....	275
680.43	Indoor Installations	275
680.44	GFCI Protection.....	276
680.45	Permanently Installed Immersion Pools	277

Part V. Fountains.....277

680.50	General.....	277
680.51	Luminaires and Submersible Equipment	277
680.54	Connection to an Equipment Grounding Conductor.....	278
680.55	Methods of Equipment Grounding	278
680.56	Cord-and-Plug-Connected Equipment.....	278
680.57	Electric Signs in or Adjacent to Fountains.....	278
680.58	GFCI Protection for Adjacent Receptacles	278

680.59	GFCI Protection for Permanently Installed Nonsubmersible Pumps	278	Part VIII. Energy Storage Systems	318
Part VII. Hydromassage Bathtubs		279	690.71	Energy Storage Systems
680.70	General	279	690.72	Self-Regulated PV Charge Control
680.71	GFCI Protection	279		318
680.73	Accessibility	279	Article 691—Large-Scale Photovoltaic (PV) Electric Supply Stations	319
680.74	Equipotential Bonding	280	691.1	Scope
Part VIII. Electrically Powered Pool Lifts		280	691.4	Special Requirements for Large-Scale PV Electric Supply Stations
680.80	General	280		319
680.81	Equipment Approval	280	691.5	Equipment
680.82	Protection	280	691.6	Engineered Design
680.83	Bonding	281	691.7	Conformance of Construction to Engineered Design
680.84	Switching Devices and Receptacles	281	691.8	Direct-Current Operating Voltage
			691.9	Disconnect for Isolating Photovoltaic Equipment
			691.10	Arc-Fault Mitigation
			691.11	Fence Bonding and Grounding
				320
Article 690—Solar Photovoltaic (PV) Systems		283	Article 695—Fire Pumps	321
Part I. General		283	695.1	Scope
690.1	Scope	283	695.3	Electric Power Source(s)
690.2	Definitions	284	695.4	Continuity of Power
690.4	General Requirements	288	695.5	Transformers
690.6	Alternating-Current Modules and Systems	289	695.6	Power Wiring
Part II. Circuit Requirements		290	695.7	Voltage Drop
690.7	Maximum PV System Direct-Current Circuit Voltage	290	695.10	Listed Equipment
690.8	Circuit Current and Conductor Sizing	294	695.14	Control Wiring
690.9	Overcurrent Protection	300	695.15	Surge Protection
690.10	Stand-Alone Systems	301		326
690.11	Arc-Fault Circuit Protection	301		326
690.12	Rapid Shutdown	301	Chapter 6—Practice Questions	327
Part III. Disconnect		303		
690.13	PV System Disconnect	303	CHAPTER 7—SPECIAL CONDITIONS	349
690.15	PV Equipment Disconnecting Means to Isolate PV Equipment	304	Article 700—Emergency Systems	351
Part IV. Wiring Methods		306	Part I. General	351
690.31	Wiring Methods	306	700.1	Scope
690.32	Component Interconnections	311	700.2	Definitions
690.33	Connectors (Mating)	311	700.3	Tests and Maintenance
690.34	Access to Boxes	312	700.4	Capacity and Rating
Part V. Grounding and Bonding		312	700.5	Transfer Equipment
690.43	Equipment Grounding and Bonding	312	700.7	Signs
690.45	Size of Equipment Grounding Conductors	314	700.8	Surge Protection
690.47	Grounding Electrode System	314		353
Part VI. Markings and Labels		315	Part II. Circuit Wiring	353
690.53	Direct-Current PV Circuit Label	315	700.10	Wiring
690.54	Interactive System Point of Interconnection	316		353
690.55	Energy Storage	316	Part III. Sources of Power	355
690.56	Identification of Power Sources	316	700.12	General Requirements
Part VII. Connections to Other Sources		317		355
690.59	Connection to Other Power Sources	317	Part IV. Emergency System Circuits for Lighting and Power	357
			700.15	Loads on Emergency Branch Circuits
			700.16	Emergency Illumination
			700.19	Multiwire Branch Circuits
				357

Part VI. Overcurrent Protection	357	705.28	Circuit Sizing and Current.....	383	
700.30	Accessibility.....	357	705.30	Overcurrent Protection	384
700.32	Selective Coordination.....	358	705.32	Ground-Fault Protection	384
			705.40	Loss of Utility Power	384
			705.45	Unbalanced Interconnections.....	385
Article 701—Legally Required Standby Systems	359	Part II. Microgrid Systems		386	
Part I. General	359	705.50	System Operation	386	
701.1	Scope	359	705.60	Primary Power Source Connection	386
701.2	Definition.....	359			
701.3	Tests and Maintenance	360	Article 706—Energy Storage Systems	387	
701.4	Capacity and Rating.....	360	Part I. General	387	
701.5	Transfer Equipment	360	706.1	Scope	387
701.6	Signals.....	361	706.2	Definitions	388
701.7	Signs.....	361	706.3	Qualified Personnel.....	388
Part II. Circuit Wiring	361	706.4	System Requirements	388	
701.10	Wiring.....	361	706.5	Listing.....	389
Part III. Sources of Power	361	706.6	Multiple Systems.....	389	
701.12	General Requirements.....	361	706.8	Storage Batteries	389
Part IV. Overcurrent Protection	362	706.9	Maximum Voltage	389	
701.30	Accessibility.....	362	Part II. Disconnect	389	
701.32	Selective Coordination.....	363	706.15	Disconnect.....	389
			Part III. Installation Requirements	390	
Article 702—Optional Standby Systems	365	706.20	General.....	390	
Part I. General	365	706.21	Directory (Identification of Power Sources)	391	
702.1	Scope	365	Part IV. Circuit Requirements	391	
702.2	Definition.....	366	706.30	Circuit Sizing and Current.....	391
702.4	Capacity and Rating.....	366	706.31	Overcurrent Protection	392
702.5	Transfer Equipment	367	706.33	Charge Control.....	392
702.6	Signals.....	368	Part V. Flow Battery Energy Storage Systems	393	
702.7	Signs.....	368			
Part II. Circuit Wiring	368	Article 710—Stand-Alone Systems		395	
702.10	Wiring.....	368	710.1	Scope	395
702.11	Portable Generator Grounding	369	710.6	Equipment Approval	395
702.12	Outdoor Generator Sets	369	710.10	Identification of Power Sources.....	396
			710.12	Stand-Alone Inverter Input Circuit Current	396
			710.15	General.....	396
Article 705—Interconnected Electric Power Production Sources	371	Article 725—Remote-Control, Signaling, and Power-Limited Circuits		399	
Part I. General	371	Part I. General		399	
705.1	Scope	371	725.1	Scope	399
705.2	Definitions	371	725.2	Definitions	400
705.6	Equipment Approval	372	725.3	Other Articles.....	400
705.8	System Installation	372	725.21	Electrical Equipment Behind Access Panels.....	404
705.10	Identification of Power Sources.....	372	725.24	Mechanical Execution of Work	404
705.11	Supply-Side Source Connections	373	725.25	Abandoned Cable.....	405
705.12	Load-Side Source Connections	375	725.31	Safety-Control Equipment.....	406
705.13	Power Control Systems	381	725.35	Circuit Requirements	406
705.16	Interrupting and Short-Circuit Current Rating.....	382			
705.20	Disconnect.....	382			
705.25	Wiring Methods	382			

Part II. Class 1 Circuit Requirements	406	Part IV. Listing Requirements	428
725.41 Class 1 Circuit Classifications and Requirements	406	760.179 Listing and Marking of Power-Limited Fire Alarm Cables (PLFA).....	428
725.43 Class 1 Circuit Overcurrent Protection.....	407		
725.45 Class 1 Circuit Overcurrent Protective Device Location	407	Article 770—Optical Fiber Cables	429
725.46 Class 1 Circuit Wiring Methods.....	407	Part I. General	429
725.48 Conductors of Different Circuits in Same Cable, Cable Tray, Enclosure, or Raceway	407	770.1 Scope	429
725.49 Class 1 Circuit Conductors.....	408	770.2 Definitions	429
725.51 Number of Conductors in a Raceway	408	770.3 Other Articles.....	430
Part III. Class 2 Circuit Requirements	408	770.21 Access to Electrical Equipment Behind Panels Designed to Allow Access	430
725.121 Power Sources for Class 2 Circuits	408	770.24 Mechanical Execution of Work	430
725.124 Circuit Marking.....	409	770.25 Abandoned Cable.....	431
725.127 Wiring Methods on Supply Side of the Class 2 Power Source	409	770.26 Spread of Fire or Products of Combustion	432
725.130 Wiring Methods on Load Side of the Class 2 Power Source	409	Part V. Installation Methods Within Buildings	432
725.135 Installation of Class 2 Cables.....	410	770.110 Raceways and Cable Routing Assemblies, and Cable Trays for Optical Fiber Cables	432
725.136 Separation from Power Conductors.....	411	770.113 Installation of Optical Fiber Cables.....	433
725.139 Conductors of Different Circuits in Same Cable, Enclosure, Cable Tray, Raceway, or Cable Routing Assembly.....	413	770.114 Grounding	433
725.143 Support	414	770.133 Installation of Optical Fiber Cables and Electrical Conductors	434
725.144 Transmission of Power and Data.....	414	770.154 Applications of Listed Optical Fiber Cables	434
725.154 Applications of Class 2 Cables.....	415	Chapter 7—Practice Questions	435
Part IV. Listing Requirements	415		
725.170 Listing and Marking of Equipment for Power and Data Transmission	415	CHAPTER 8—COMMUNICATIONS SYSTEMS	455
725.179 Listing and Marking of Class 2 Cables.....	416	Article 800—General Requirements for Communications Systems	457
		Part I. General	457
Article 760—Fire Alarm Systems	419	800.1 Scope	457
Part I. General	419	800.2 Definitions	457
760.1 Scope	419	800.3 Other Articles.....	458
760.2 Definitions	419	800.21 Access to Electrical Equipment Behind Panels Designed to Allow Access	459
760.3 Other Articles.....	420	800.24 Mechanical Execution of Work	459
760.21 Access to Electrical Equipment Behind Panels Designed to Allow Access	422	800.25 Abandoned Cable.....	460
760.24 Mechanical Execution of Work	422	800.26 Spread of Fire or Products of Combustion	460
760.25 Abandoned Cables.....	423	Part II. Wires and Cables Outside and Entering Buildings	462
760.30 Fire Alarm Circuit Identification.....	424	800.49 Metal Entrance Conduit Bonding	462
760.35 Fire Alarm Circuit Requirements	424	800.53 Separation from Lightning Conductors	462
Part III. Power-Limited Fire Alarm (PLFA) Circuits	424	Part III. Bonding Methods	462
760.121 Power Sources for Power-Limited Fire Alarm Circuits	424	800.100 Cable and Primary Protector Bonding	462
760.124 Marking.....	425	Part IV. Installation Methods Within Buildings	464
760.127 Wiring Methods on Supply Side of the Power-Limited Fire Alarm Source	425	800.110 Raceways and Cable Routing Assemblies	464
760.130 Wiring Methods on Load Side of the Power-Limited Fire Alarm Power Source	425	800.113 Installation of Communications Wires, Cables, Raceways, and Cable Routing Assemblies.....	465
760.135 Installation of PLFA Cables in Buildings	426	800.154 Applications of Listed Communications Wires, Cables, and Raceways, and Listed Cable Routing Assemblies.....	466
760.136 Separation from Power Conductors.....	427	800.179 Plenum, Riser, General-Purpose, and Limited-Use Cables.....	466
760.143 Support of PLFA Cables	427		
760.154 Applications of Power-Limited Fire Alarm Cables (PLFA)	427		

Article 805—General Requirements for Communications Circuits	467
Part I. General	467
805.1 Scope	467
805.2 Definitions	467
805.18 Installation of Equipment	467
Part III. Protection	468
805.90 Primary Protection	468
805.93 Bonding or Interruption	468
Part IV. Installation Methods Within Buildings	468
805.133 Installation of Communications Wires, Cables, and Equipment.....	468
805.154 Communications Cable(s) Substitutions	469
805.156 Dwelling Unit Communications Outlet	469
 Article 810—Radio and Television Antenna Equipment	471
Part I. General	471
810.1 Scope	471
810.4 Community Television Antenna	472
Part II. Receiving Equipment—Antenna Systems	472
810.12 Supports	472
810.13 Avoid Contact with Conductors of Other Systems	472
810.15 Metal Antenna Supports—Bonding	473
810.18 Clearances	473
810.20 Antenna Discharge Unit.....	473
810.21 Bonding Conductors and Grounding Electrode Conductors....	474
Part III. Amateur and Citizen Band Transmitting and Receiving Stations—Antenna Systems	476
810.51 Other Sections.....	476
810.57 Antenna Discharge Units—Transmitting Stations.....	476
810.58 Bonding Conductors and Grounding Electrode Conductors—Amateur and Citizen Band Transmitting and Receiving Stations	476

Article 820—Community Antenna Television (CATV) and Radio Distribution Systems (Coaxial Cable)	477
Part I. General	477
820.1 Scope	477
Part III. Protection	478
820.93 Grounding of the Outer Conductive Shield of Coaxial Cables ...	478
Part IV. Grounding Methods	478
820.100 Bonding and Grounding Methods.....	478
Part V. Installation Methods Within Buildings	478
820.133 Installation of Coaxial Cables and Equipment.....	478
 Chapter 8—Practice Questions	481

Final Exam A—Straight Order	487
--	-----

Final Exam B—Random Order	497
--	-----

INDEX	507
--------------------	-----

About the Author	515
-------------------------------	-----

About the Illustrator	516
------------------------------------	-----

About the Mike Holt Team	517
---------------------------------------	-----

Electrical Exam Preparation

TABLE OF CONTENTS

About This Textbook	x	1.21 Ohm's Law	25
Passing Your Exam	xiii	1.22 Ohm's Law Formula Circle	26
Additional Products to Help You Learn	xvii	Part C—Summary	27
How to Use the <i>National Electrical Code</i>	1	Part C—Conclusion	28
 		Unit 1—Review Questions	29
 		Unit 1—Challenge Questions	32
CHAPTER 1—ELECTRICAL FUNDAMENTALS	7	Unit 2—Electrical Circuits	35
Unit 1—Basic Math, Advanced Math, and Electrical Circuits and Ohm's Law	9	Part A—Series Circuits	35
Part A—Basic Math	9	Introduction.....	35
Introduction.....	9	2.1 Practical Uses of Series Circuits.....	35
1.1 Whole Numbers and Integers.....	9	2.2 Understanding Series Circuits	37
1.2 Fractional Numbers	9	2.3 Series Circuit Notes	39
1.3 Decimal Numbers.....	9	2.4 Series-Connected Power Supplies	39
1.4 Percentages.....	10	Part A—Summary	39
1.5 Multipliers	10	Part A—Conclusion	40
1.6 Percentage Increase.....	12	Part B—Parallel Circuits	40
1.7 Reciprocals	13	Introduction.....	40
1.8 Parentheses.....	13	2.5 Practical Uses of Parallel Circuits.....	40
1.9 Squaring a Number	14	2.6 Understanding Parallel Calculations	42
1.10 Square Root.....	14	2.7 Circuit Resistance	42
1.11 Kilo.....	15	2.8 Parallel Circuit Notes.....	46
1.12 Rounding.....	16	2.9 Parallel-Connected Power Supplies	46
1.13 Testing Your Answer	16	Part B—Summary	46
Part A—Summary	17	Part B—Conclusion	47
Part A—Conclusion	17	Part C—Series-Parallel Circuits	47
Part B—Advanced Math	18	Introduction.....	47
Introduction.....	18	2.10 Review of Series and Parallel Circuits.....	47
1.14 Units of Measurement	18	2.11 Working with Resistance in Series-Parallel Circuits.....	48
1.15 Surface Area.....	18	2.12 Working with Voltage in Series-Parallel Circuits.....	50
1.16 Volume.....	21	Part C—Summary	50
1.17 Geometry and Trigonometry	21	Part C—Conclusion	51
Part B—Summary	24	Part D—Multiwire Circuits	51
Part B—Conclusion	24	Introduction.....	51
Part C—Electrical Circuits and Ohm's Law	24	2.13 Neutral Wire.....	51
Introduction.....	24	2.14 Current Flow through the Neutral Wire.....	52
1.18 Electrical Circuit	24	2.15 Balanced Systems.....	53
1.19 Electrical Power Source	25	2.16 Multiwire Branch Circuits	53
1.20 Circuit Resistance	25	2.17 Dangers of Multiwire Circuits.....	55

2.18	NEC Requirements.....	56	3.26	Using the Formula Wheel.....	82
Part D—Summary.....	57	3.27	Power Losses of Wires.....	82	
Part D—Conclusion.....	57	3.28	Power Factor.....	84	
Unit 2—Review Questions.....	58	3.29	Unity Power Factor.....	85	
Unit 2—Challenge Questions.....	62	3.30	True Power (Watts).....	85	
Unit 3—Alternating Current.....	63	3.31	Power Factor Formulas.....	85	
Part A—Understanding Alternating Current.....	63	3.32	Effects of Power Factor.....	86	
Introduction.....	63	3.33	Efficiency.....	88	
3.1 Current Flow.....	63	3.34	Efficiency Formulas.....	88	
3.2 Use of Alternating Current and Direct Current.....	63	Part D—Summary.....	90		
3.3 How Alternating Current is Produced.....	64	Part D—Conclusion.....	91		
3.4 Alternating-Current Generator.....	64	Unit 3—Review Questions.....	92		
3.5 Waveforms.....	64	Unit 3—Challenge Questions.....	98		
3.6 Sine Wave—Sinusoidal Waveform.....	65	Unit 4—Motors and Transformers.....	101		
3.7 Frequency.....	66	Part A—Motor Basics.....	101		
3.8 Phase.....	66	Introduction.....	101		
3.9 Phase Angle in Degrees.....	67	4.1 Motor Principles.....	101		
3.10 Leading or Lagging Waveform.....	67	4.2 Dual-Voltage Alternating-Current Motors.....	102		
3.11 Values in Alternating-Current Waveforms.....	68	4.3 Motor Horsepower Ratings.....	102		
Part A—Summary.....	69	4.4 Motor Current Ratings.....	103		
Part A—Conclusion.....	70	4.5 Calculating Motor FLA (Nameplate).....	104		
Part B—Capacitance.....	70	4.6 Motor Starting Current.....	105		
Introduction.....	70	4.7 Motor Running Current.....	106		
3.12 How Capacitors Work.....	70	4.8 Motor Overload Protection.....	106		
3.13 Determining Capacitance.....	72	Part A—Summary.....	107		
3.14 Uses of Capacitors.....	73	Part A—Conclusion.....	107		
Part B—Summary.....	74	Part B—Transformers.....	108		
Part B—Conclusion.....	74	Introduction.....	108		
Part C—Induction.....	75	4.9 Transformers.....	108		
Introduction.....	75	4.10 Transformer Theory.....	108		
3.15 How Induction Works.....	75	4.11 Primary vs. Secondary.....	108		
3.16 Self-Induction.....	75	4.12 Transformer Induction.....	108		
3.17 Conductor Alternating-Current Resistance.....	75	4.13 Induced Voltage, Secondary.....	109		
3.18 Conductor Shape.....	77	4.14 Transformer Turns Ratio.....	109		
3.19 Magnetic Cores.....	77	4.15 Autotransformers.....	112		
3.20 Self-Induced (CEMF) and Applied Voltage.....	78	4.16 Power Losses.....	113		
3.21 Phase Relationship.....	78	4.17 Efficiency.....	114		
3.22 Uses of Induction.....	78	4.18 Transformer kVA Rating.....	114		
Part C—Summary.....	79	4.19 Current Rating.....	115		
Part C—Conclusion.....	79	Part B—Summary.....	116		
Part D—Power, Power Factor, and Efficiency.....	80	Part B—Conclusion.....	117		
Introduction.....	80	Unit 4—Review Questions.....	118		
3.23 Power.....	80	Unit 4—Challenge Questions.....	122		
3.24 PIE Power Formula Circle.....	80				
3.25 Formula Wheel.....	81				

CHAPTER 2—NEC CALCULATIONS	125
Unit 5—Raceway and Box Calculations	127
Part A—Raceway Sizing	127
Introduction.....	127
5.1 Conductor Dimensions—Chapter 9, Tables 5 and 8.....	128
5.2 Raceway Properties.....	131
5.3 Raceways with Different Size Conductors	133
5.4 Raceway Sizing Steps.....	134
5.5 Multiconductor and Optical Fiber Cables—Chapter 9, Note (5) and Note (9).....	136
5.6 Cables with Elliptical Cross Sections—Chapter 9, Note (9).....	138
5.7 Sizing Raceways Using Annex C.....	139
5.8 Conductor Jamming—Chapter 9, Table 1, Note 2	142
5.9 Sizing Wireways	143
5.10 Sizing Wireways for Conductor Bending Radius [376.23(A)].....	146
5.11 Tips for Raceway Calculations.....	146
Part B—Outlet Box Fill	146
Introduction.....	146
5.12 Box Sizing—Conductors All the Same Size [314.16(A)].....	147
5.13 Box Fill Calculations [314.16(B)].....	149
5.14 Outlet Box Sizing Steps	153
5.15 Tips for Outlet Box Sizing	155
Part C—Pull Boxes, Junction Boxes, and Conduit Bodies	155
Introduction.....	155
5.16 Pull/Junction Box Sizing Requirements	155
5.17 Tips for Pull/Junction Box Sizing.....	157
5.18 Pull Box Examples.....	157
5.19 Tips for Pull Box Sizing	160
Unit 5—Conclusion	160
Unit 5—Review Questions	161
Unit 5—Challenge Questions	167
Unit 6—Conductor Sizing and Protection Calculations	169
Part A—Conductor Requirements	169
Introduction.....	169
6.1 Conductor Insulation [310.4].....	169
6.2 Conductor Sizes	172
6.3 Minimum Conductor Size [310.3]	172
6.4 Conductor Size—Equipment Terminal Rating [110.14(C)].....	172
6.5 Overcurrent Protection [240.4].....	175
Part B—Conductor Ampacity	179
Introduction.....	179
6.6 Conductor Ampacity [310.14]	180
6.7 Ampacity Table [310.15]	180
6.8 Ambient Temperature Correction [310.15(B)].....	181
6.9 Ampacity Adjustment [310.15(C)]	183
6.10 Combining Ambient Temperature Correction and Conductor Bundling Adjustment	185
6.11 Current-Carrying Conductors [310.15(E)].....	186
6.12 Wireways—Conductor Ampacity Adjustment.....	188
6.13 Overcurrent Protection and Conductor Sizing	189
6.14 Feeder Tap Rules [240.21].....	200
6.15 Transformer Secondary Conductors [240.21(C)].....	204
Unit 6—Conclusion	206
Unit 6—Review Questions	207
Unit 6—Challenge Questions	213
Unit 7—Motor, Air-Conditioning, and Transformer Calculations	217
Part A—Motor Calculations	217
7.1 Scope of Article 430	217
7.2 Motor Full-Load Current (FLC)	218
7.3 Motor Full-Load Current and Motor Nameplate Current Rating [430.6(A)].....	219
7.4 Branch-Circuit Conductor Sizing [430.22].....	220
7.5 Feeder Conductor Sizing [430.24]	223
7.6 Overcurrent Protection	225
7.7 Overload Protection Sizing	226
7.8 Branch-Circuit Short-Circuit and Ground-Fault Protection.....	230
7.9 Branch-Circuit Summary	234
7.10 Combined Branch-Circuit Overcurrent Protection [430.55]	235
7.11 Feeder Short-Circuit and Ground-Fault Protection [430.62].....	235
7.12 Motor Watts versus Motor Volt-Amperes (VA)	238
7.13 Adjustable-Speed Drives	241
7.14 Fire Pump Motor Circuits.....	242
Part B—Air-Conditioning Calculations	243
7.15 Scope of Article 440	243
7.16 Multimotor Air-Conditioning Equipment [440.4(B)].....	244
Part C—Transformers	245
7.17 Transformer Overcurrent Protection [450.3(B)]	245
7.18 Primary Conductor Sizing.....	248
7.19 Secondary Conductor Sizing.....	249
7.20 Bonding and Grounding.....	252
Unit 7—Conclusion	256
Unit 7—Review Questions	257
Unit 7—Challenge Questions	264

Unit 8—Voltage-Drop Calculations	267	Part C—Neutral Load Calculations	317
Part A—Conductor Resistance Calculations	267	9.13 Service Neutral Calculations—Dryers and Ranges [220.61]	317
Introduction	267	9.14 Neutral Service and Feeder Calculation [220.61(B)] Example	317
8.1 Conductor Size	267	9.15 Number of General Lighting and General-Purpose Receptacle Circuits [210.11(A)]	318
8.2 Conductor Resistance	269	Unit 9—Conclusion	319
8.3 Alternating-Current Conductor Resistance	272	Unit 9—Review Questions	320
8.4 Alternating-Current Resistance [Chapter 9, Table 9]	272	Unit 9—Challenge Questions	326
8.5 Alternating-Current Resistance versus Direct-Current Resistance	274		
Part B—Voltage-Drop Considerations	275	CHAPTER 3—ADVANCED NEC CALCULATIONS	333
Introduction	275	Unit 10—Multifamily Dwelling Calculations	335
8.6 Voltage-Drop—Manufacturer and NEC Recommendations	275	Part A—Optional Method Load Calculations [Article 220, Part IV]	336
8.7 Determining Circuit Conductors' Voltage Drop—Ohm's Law Method	278	Introduction	336
8.8 Sizing Conductors for Voltage-Drop Consideration	279	10.1 Multifamily Dwelling Optional Load Calculations [220.84]	336
8.9 Determining Circuit Conductors' Voltage Drop—Formula Method	283	10.2 Multifamily Dwelling Optional Method [220.84] Examples	337
8.10 Limiting Conductor Length (Distance) to Minimize Voltage Drop	285	Part B—Standard Method Load Calculations [Article 220, Part III]	339
8.11 Limiting Current to Limit Voltage Drop	288	Introduction	339
Unit 8—Conclusion	291	10.3 General Lighting and General-Use Receptacle Demand Load [220.42]	340
Unit 8—Review Questions	292	10.4 Appliance Demand Load [220.53]	341
Unit 8—Challenge Questions	297	10.5 Dryer Demand Load [220.54]	342
		10.6 Electric Cooking Equipment Demand Load [220.55]	346
Unit 9—Dwelling Unit Calculations	299	10.7 Air-Conditioning versus Heating Demand Load [220.60]	350
Introduction	299	10.8 Service Conductor Sizing [310.16]	353
Part A—Optional Method Load Calculations [Article 220, Part IV]	299	10.9 Multifamily Dwelling Calculations—Standard Method Examples	354
Introduction	299	10.10 Two-Family Dwelling Units [220.85]	356
9.1 Dwelling Unit Optional Load Calculations [220.82]	300	Part C—Neutral Load Calculations	358
9.2 Dwelling Unit Optional Load Calculation [220.82] Example	301	10.11 Dryers and Cooking Equipment [220.61]	358
9.3 Existing Dwelling Unit Optional Load Calculations [220.83]	302	10.12 Service Neutral [220.61(B)]	360
9.4 Existing Dwelling Unit Optional Load Calculation [220.83] Example	303	Unit 10—Conclusion	361
Part B—Standard Method Load Calculations [Article 220, Part III]	304	Unit 10—Review Questions	362
9.5 Dwelling Unit Standard Load Calculation	304	Unit 10—Challenge Questions	368
9.6 General Lighting and General-Use Receptacle Demand Load [220.42]	304		
9.7 Fixed Appliance Demand Load [220.53]	306	Unit 11—Commercial Calculations	373
9.8 Dryer Demand Load [220.54]	307	Part A—General	373
9.9 Electric Cooking Equipment Demand Load [220.55]	307	Introduction	373
9.10 Air-Conditioning, Heating, and Air Handlers [220.60]	311	11.1 General Lighting Demand Factors [Tables 220.12 and 220.42]	373
9.11 Feeder and Service Conductor Size [Table 310.12]	312	11.2 General Lighting Load Examples	376
9.12 Standard Method Load Calculations Example [Article 220, Part III]	315	11.3 Sign Circuit [220.14(F) and 600.5(A)]	377
		11.4 Show-Window Lighting [220.14(G)]	377
		11.5 Multioutlet Receptacle Assemblies [220.14(H)]	378
		11.6 Receptacle Load [220.14(I) and 220.44]	378
		11.7 Offices—Receptacle Demand Load [220.14(K)]	381
		11.8 Air-Conditioning versus Heating Demand Load [220.60]	382

Part B—Examples	383	<i>NEC</i> Practice Quiz 13—Straight Order [430.1–525.23]	475
11.9 Office Buildings	383	<i>NEC</i> Practice Quiz 14—Random Order [90.1–525.23]	480
11.10 Manufactured Home Parks [550.31]	385	<i>NEC</i> Practice Quiz 15—Straight Order [547.1–680.25]	485
11.11 Recreational Vehicle Parks [551.73]	385	<i>NEC</i> Practice Quiz 16—Random Order [90.1–680.25]	491
11.12 Marinas [555.6]	386	<i>NEC</i> Practice Quiz 17—Straight Order [680.26–701.12]	496
Part C—Optional Method—New Restaurant Feeder/Service Load Calculations	387	<i>NEC</i> Practice Quiz 18—Random Order [90.1–701.12]	501
Introduction.....	387	<i>NEC</i> Practice Quiz 19—Straight Order [90.1–820.100]	506
11.13 New Restaurant—Optional Method [220.88]	387	<i>NEC</i> Practice Quiz 20—Random Order [90.1–820.100]	512
Part D—Welders	390	<i>NEC</i> Challenge Exam 1—Articles 90–820	517
Introduction.....	390	<i>NEC</i> Challenge Exam 2—Articles 90–820	522
11.14 Arc Welders	390	<i>NEC</i> Challenge Exam 3—Articles 90–820	527
11.15 Resistance Welders	392	<i>NEC</i> Challenge Exam 4—Articles 90–820	532
Part E—Light Industrial and School Calculations Examples	394	<i>NEC</i> Challenge Exam 5—Articles 90–820	537
11.16 Light Industrial Calculations Examples.....	394	<i>NEC</i> Challenge Exam 6—Articles 90–820	543
11.17 School Optional Method Load Calculations [220.86]	396	<i>NEC</i> Challenge Exam 7—Articles 90–820	548
Unit 11—Conclusion	397	<i>NEC</i> Challenge Exam 8—Articles 90–820	553
Unit 11—Review Questions	398	<i>NEC</i> Challenge Exam 9—Articles 90–820	558
Unit 11—Challenge Questions	402	<i>NEC</i> Challenge Exam 10—Articles 90–820	563
 CHAPTER 4—NEC PRACTICE QUIZZES AND CHALLENGE EXAMS	409	<i>NEC</i> Challenge Exam 11—Articles 90–820	568
<i>NEC</i> Practice Quiz 1—Straight Order [90.1–110.16]	411	<i>NEC</i> Challenge Exam 12—Articles 90–820	573
<i>NEC</i> Practice Quiz 2—Random Order [90.1–110.16]	416	<i>NEC</i> Challenge Exam 13—Articles 90–820	578
<i>NEC</i> Practice Quiz 3—Straight Order [110.21–225.39]	421	<i>NEC</i> Challenge Exam 14—Articles 90–820	583
<i>NEC</i> Practice Quiz 4—Random Order [90.1–225.39]	426	<i>NEC</i> Challenge Exam 15—Articles 90–820	588
<i>NEC</i> Practice Quiz 5—Straight Order [230.1–250.64]	432	<i>NEC</i> Challenge Exam 16—Articles 90–820	593
<i>NEC</i> Practice Quiz 6—Random Order [90.1–250.64]	437	<i>NEC</i> Challenge Exam 17—Articles 90–820	599
<i>NEC</i> Practice Quiz 7—Straight Order [250.66–314.16]	442	<i>NEC</i> Challenge Exam 18—Articles 90–820	604
<i>NEC</i> Practice Quiz 8—Random Order [90.1–314.16]	448	<i>NEC</i> Challenge Exam 19—Articles 90–820	610
<i>NEC</i> Practice Quiz 9—Straight Order [314.17–362.30]	454	<i>NEC</i> Challenge Exam 20—Articles 90–820	615
<i>NEC</i> Practice Quiz 10—Random Order [90.1–362.30]	459	<i>NEC</i> Final Exam.....	621
<i>NEC</i> Practice Quiz 11—Straight Order [376.22–422.31]	464	 About the Author	631
<i>NEC</i> Practice Quiz 12—Random Order [90.1–422.31]	469	About the Illustrator	632
		About the Mike Holt Team	633

Master Electrician Practice Exam

TABLE OF CONTENTS

About the Author.....	vi
-----------------------	----

Practice Exam Instructions.....	vii
---------------------------------	-----

Part 1—Electrical Theory

Electrical Theory Exam (4 Hours).....	1
---------------------------------------	---

Electrical Theory Answer Key.....	31
-----------------------------------	----

Electrical Theory Answer Sheet.....	59
-------------------------------------	----

Part 2—National Electrical Code®

National Electrical Code Exam (4 Hours).....	11
--	----

National Electrical Code Answer Key.....	35
--	----

National Electrical Code Answer Sheet.....	61
--	----

Part 3—Electrical Calculations

Electrical Calculations Exam (8 Hours)	21
--	----

Electrical Calculations Answer Key.....	37
---	----

Electrical Calculations Answer Sheet.....	63
---	----